# Index

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INTRODUCTION</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>ORGANIZATION</strong></td>
<td>4</td>
</tr>
<tr>
<td>Economy</td>
<td>6</td>
</tr>
<tr>
<td>Personnel</td>
<td>7</td>
</tr>
<tr>
<td>Environment</td>
<td>10</td>
</tr>
<tr>
<td>Equal Opportunities</td>
<td>12</td>
</tr>
<tr>
<td>The Third Task</td>
<td>13</td>
</tr>
<tr>
<td><strong>UNDERGRADUATE EDUCATION</strong></td>
<td>14</td>
</tr>
<tr>
<td>Engineering Programs</td>
<td>14</td>
</tr>
<tr>
<td>Biology</td>
<td>15</td>
</tr>
<tr>
<td>Chemistry</td>
<td>17</td>
</tr>
<tr>
<td>Physics</td>
<td>18</td>
</tr>
<tr>
<td>Master’s Programmes</td>
<td>19</td>
</tr>
<tr>
<td><strong>GRADUATE EDUCATION</strong></td>
<td>20</td>
</tr>
<tr>
<td>Forum Scientium</td>
<td>20</td>
</tr>
<tr>
<td>IFM Graduate Program</td>
<td>21</td>
</tr>
<tr>
<td><strong>SCIENTIFIC BRANCH OF APPLIED PHYSICS</strong></td>
<td>22</td>
</tr>
<tr>
<td>Applied Optics</td>
<td>24</td>
</tr>
<tr>
<td>Applied Physics</td>
<td>26</td>
</tr>
<tr>
<td>Biomolecular and Organic Electronics</td>
<td>29</td>
</tr>
<tr>
<td>Biosensors and Bioelectronics</td>
<td>31</td>
</tr>
<tr>
<td>Biotechnology</td>
<td>33</td>
</tr>
<tr>
<td>Molecular Surface Physics &amp; Nano science</td>
<td>35</td>
</tr>
<tr>
<td>Sensor Science and Molecular Physics</td>
<td>37</td>
</tr>
<tr>
<td><strong>SCIENTIFIC BRANCH OF CHEMISTRY</strong></td>
<td>48</td>
</tr>
<tr>
<td><strong>SCIENTIFIC BRANCH OF MATERIAL PHYSICS</strong></td>
<td>55</td>
</tr>
<tr>
<td>Functional Electronic Materials</td>
<td>57</td>
</tr>
<tr>
<td>Nanostructured Materials</td>
<td>58</td>
</tr>
<tr>
<td>Plasma &amp; Coatings Physics</td>
<td>60</td>
</tr>
<tr>
<td>Semiconductor Materials</td>
<td>62</td>
</tr>
<tr>
<td>Surface &amp; Semiconductor Physics</td>
<td>68</td>
</tr>
<tr>
<td>Surface Physics &amp; Chemistry</td>
<td>70</td>
</tr>
<tr>
<td>Thin Film Physics</td>
<td>72</td>
</tr>
<tr>
<td><strong>SCIENTIFIC BRANCH OF THEORY &amp; MODELING</strong></td>
<td>75</td>
</tr>
<tr>
<td>Bioinformatics</td>
<td>76</td>
</tr>
<tr>
<td>Computational Physics</td>
<td>77</td>
</tr>
<tr>
<td>Theoretical Biology</td>
<td>78</td>
</tr>
<tr>
<td>Theoretical Physics</td>
<td>79</td>
</tr>
<tr>
<td><strong>OTHER</strong></td>
<td>83</td>
</tr>
<tr>
<td>CeNano</td>
<td>83</td>
</tr>
<tr>
<td>FunMat</td>
<td>84</td>
</tr>
<tr>
<td>LiLi-NFM</td>
<td>86</td>
</tr>
<tr>
<td>LBB</td>
<td>89</td>
</tr>
<tr>
<td>MS^E</td>
<td>91</td>
</tr>
<tr>
<td>SIMARC</td>
<td>93</td>
</tr>
<tr>
<td><strong>PUBLICATIONS</strong></td>
<td>95</td>
</tr>
<tr>
<td><strong>THESIS</strong></td>
<td>107</td>
</tr>
<tr>
<td>Doctoral Theses</td>
<td>107</td>
</tr>
<tr>
<td>Licentiate Theses</td>
<td>107</td>
</tr>
<tr>
<td>Undergraduate Theses</td>
<td>108</td>
</tr>
</tbody>
</table>
The Department of Physics, Chemistry and Biology (IFM) hereby presents its 40th consecutive progress report since the start in 1970. The report contains a description of activities in research and education within the department and is intended as a source of information for colleagues and other interested readers.

IFM IS ORGANIZED IN FIVE SCIENTIFIC AREAS
- Applied Physics
- Biology
- Chemistry
- Material Physics
- Theory and Modeling.

A large part of the research within these divisions is made possible by generous grants from founding agencies like The Swedish Research Council (VR), The Swedish Foundation for Strategic Research (SSF), VINNOVA, Formas, The Knut and Alice Wallenberg Foundation and internationally also through the European Union and the FP6 and FP7 framework programmes.

During the year 2010, 23 doctoral and 9 licenciate theses were presented. More than 230 undergraduate courses were presented in Master of Science in Engineering programmes, in Master of Science programmes, in Bachelor of Science in Engineering programmes, and in teacher training programmes.

THE FIGURES ON THE COVER show examples of the very different research activities at the department that are presented in this Activity report. At the top there is a figure showing the results of a simulation of the microstructural evolution during spinodal decomposition of a TiAlN alloy. In the middle there are pictures of a Baltic Harbour porpoise (tumlare) and a Zygaena filipendulae butterfly (bastardsvärmare) studied in Zoology and Ecology respectively. At the bottom there is a graph showing spectra of two electron paramagnetic resonance (EPR) centers in 6H-SiC (Patrick Carlsson thesis).

More details of our research, graduate and undergraduate programmes can be found at www.ifm.liu.se.

Please also feel free to contact us by mail, e-mail or telephone.

Göran Hansson, Professor
Head of Department
Organization
DECEMBER 2010

Administration
Head of Department
Göran Hansson

Deputy Heads
Kajsa Uvdal
Per Jensen

Financial Administrator
Inger Johansson

Personnel Administrator
Louise Gustafsson Rydström

Principal Research Engineer
Bengt Andersson

Department Board

MEMBERS
Göran Hansson, Chairperson
Igor Abrikosov, Teacher representatives
Karl-Olof Bergman
Johanna Rosén
Anita Lloyd Spetz
Jeanette Nilsson, Techn/adm. representatives
Daniel Nilsson, PhD stud. representatives
Mattias Tengdelius
Pontus Stenberg, Student representatives
Mats Werme
Ingegärd Andersson, Secretary

DEPUTY MEMBERS
Peter Konradsson
Uno Wennergren
Susanne Andersson
Leif Johansson
Monica Malmbecker Edstam

Research and Education

Scientific areas

Applied Physics
Applied Optics, Applied Physics, Biomolecular and Organic Electronics, Biointerface and Biomimetics, Biotechnology, Molecular Surface Physics, Sensor Science and Molecular Physics

Chemistry
Inorganic Chemistry, Molecular biotechnology, Organic Analytical Chemistry, Organic Chemistry, Physical Chemistry, Protein Chemistry

Material Physics

Theory and Modeling
Bioinformatics, Computational Physics, Theoretical Biology, Theoretical Physics

Study Programmes

Ph.D. studies

Biology

Engineering

Chemistry

Physics – Natural Science

Physics Measurement and Technology

Research Centra

Biosensors and Bioelectronics Centre

CoNano

FunMat

LILI-NEM

MPE

SIMAHC

Central department functions

LSG, Local co-operation group

Computer support

Technical

Economy

Personnel

Department board

Head of Department
**Undergraduate Teaching**

<table>
<thead>
<tr>
<th>AREA</th>
<th>DIRECTOR OF STUDIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>Agneta Johansson</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Stefan Svensson</td>
</tr>
<tr>
<td>Measurement Technology</td>
<td>Ragnar Erlandsson</td>
</tr>
<tr>
<td>Physics-engineering programs</td>
<td>Leif Johansson</td>
</tr>
<tr>
<td>Physics-natural science</td>
<td>Magnus Boman</td>
</tr>
<tr>
<td><strong>International Master’s programmes</strong></td>
<td></td>
</tr>
<tr>
<td>Applied Biology</td>
<td>Agneta Johansson</td>
</tr>
<tr>
<td>Materials Physics and Nanotechnology</td>
<td>Leif Johansson</td>
</tr>
</tbody>
</table>

**Graduate Teaching**

<table>
<thead>
<tr>
<th>IFM Graduate Programme</th>
<th>DIRECTOR OF STUDIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forum Scientium</td>
<td>Per-Olof Holtz</td>
</tr>
<tr>
<td></td>
<td>Stefan Klintström</td>
</tr>
</tbody>
</table>

**Research Divisions**

**SCIENTIFIC BRANCH OF APPLIED PHYSICS**

- Applied Optics
- Applied Physics
- Biomolecular and Organic Electronics
- Biosensors and Bioelectronics
- Biotechnology
- Molecular Surface Physics and Nanoscience
- Sensor Science and Molecular Physics

<table>
<thead>
<tr>
<th>Area</th>
<th>Professors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hans Arwin, prof.</td>
</tr>
<tr>
<td></td>
<td>Stefan Klintström, acting prof./acting chairperson</td>
</tr>
<tr>
<td></td>
<td>Olle Inganäs, prof.</td>
</tr>
<tr>
<td></td>
<td>Anthony Turner, prof.</td>
</tr>
<tr>
<td></td>
<td>Carl-Fredrik Mandenius, prof.</td>
</tr>
<tr>
<td></td>
<td>Kajsa Uvdal, prof.</td>
</tr>
<tr>
<td></td>
<td>Bo Liedberg, prof., chairperson/</td>
</tr>
<tr>
<td></td>
<td>Thomas Ederth, assoc.prof./acting head of division</td>
</tr>
</tbody>
</table>

**SCIENTIFIC BRANCH OF BIOLOGY**

- Ecology
- Molecular genetics
- Zoology

<table>
<thead>
<tr>
<th>Area</th>
<th>Professors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per Jensen, prof., chairperson</td>
</tr>
<tr>
<td></td>
<td>Per Milberg, prof./Karin Tonderski, assoc. prof.</td>
</tr>
<tr>
<td></td>
<td>Johan Edqvist, assoc. prof.</td>
</tr>
<tr>
<td></td>
<td>Jordi Altimiras, assoc. prof.</td>
</tr>
</tbody>
</table>

**SCIENTIFIC BRANCH OF CHEMISTRY**

- Biochemistry
- Inorganic Chemistry
- Molecular Biotechnology
- Organic Analytical Chemistry
- Organic Chemistry
- Physical Chemistry
- Protein Chemistry

<table>
<thead>
<tr>
<th>Area</th>
<th>Professors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uno Carlsson, prof.</td>
</tr>
<tr>
<td></td>
<td>Per-Olov Käll, prof.</td>
</tr>
<tr>
<td></td>
<td>Bengt Harald Jonsson, prof., chairperson</td>
</tr>
<tr>
<td></td>
<td>Roger Sävenhed, assoc. prof.</td>
</tr>
<tr>
<td></td>
<td>Peter Konradsson, prof.</td>
</tr>
<tr>
<td></td>
<td>Lars Ojamäe, prof.</td>
</tr>
<tr>
<td></td>
<td>Per Hammarström, prof.</td>
</tr>
</tbody>
</table>

**SCIENTIFIC BRANCH OF MATERIAL PHYSICS**

- Functional Electronic Materials
- Nanostructured Materials
- Plasma & Coatings Physics
- Semiconductor Materials
- Surface and Semiconductor Physics
- Surface Physics and Chemistry
- Thin Film Physics

<table>
<thead>
<tr>
<th>Area</th>
<th>Professors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weimin Chen, prof.</td>
</tr>
<tr>
<td></td>
<td>Magnus Odén, prof.</td>
</tr>
<tr>
<td></td>
<td>Ulf Helmerson, prof.</td>
</tr>
<tr>
<td></td>
<td>Erik Jazén, prof., deputy chairperson</td>
</tr>
<tr>
<td></td>
<td>Roger Uhrberg, prof.</td>
</tr>
<tr>
<td></td>
<td>Mats Fahlman, prof.</td>
</tr>
<tr>
<td></td>
<td>Lars Hultman, prof., chairperson</td>
</tr>
</tbody>
</table>

**SCIENTIFIC BRANCH OF THEORY AND MODELLING**

- Bioinformatics
- Computational Physics
- Theoretical Biology
- Theoretical Physics

<table>
<thead>
<tr>
<th>Area</th>
<th>Professors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bengt Persson, prof.</td>
</tr>
<tr>
<td></td>
<td>Sven Stafström, prof.</td>
</tr>
<tr>
<td></td>
<td>Bo Ebenman, prof.</td>
</tr>
<tr>
<td></td>
<td>Igor Abrikosov, prof., chairperson</td>
</tr>
</tbody>
</table>
Financial Summary

**OPERATING INCOME (AMOUNTS IN MSEK)**

<table>
<thead>
<tr>
<th>Source</th>
<th>2010</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>University allocations for teaching</td>
<td>75</td>
<td>62</td>
</tr>
<tr>
<td>University allocations for research</td>
<td>117</td>
<td>93</td>
</tr>
<tr>
<td>University allocations for rental and maintenance of buildings</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>External sources of income</td>
<td>155</td>
<td>144</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>396</td>
<td>345</td>
</tr>
</tbody>
</table>

**OPERATING EXPENSES (AMOUNTS IN MSEK)**

<table>
<thead>
<tr>
<th>Expense</th>
<th>2010</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expences for staff</td>
<td>201</td>
<td>178</td>
</tr>
<tr>
<td>Expences for premises</td>
<td>62</td>
<td>62</td>
</tr>
<tr>
<td>Other operating expenses</td>
<td>100</td>
<td>79</td>
</tr>
<tr>
<td>Depreciation</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>380</td>
<td>339</td>
</tr>
</tbody>
</table>

Change in capital for the year

<table>
<thead>
<tr>
<th>Capital</th>
<th>2010</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balanced capital January</td>
<td>43</td>
<td>39</td>
</tr>
<tr>
<td>Balanced capital December</td>
<td>59</td>
<td>43</td>
</tr>
</tbody>
</table>

**EXTERNAL SOURCES OF INCOME (AMOUNTS IN MSEK)**

<table>
<thead>
<tr>
<th>Source</th>
<th>2010</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swedish Research Council, VR</td>
<td>52</td>
<td>51</td>
</tr>
<tr>
<td>Other Research-funding agencies, e.g. Vinnova, Formas</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>Research foundations, e.g. SFF</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>Other private foundations, e.g. Wallenberg</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>Funding from the European Union</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Other sources of funding</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>Contract research</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>155</td>
<td>144</td>
</tr>
</tbody>
</table>
## Personnel Situation 2010

### IFM Staff June 2010

<table>
<thead>
<tr>
<th>Position</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professors</td>
<td>41</td>
<td>8</td>
<td>49</td>
</tr>
<tr>
<td>Adj professors</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Guest professors</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>University lecturers</td>
<td>38</td>
<td>9</td>
<td>47</td>
</tr>
<tr>
<td>Adj lecturers</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Guest lecturers</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Adjunct teachers</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Researchers</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Assistant professors</td>
<td>14</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>Postdocs</td>
<td>32</td>
<td>10</td>
<td>42</td>
</tr>
<tr>
<td>Other researchers</td>
<td>17</td>
<td>6</td>
<td>23</td>
</tr>
<tr>
<td>PhD students</td>
<td>63</td>
<td>60</td>
<td>123</td>
</tr>
<tr>
<td>Administrators</td>
<td>3</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td>Engineers</td>
<td>24</td>
<td>4</td>
<td>28</td>
</tr>
<tr>
<td>Coordinator/Environm.</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>251</td>
<td>131</td>
<td>382</td>
</tr>
</tbody>
</table>

### New Employments During 2010

<table>
<thead>
<tr>
<th>Personnel category</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professors</td>
<td>5</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>University lecturers</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Assistant professors</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Other researchers</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Postdocs</td>
<td>17</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>PhD students</td>
<td>8</td>
<td>11</td>
<td>19</td>
</tr>
<tr>
<td>Administrators</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Engineers</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>39</td>
<td>18</td>
<td>57</td>
</tr>
</tbody>
</table>

During 2010, 57 persons began their employment at the department.
New Professors 2010

**PEDER BERGMAN** professor in semiconductor materials received his PhD in 1990 in materials science at LiU. He spent one year as post doc at France Telecom research center CNET in Lannion, France.

He become docent in material science in 1996 and was during 1996–2008 partly absent from the university working in external research projects and start-up companies.

His research interest has been on characterization and development of different semiconductor materials. The initial specialty was time resolved optical spectroscopy to study recombination process and emissions related to defects. During recent years the research has focused on semiconductor material with wide bandgap such as Silicon Carbide (SiC) and nitrides, i.e. different alloys of InN, GaN and AlN. Nitrides have a great technological potential for light emitting devices, and will in the future completely replace todays light bulbs for general illumination. Light emitting diodes, and also lasers, based on semiconductor material are more effective and less energy consuming than other alternative. Further development and improvement of the material requires a better understanding on the influence of defects and the recombination processes.

Another research area is SiC, which is a semiconductor material for future power electronics. SiC has since long been a strong research activity at LiU, both regarding material growth and material characterization. The original interest in SiC was to measure the carrier lifetime in the material, which is an important parameter for power devices. His research interest has since then broadened to cover a general research about device critical defects, and development to reduce these. The semiconductor material SiC is still under development but has a large potential to become the dominating material for power electronics, in i.e. future hybrid- and electrical vehicles.


In her research in Structural Biology, Maria Sunnerhagen studies the interplay between protein structure and function. The subject is fundamentally interdisciplinary since the biophysical techniques demand high technical competence, while the proteins themselves are involved in complex biomedical functions. In contrast to the well established crystallographic techniques, Maria Selander Sunnerhagen uses a new method for structure determination in solution – Nuclear Magnetic resonance (NMR) which she combines with other biophysical techniques in order to get information on protein interaction, stability and dynamics. These results can for example explain why a disease-mutated protein does not function, and can hint on novel therapeutic strategies. After her PhD, where Sunnerhagen presented the first structures in solution of protein domains from coagulation factor Xa, she has studies proteins in the redox system, lipid-binding proteins, gene regulatory proteins and proteins which result in antibiotics resistance. Today her main research objectives are found in cancer research and autoimmunity.

Characteristic for Sunnerhagen’s research is her interdisciplinary collaborations, in particular twinning between technology and medicine. In Chemical Biology her integration of research questions into undergraduate teaching has been highly approved by LiU students. During the last three years, Maria has held a position as VINNMER fellow of Vinnova, including a year as a visiting professor at University of Toronto, where she has participated in technology development and research within the international structural genomics that has developed after the HUGO genome project, and which she is now establishing at LiU.
Professor Anthony (Tony) Turner’s name is synonymous with the field of Biosensors and in November 2010, he joined IFM-Linköping as a Head of Division to create a new Centre for Biosensors and Bioelectronics.

His previous thirty-five year academic career in the UK culminated in the positions of Principal (Rektor) of Cranfield University at Silsoe and Distinguished Professor of Biotechnology. He retains part-time positions at Cranfield as an Emeritus Professor and as Director of Cranfield Ventures Ltd, with responsibility for leveraging Cranfield University’s IP via spin outs and licensing. He was elected a Fellow of the Royal Society of Chemistry in 1996, invited to Fellowship of the Institute of Biology in 1999 and the Institute of Physics in 2006. He was awarded a Higher Doctorate (DSc) for his exceptional contribution to biosensors by the University of Kent in 2001 and an Honorary DSc by the University of Bedfordshire in 2008, where he served as a Governor for six years. He was made a Foreign Associate of the USA National Academy of Engineering in 2006, for his work on glucose sensors, environmental monitors and synthetic recognition molecules and is a Visiting Professor at the University of Florence.

Professor Turner has over 600 publications and patents in the field of biosensors and biomimetic sensors and is best known for his role in the development of glucose sensors for home-use by people with diabetes. He has won a number of prestigious scientific awards and presented well over 400 keynote and plenary lectures at a range of international meetings and honour ceremonies around the world. He published the first textbook on Biosensors in 1987 and is Editor-In-Chief of the principal journal in his field, Biosensors & Bioelectronics, which he co-founded in 1985. He has helped create and been a board member of a number of biosensor start ups and has served as expert witness in patent litigations on three continents.

In addition to leading the new Centre, Professor Turner will be continuing his personal research on electrochemical, piezoelectric and optical biosensors, nanomaterials and synthetic receptors, with an emphasis on the interface between biomolecules and electronics and on the practical application of sensing devices.

**UNO WENNERGREN**, Professor of Theoretical Biology, received his PhD in Theoretical Biology 1993 at LiU and spent two years of postdoc at University of Washington, Seattle, with Professor Peter Kareiva at the department of Zoology.

He was Director of studies and Chairman of the Educational Board of Mathematics and Science at LiTH during 1995 to 2005. During 2005 he became associate professor of Theoretical Biology.

His research interest is to apply mathematics and mathematical models to solve biological issues. The main area has been ecological issues, as control of pest species to improve efficiency of organic farming or determine risks of extinctions of threatened species. Lately he has also started a set of projects related to spread of animal diseases and animal welfare issues within modern animal production systems. These projects are supported by FORMAS, Swedish Civil Contingencies Agency, and US Department of Homeland Security.

Most of his work concerns spatial and temporal effects on population densities and distributions. The methodology is based on Fourier transform and statistical issues and his group, the SPABIO group, consists of five graduate students and two postdocs.
The Work Environment

The work environmental plan states that everyone working at IFM shall:

- be able to perform their work in a safe, secure and effective way
- feel stimulated in their daily work
- feel responsible for and be given the opportunity to influence their work environment.

The Chairman is responsible for the work environment. Parts of that responsibility, concerning personnel and labs/offices have been delegated to the employer representative of every division at IFM.

Work safety delegates, appointed by the union organizations, have the task of monitoring the measures implemented to prevent ill-health and accidents in the workplace.

Every lab has a person responsible for different tasks in the lab. These tasks have been decided by agreements between the lab responsible and the employer representative.

THE LOCAL CO-OPERATING GROUP (LSG).

A local co-operating group (LSG) at IFM monitors and deals with different work safety issues. The group consists of the chairman at IFM, the personnel administrator, the central safety delegate, union representatives for OFR/S, SACO and the environmental engineer.

Every year a work environment plan is drawn up by LSG and ratified by the IFM board. The board is regularly informed about the status of the work environment at IFM.

Work Environment plan 2010–2012

- Increase knowledge of safety in laboratory work.
  Provide opportunities, on a yearly basis, for presentations in order to increase safety in the laboratory, including, e.g., risk analysis.
  Person responsible: Petra Hagstrand
  To be accomplished by 2012-12-31

- Contributions to a healthier work environment:
  The desks in all offices of all technical and administrative staff will exchanged for combination-desks, for both sitting and standing work positions.
  Person responsible: Louise Rydström
  To be accomplished by 2012-12-31

- Clarify the organization structure of IFM:
  The institution’s internet home page will be restructured.
  Person responsible: Göran Hansson
  To be accomplished by 2012-12-31

IRINA YAKIMENKO, professor in theoretical physics, received the PhD in Theoretical and Mathematical Physics at the Bogolyubov Institute for Theoretical Physics, Ukrainian Academy of Sciences, Kiev. Over a period of seven years she was a researcher at this institute and spent a year as a post-doc at the Centre of Nuclear Investigations, Saclay, France. Since 1996 she has been working at Linköping University as a guest researcher, guest professor, and university lecturer. In 2005 she became Docent in Theoretical Physics.

Her research work concerns theoretical developments in the studies of molecular and quantum mesoscopic systems and their applications to molecular and nanoelectronics. In close long-term collaboration with Prof. K.-F. Berggren she has received a number of the scientific results which have been recognized generally in nanoscience and nanotechnology. One of the most profound breakthroughs is the elaboration of the spin-polarization model in the many-body theory of the low-dimensional semiconductor systems which is widely used as a proper candidate for an explanation of conductance anomalies in semiconductor quantum point contacts and wires.

Current work deals with the study of electronic states, effects of electron interactions, bound states and effects of localization, formation of spin lattices, and finding ways for the creation, manipulation and detection of spin-polarized currents by purely electric means. Important aspects are spontaneous nanomagnetism, spin transfer and spin injection, modeling and functionality of nanodevices for spintronics and spin-based quantum information processing.

The results of the research work are also used by Irina Yakimenko in her courses for undergraduate and research students such as Analytical Mechanics, Quantum Mechanics, Quantum Dynamics and Mathematical Methods in Physics. Moreover the research in the field of nanophysics has served as the basis for creation of new courses like “Quantum Computers”. She has also supervised a number of master and PhD theses in the field of nanoscience.
• Clarify the organization structure of IFM:
  Selected prioritized sections of the IFM home page will be
translated into English.
  Person responsible: Göran Hansson
  To be accomplished by 2012-12-31

• Clarify the organization structure of IFM:
  The names and pictures of all employees at IFM will be
  present on IFM’s intranet.
  Person responsible: Louise Rydström
  To be accomplished by 2012-12-31

• Include student representation in the local co-operating group
  According to the Policy document for a Good Work and
  Study Environment, even students shall be included.
  Person responsible: Louise Rydström
  To be accomplished by 2012-12-31

• Promote cooperation among coworkers:
  Provide an inventory document of how supervisors meet
  with employees, including suggestions to stimulate individu-
  al or group work-place discussions.
  Person responsible: Louise Rydström
  To be accomplished by 2012-12-31

• Contributions to a healthier work environment:
  Review the duties of teachers with a view towards a new
  Contract on working hours.
  Person responsible: Göran Hansson
  To be accomplished by 2012-12-31

The Environment

LEGISLATION
IFM has an injunction, according to the Swedish Environmental
Code, to submit a yearly report to the local environmental
agency describing the laboratory work at the department. The
agency makes regular inspections at IFM.

ENVIRONMENTAL MANAGEMENT SYSTEMS
In 2006 the Rector at Linköping University decided that all de-
partments must work according to an environmental manage-
ment system. A regulation about environmental management
for government agencies came during 2009 that clarifies how
the LiU environmental management work shall be done.
At IFM a plan for the environmental work was first established
in December 2004 and resulted in several measures taken
towards reaching an environmental management system that
can be certified.
A new plan, for 2010, was decided by the IFM board in
March 2010. The environmental work has been presented in
the local co-operating group continuously during the year.
The environmental plan for 2010 consisted of descriptions of laws
and regulations that IFM has to follow, the results of an en-
vironmental analysis made at the end of 2005, the process of
creating an environmental management system at the depart-
ment and finally an action plan consisting of environmental
targets and measures needed to be taken during the year.

ENVIRONMENTAL TARGETS 2010
The following environmental targets, established by the IFM
board were to be fulfilled before December 31 2010. The four
targets have been sorted according to IFM’s four long-term
environmental goals.

LIMIT THE CONTRIBUTION TO THE CLIMATE CHANGES
1. Decrease the usage of electricity from IT-equipment by
   installing energy-saving mode and increasing the number
   of switched off equipment.

   Measures to achieve the target partly fulfilled A method
   was developed during 2009 to measure how many of the
cable connected computers were turned off during nights
and weekends. During 2010 the intensions was to review the
method but this has not been done. The work will continue
during 2011.

   A discussion was held with the student representative for
   the student computer labs “Midgård” at IFM about the possi-
bilities to install a script that inactives the computers
   at a certain time. The computers will now be turned off at
   midnight. They are turned on manually when needed, but
   will start in a few seconds. This means that the computers
   are turned off during nights, weekends and holidays and
   will start if needed.

   The usage of electricity was supposed to be visualized on
   the IFM webpage during 2010 but Akademiska Hus could
   not provide the necessary signal needed to read the result.

   All employees were informed about energy saving measu-
   res in the IFM newsletter and e-mail. The work will con-
   tinue during 2011.

2. A three year action plan for decreasing IFMs environmental
   impact from travels at work shall be established and person-
   nel shall be informed about it.

   Measures to achieve the target were partly fulfilled but will
   be ready in spring 2011. All employees will be informed
   about it.

EFFICIENT USE OF NATURAL RESOURCES
3. An inventory of IFMs introduction of the waste sorting
   system at LiU. Employees at IFM shall be informed about
   the waste sorting system in weekly newsletters, e-mail etc.

   An inventory has been made. The waste sorting system at
   IFM needs to be complemented at some places. Comple-
   mentation will be implemented in 2011.

   All employees were informed about the waste sorting sys-
   tem at IFM in the IFM newsletter and an information oc-
   casion was held at IFM in January 2011 (about 10 employees
   attended).
Equal Opportunities

IFM believes that equal opportunity is important for both students and employees. The institution has therefore assigned the responsibility of equal opportunity to a group with the following members: Anette Andersson (administrative staff), Ulf Frykman (technical staff), Göran Hansson (prefect), Agneta Johansson (director of studies), Parisa Sehati (PhD student), Linnéa Selegård (PhD student) and Kaja Uvdal (professor).

The group meets once a month and discuss ongoing projects and initiate new ones. These projects are in some way related to one or several of the five main issues that we build our work around: gender equality and gender issues, ethnicity and religion or other belief systems, disability, sexual orientation and gender identity and victimization, discrimination and harassment at an individual level.

In order to prevent discrimination and harassment the group has drawn up an Equal Opportunity Strategy. We believe that this strategy will contribute to the following:

- an attractive study and work environment
- development and creativity
- quality in education and research
- equitable structures and processes

The Equal Opportunities vision

- IFM aims to be a study and working environment that makes full use of the resources contributed to the department by students and employees with different backgrounds, life situations and skills.
- IFM seeks to promote equal opportunities in the academic world and the community at large.
- Admission and recruitment processes should be non-discriminatory.
- IFM’s study programmes should formally offer equal opportunities and be accessible to, prepared for and considerate of the needs of various student categories.
- The content of IFM’s study programmes should promote equal opportunities as far as possible.
- New students should be received in such a way that they all feel welcome.
- Equal opportunities should prevail in terms of employees’ working conditions, salaries, influence, career prospects and scope for combining a professional career with responsibility for home and family.
- IFM seeks to make it easier for employees and students, irrespective of gender, to combine their studies with parental responsibilities.
- IFM aims to be free from all discrimination and harassment.

IFM, together with two other institutions, arraigned a seminar that focused on cultural differences among employees and students and how we can be more aware of these differences.

Our website is continuously being updated with new information about our work. There are links to the university central equal opportunity group with related information found in both Swedish and English.

Information about upcoming events such as seminars, lectures and meetings was continuously sent out to all employees.

The personnel department ensured that there were not any unjustified differences in salaries between men and women.

We are trying to achieve a distribution according to gender that is within 40%–60% in the Board of Directors and all other working groups at IFM.

We are continuously trying to increase the number of female guest lecturers and our goal is to have both genders within a range of 40%–60%.

This year we focused on highlighting cultural differences in order to increase communication between different groups of people and by doing so trying to reduce misunderstandings that easily can occur.
The third university task

School contacts

Our department has always been very active in different forms of school contacts. For several years we have had young researchers part time employed for external contacts, one each from physics, chemistry and biology. IFM is represented in the board for school contacts of LiTH. The goal of this board is to coordinate and support existing activities, as well as developing new exciting activities.

Perhaps the most frequent activity is various study visits by children, young people and teachers. In May we have a popular activity directed to secondary and upper secondary school teachers, the May Mingle, Majminglingen. School teachers and university teachers meet in lectures and discussions. This activity is arranged in cooperation with the Mathematics department.

The Summer week in August is directed to young people beginning grade 8. Around fifty young people spend a week with experiments in physics, chemistry, biology and technology. This year the Summer week was arranged in cooperation with Ebersteinska gymnasiet and Hagagymnasiet, two upper secondary schools in Norrköping. The first day of the week the activities took place at our department, the next three days at Hagagymnasiet and Ebersteinska gymnasiet and the last day at Campus Norrköping and the new Norrköping Visualization Center. The pupils showed great interest and enthusiasm in the activities. This activity is a successful example of how science studies can be presented as an attractive alternative for young pupils.

In October we had a Popular Science day for school teachers and pupils. This event was initiated by Professor Per Jensen in 2005, and the interest is growing. Around 1100 people attended, and the lectures were given in parallel sessions.

A natural contact with schools is in the teachers education program, where teacher students take part of their education as observations and teaching practice in schools. New school and education reforms are on their way in Sweden, and many of our teachers at the department have been quite busy with preparations for a new upper secondary school and a reformed teacher education.

Our department and the university is also developing new forms to support practising teachers with further education. The need for higher competence in science and mathematics among school teachers has been pointed out in several reports, and new national programs to meet this need have recently been implemented. Our department offers both ordinary science courses and specially designed courses directed to practising teachers.

Numerous study visits have been arranged at IFM during the year, where children and teenagers could listen to interesting talks given by our researcher, or perform experiments in our laboratories. IFM received about one hundred high-school girls within the Quintek program, aimed to promote the interest for science and technology among the young women. School teachers meet university teachers during the yearly event “Maj-minglingen”, arranged together with the Mathematics department.

IFM participated in the exhibitions at the open-house events arranged by Linköping University for high-school pupils. Furthermore, exhibitions and talks on hot research topics were presented at the yearly Popular Science day. Each of these activities attracts about one thousand people.
Education for Undergraduate Students

The undergraduate education given by the Department of Physics, Chemistry and Biology (IFM) had five main divisions 2010.

- Physics at the Engineering and the Natural science programs (Director of Studies: Leif Johansson)
- Measurement Technology at the engineering programs and physics at the Engineering Biology and Chemical Biology programs (Director of Studies: Ragnar Erlandsson)
- Biology at the Natural science, Teachers and Engineering programs (Director of Studies: Agnete Johansson)
- Chemistry at the Natural science, Teachers and Engineering programs (Director of Studies: Stefan Svensson)
- Physics at the Teachers programs and the Basic year (Director of Studies: Magnus Boman)

These divisions have in turn subprograms.

Engineering Programs

STAFF
- Directors of studies: Leif Johansson and Ragnar Erlandsson
- Administrative assistants: Marie Martinell Wirdeland/Agne Virsilaite Maras and Anette Svensson
- Technical staff: Hasan Dzhuo, Anders Evaldsson, Jonas Wissting, Jan-Ove Järrhed, Ingemar Skarp

The Institute of Technology at Linköping University offers seven different engineering M.Sc. programs. The Swedish name of the degree from one of these programs is “Civilingenjör”. A total of about 700 students are annually accepted in these programs:

M: Mechanical engineering (120)
D: Computer science and engineering (70)
Y: Applied physics and Electrical engineering (115)
Yi: Applied physics and Electrical engineering, international (20)
I: Industrial engineering and Management (180)
Ii: Industrial engineering and Management, international (55)

TB: Engineering Biology (30)
KB: Chemical Biology (30)
IT: Information Technology (40)

The nominal time for the M.Sc. programs is 3 years. The first three years mainly consist of compulsory courses in basic subjects and corresponds to B.Sc. degree. During the third year the students make a choice among the different specialisations (profiles) in years 4–5, which contain some compulsory courses (profile courses) but most are selectable and can be composed to fit the students own interest.

The majority of courses given by IFM are for the Y, Yi, TB and KB-programs, but some basic courses are also given for the other programs. The Y(Yi)-students can choose between twelve profiles, three of which are related to the Department of Physics, Chemistry and Biology (IFM):
- Theory, modelling and visualization (Inna Yakimenko)
- Material and nano physics (Jens Birch)
- Organic systems and sensors (Thomas Ederth)

At the TB and KB programs, the profiles are:
- Pharma biotechnology and production (TB, KB)
- Devices and materials in biomedicine (TB)
- Protein science and technology (KB)

Below is a list of the IFM courses given for the engineering M.Sc. programs. The courses are classified in three fields: Tuition in Physics, Tuition in Biological Engineering and Tuition in Measurement Technology.

Some Measurement Technology courses are also given for the engineering B.Sc. programs: EI Electrical Engineering, DI Computer Engineering and KI Chemical Engineering.

TUITION IN PHYSICS
- Basic (compulsory) courses in Physics:
  - Engineering Projects, 6hp
  - Wave Physics, 8hp
  - Wave Physics, 4hp
  - Electromagnetic Field Theory, 8hp
  - Modern Physics, 6hp
  - Thermodynamics & Statist, Mechanics, 6hp
  - Electromagnetic Theory and Experimental Physics Lab 6hp
  - Wave Physics and Modern Physics 6hp
  - Physics 6 hp
  - Engineering Mechanics, 6hp
  - Electromagnetism, 4.5hp
  - Modern Physics, 6hp
  - Wave Physics and Modern Physics, 6hp
  - Biotechnology, 2.5p
  - Principles of Physics, 2.5p
  - Physics, TB, 6 hp
  - Engineering Mechanics, 6hp
  - Molecular and Surface Physics, 6p
  - Models in Physics, 8hp
  - Perspectives on Physics, 2hp
• Specialised courses, mainly aimed at the Y-profiles. Mathematical Methods of Physics, 6hp
  Analytical Mechanics, 6hp
  Quantum Mechanics, 6hp
  Experimental Physics, 6hp
  Analytical Methods in Material Science, 6hp
  Optoelectronics, 6hp
  Elementary Particle Physics, 6hp
  Semiconductor Technology, 6hp
  Quantum Dynamics, 6hp
  Physics of Condensed Matter part I, 6hp
  Physics of Condensed Matter part II, 6hp
  Chemistry, 3.5p
  Chaos and Nonlinear Phenomena, 6hp
  Thin Film Physics, 6hp
  Materials Optics, 6hp
  Cosmology, 6hp
  Soft Condensed Matter, 6hp
  Physical Metallurgy, 6hp
  Semiconductor Physics, 6hp
  Quantum Computing, 6hp
  Relativistic Quantum Mechanics, 6hp
  Surface Physics, 6hp
  Classical Electrodynamics, 6hp
  Organic Electronics, 6hp
  Adv Project Work in Applied Physics, 6hp

• Tuition in Biological Engineering
  Industrial biotechnology, 6hp
  Design of biotechnical process and production systems (CDIO), 6hp
  Biotechnology manufacturing, 6hp
  Biotechnology project, 6hp
  Biomedical materials, 6hp
  Materials in medicine (CDIO), 6hp
  Materials and nanotechnology, 6hp
  Microsystems and nanobiology, 6hp
  Biosensor technology, 6hp
  Surface science, 6hp
  Molecular physics, 6hp
  Surfaces and interfaces, 6hp
  Supramolecular chemistry, 6hp
  Imaging and ubiquitous biosensing, 6hp
  Engineering project, 6hp

• Tuition in Measurement Technology
  Contemporary sensor systems, 6hp
  Computers in measurement systems, 6hp
  Measurement technology, 6hp
  Electrical measurement systems, 4hp
  Measurement technology, 4hp

Biology

STAFF
• Director of studies: Agneta Johansson
• Administrative assistant: Kerstin Johansson and Jessica Lövdahl
• Technical staff: Ingevald Abrahamsson and Tove Bjerg
• Teachers: Jordi Altimiras, Mats Amundin, Karl-Olof Bergman, Kjell Carlsson, Bo Ebenman, Johan Edqvist, Anders Hargeby, Per Jensen, Matthias Laska, Ronny Lock, Örjan Lönnvik, Eva Mattsson, Per Milberg, Bengt Persson, Lina Roth, Karin S Tonderski, Cornelia Spetea-Wiklund, Uno Wennnergren and Thomas Östhölm

Courses in biology are offered as parts of the following study programmes:
• Biology Programme
• Bachelor of Science in Biology, profiles in Ecology, Environmental Management and Nature Conservation, Ethology and Animal Biology and Molecular Genetics and Physiology
• Masters of Science in Biology, profiles, Applied Ethology and Animal Biology, Ecology and the Environment and Molecular Genetics and Physiology
• Programme for Biology and Chemistry with Mathematics
• Chemical Biology
• Engineering Biology
• The Program for education in Linköping
• Separate courses
• Basic year

THE BIOLOGY PROGRAMME, leading to the degree of Master of Science (240hp) or to the degree of Bachelor of Science (180hp). The programme includes, in the first two years, basic courses in chemistry and general biology. In the third and fourth years there are a number of advanced level courses, mainly seven profiles; Ecology, Ethology, Microbiology and Molecular Genetics, Conservation Biology, Theoretical Ecology, Zoology and Zoophysiology and Biomedicine and Cellbiology. The latter profile is carried out in collaboration with the department of Pharmacology and others within the Faculty of Health Science, Linköping University.

BACHELOR OF SCIENCE IN BIOLOGY, profiles in Ecology, Environmental Management and Nature Conservation, Ethology and Animal Biology and Molecular Genetics and Physiology (180hp). The Programmes include, in the first two years, basic courses in chemistry and general biology. In the third year there are courses specific for each profile.

MASTER OF SCIENCE IN BIOLOGY, profile in Applied Ethology and Animal Biology, Ecology and the Environment and Molecular Genetics and Physiology (120hp). The profiles in Applied Ethology and Physiology are a collaboration between the department of biology at Linköping University and the Kolmården’s Djurpark.

The first year includes nine courses and at the end of the year the student start with his/her Master thesis. The Master thesis is a full year project that will take most of the second
year. At the end of the second year the programme ends with a final course – Communicating science.

**THE PROGRAMME FOR BIOLOGY AND CHEMISTRY WITH MATHEMATICS**, leading to the degree of Master of Science (240hp) or to the degree of Bachelor of Science (180hp). After study of mathematics (60hp) the student makes a choice of further studies in biology or chemistry.

**THE CURRENT PROGRAM FOR EDUCATION** for the Upper Secondary School and the Primary School started in 2001. The program involves a Biology and a Nature Science profile. The division has been responsible for the biology part of the program.

Biology courses are also given in the program **CHEMICAL BIOLOGY** (240 or 300hp) and **ENGINEERING BIOLOGY** (300hp).

**SEPARATE COURSES.** All courses within the Biology programme are also available as separate courses. Besides the courses in the Biology program 6 separate courses have been given.

**BASIC YEAR**, with introductory courses in biology on the Upper Secondary School level.

In the period 01.01.2010–31.12.2010 27 students in the programme Bachelor of Science in Biology put forward their theses, 3 students in the Masters programme in Ecology and the environment, 3 students in the Masters programme in Applied ethology and animal biology, 8 students in the Masters programme in Molecular genetics and Physiology and 14 students in the Biology programme.

29 students were awarded their Bachelor of Biology degree, 2 students were awarded their Bachelor of Science degree, 13 students were awarded their Master of Science (two year) degree and 9 students were awarded their Master of Science degree.

**BACHELOR PROGRAMME, BIOLOGY PROGRAMME**

Animal Husbandry and its Administration, 6hp
Botany 1 6hp
Botany 2 6hp
Cell Biology 6hp,
Degree Project – Bachelor’s Thesis, 16hp
Ecology, second course, 15hp
Ecology 6hp
Environmental Management, 6hp
Ethology and Animal Welfare, 15hp
Environmental Engineering for Biologists, 15hp
Evolution 6hp
Genetics 6hp
Genomics and Bioinformatics, 9hp
Human and Animal Physiology; a problem based approach, 15hp
Introduction to Biology 3hp
Introduction to Molecular Genetics, 6hp
Introduction to Scientific Methods, Analysis and Statistics, 6hp
Microbiology 6hp
Molecular Biology, 15hp
Nature Conservation in Practise, 15hp
Principals in Physiology, 6hp

Scientific Methods and Ethics, 6hp
Zoology, Physiology, Morphology and Systematics, 6hp

**The Programme for Biology and Chemistry with Mathematics**

Animal Husbandry and its Administration, 6hp
Ecology, second course, 15hp
Environmental Engineering for Biologists, 15hp
Environmental Management, 6hp
Evolution 6hp
Final thesis, 30hp
Genomics and Bioinformatics, 9hp
Nature Conservation in Practise, 15hp
Population Ecology: Theories and Applications, 12hp

**Master of Science in Biology, profile Molecular Genetics and Physiology**

Adaption: Molecules to Organism, 6hp
Communicating science, 6hp
Current Concepts, 6hp
Degree Project – Master’s Thesis, 60hp
Functional Genomics, 6hp
Gene Expression Analysis, 6hp
Immunological Techniques, 6hp
Molecular Physiology, 6hp
Plant Molecular Genetics, 6hp

**Masters of Science in Biology, profile Ecology and the Environment**

Advancements in Ecology and the Environment – Part I, 6hp
Advancements in Ecology and the Environment – Part II, 6hp
Communicating science, 6hp
Conservation Biology in situ, 6hp
Current Concepts, 6hp
Degree Project – Master’s Thesis, 60hp
Methods in ecology, 6hp
Modelling of Biological Systems, 6hp
Population Ecology: Theories and Applications, 12hp

**Masters of Science in Biology, profile Applied Ethology and Animal Biology**

Adaption: Molecules to Organism, 6hp
Behavioral Neurobiology, 6hp
Communicating science, 6hp
Conservation Biology in situ, 6hp
Current Concepts, 6hp
Degree Project – Master’s Thesis, 60hp
Methods of Applied Ethology, 6hp
Primate Ethology, 6hp
Theory of Applied Ethology, 6hp
Zoo Biology, 6hp

Programme For Education – Biology courses

Biologi: Genetics, Botany, 15hp
Biologi: Zoology, Physiology, Morphology and Systematics, 15hp
Biologi: Cell Biology and Microbiology (ae 1–10), 15hp
Evolution and Applied Ethology (41–50), 15hp
Environmental Science & Introduction to Molecular Genetics (51–60), 15hp
Engineering Biology
Bioinformatics – Overview and Practical Applications, 6hp
Cell Biology, 6hp
Microbiology, 6hp
Principals in Physiology, 6hp

Chemical Biology
Behavioral Neurobiology, 6hp
Bioinformatics, 3hp
Bioinformatics – Overview and Practical Applications, 6hp
Cell Biology 6hp
Genetics 6hp
Immunological Techniques, 6hp
Microbiology 6hp
Molecular Biology, 15hp
Molecular Physiology 6hp
Plant Molecular Genetics, 6hp
Principals in Physiology, 6hp

Separate Courses
Animal Behaviour 15hp
Animal Communication I, 7.5hp
Animal Communication II, 7.5hp
Behaviour and Biology of the Dog, part I: 7.5hp
Behaviour and Biology of the Dog, part 2, 7.5hp
Faunistics & Floristics 6hp summer course
Wetlands and Streams, Ecological Applications, 15hp

BASIC YEAR
Biological for Foundation Year 3hp
Biological for Foundation Year 7.5hp

Chemistry

STAFF
• Director of studies: Stefan Svensson
• Adm. assistant: Rita Fantl
• Study counselor: Helena Herbertsson
• Technical staff: Bo Palmquist

Study programmes in Chemistry:
• Chemistry (Ke)
• Chemical Biology (KB)
• Chemical Analysis Engineering (KA)
• Chemical Engineering (KBI)
• Master of Science program. Profiles: Organic Synthesis/ Medicinal Chemistry and Protein Science.
• Technical Biology (TB)
• Teacher Training Programs
• Separate Courses
• Basic Year

Most of the chemistry courses offered are part of the four-year programmes, CHEMISTRY (Ke) and CHEMICAL BIOLOGY (KB), (240 credits points/hp). Students completing these programmes are awarded the degree of Master of Science in Chemistry. All courses within the Chemistry Program are also available as separate courses.

The program, CHEMICAL BIOLOGY (KB), has an open entrance for the students: after a year of studies the students can choose to continue in natural science (or to choose a more technical variant to become engineers). Chemical Biology combines understanding of complex biological processes with the fundamental principles of chemistry.

During 2009 these two programs were transformed into three-year Bachelor of science programs (180hp) and master programs on advanced level for further two years (120hp). Chemistry offer master profiles in ORGANIC SYNTHESIS/MEDICINAL CHEMISTRY and PROTEIN SCIENCE.

Some of the chemistry courses are also included in the study programmes of students majoring in BIOLOGY and in TEACHER TRAINING PROGRAMS (students becoming Upper Secondary School teachers). Biology majors are required to earn about 21 hp chemistry, while Science Education majors earn up to 90–120 hp of chemistry.

Besides the above mentioned courses as part of the Mathematical Natural Science, chemistry courses are offered for engineering students in the M.Sc. program CHEMICAL BIOLOGY (also mentioned above) and ENGINEERING BIOLOGY (TB) (300 hp). The CHEMICAL ANALYSIS ENGINEERING(KA), a three year programme introduced 2006 has analytical chemistry as the main profile.

BASIC YEAR (125 students, 13hp), with introductory courses in Chemistry on a secondary school level, is offered to students who do not meet the requirements for studies at the University.

Final theses, the last 30hp in the Chemistry and Chemical Biology program, have been carried out by 22 students, while 12 students completed a 45/60hp variant. Besides projects conducted on campus or at the University Hospital, some projects were performed at Max Planck Institute in Tübingen and at Northeastern University of Boston. For the engineering programs 21 KA students carried out the 16hp, and 16 KB students the 30hp final theses work in the chemistry area.

Under the period 21 students were awarded the Master of Science degree and nine students the Bachelor science degree from the Chemistry and Chemical Biology program. From the Chemical Analysis Engineering program were 25 awarded the degree Bachelor of Science in Chemical Analysis Engineering and 18 Chemical Biology engineering students were awarded the M.Sc degree.

Altogether approximately 600 students have enrolled in about 70 courses in chemistry through the year 2010.
**COURSES**

### NATURAL SCIENCES COURSES

<table>
<thead>
<tr>
<th>Course</th>
<th>HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Chemistry 1</td>
<td>6</td>
</tr>
<tr>
<td>General Chemistry 2</td>
<td>6</td>
</tr>
<tr>
<td>Organic Chemistry 1</td>
<td>6</td>
</tr>
<tr>
<td>Organic Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>Biochemistry 1</td>
<td>6</td>
</tr>
<tr>
<td>Physical Chemistry – Thermodynamic</td>
<td>6</td>
</tr>
<tr>
<td>Analytical Chemistry S</td>
<td>6</td>
</tr>
<tr>
<td>Organic Chemistry 2</td>
<td>12</td>
</tr>
<tr>
<td>Analytical Chemistry T</td>
<td>6</td>
</tr>
<tr>
<td>Inorganic Chemistry</td>
<td>6</td>
</tr>
<tr>
<td>Calculation Tools for Chemistry Students</td>
<td>6</td>
</tr>
<tr>
<td>Experimental Chemistry</td>
<td>6</td>
</tr>
<tr>
<td>Physical Chemistry – Spectroscopy</td>
<td>6</td>
</tr>
<tr>
<td>Analytical Chemistry – Chromatography</td>
<td>6</td>
</tr>
<tr>
<td>Biochemistry 2</td>
<td>12</td>
</tr>
<tr>
<td>Organic Chemistry – Molecular Design</td>
<td>12</td>
</tr>
<tr>
<td>Organic Analytical Chemistry</td>
<td>12</td>
</tr>
<tr>
<td>Organic Spectroscopy</td>
<td>3</td>
</tr>
<tr>
<td>Physical-Organic Chemistry</td>
<td>6</td>
</tr>
<tr>
<td>Nano Chemistry: Surface and Colloid Chemistry</td>
<td>6</td>
</tr>
<tr>
<td>Advanced Organic Synthesis</td>
<td>18</td>
</tr>
<tr>
<td>Medicinal Chemistry 2</td>
<td>12</td>
</tr>
<tr>
<td>Medicinal Chemistry</td>
<td>12</td>
</tr>
<tr>
<td>Organic Synthesis</td>
<td>18</td>
</tr>
<tr>
<td>Protein Chemistry</td>
<td>12</td>
</tr>
<tr>
<td>Combinational Protein Engineering</td>
<td>6</td>
</tr>
<tr>
<td>Biomolecular Design</td>
<td>6</td>
</tr>
<tr>
<td>Final Thesis D</td>
<td>15</td>
</tr>
<tr>
<td>Final Thesis D</td>
<td>30</td>
</tr>
<tr>
<td>Degree Project – Bachelor’s Thesis (KB)</td>
<td>16</td>
</tr>
<tr>
<td>Degree Project – Bachelor’s Thesis</td>
<td>16</td>
</tr>
<tr>
<td>Degree Project – Master’s Thesis</td>
<td>30</td>
</tr>
<tr>
<td>Degree Project – Master’s Thesis</td>
<td>45</td>
</tr>
<tr>
<td>Degree Project – Master’s Thesis (KB)</td>
<td>60</td>
</tr>
<tr>
<td>Degree Project – Master’s Thesis (KB)</td>
<td>30</td>
</tr>
<tr>
<td>Degree Project – Master’s Thesis (KB)</td>
<td>60</td>
</tr>
</tbody>
</table>

### TECHNICAL COURSES

<table>
<thead>
<tr>
<th>Course</th>
<th>HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry for Foundation Year</td>
<td>75+6</td>
</tr>
<tr>
<td>Chemistry (C, Y, I)</td>
<td>6</td>
</tr>
<tr>
<td>Physical Chemistry (KB)</td>
<td>6</td>
</tr>
<tr>
<td>Analytical Chemistry (TB)</td>
<td>6</td>
</tr>
<tr>
<td>Biotechnical Biochemistry (I)</td>
<td>6</td>
</tr>
<tr>
<td>Life Scientific Research Review</td>
<td>6</td>
</tr>
<tr>
<td>Biostructural Technologies</td>
<td>6</td>
</tr>
<tr>
<td>Biochemistry 2</td>
<td>6</td>
</tr>
<tr>
<td>Biological Measurements</td>
<td>6</td>
</tr>
<tr>
<td>Gene Technology</td>
<td>3</td>
</tr>
<tr>
<td>Project Course; Chemical Biology</td>
<td>6</td>
</tr>
<tr>
<td>Applied Structural Biology</td>
<td>6</td>
</tr>
<tr>
<td>Proteomics</td>
<td>6</td>
</tr>
<tr>
<td>Spectroscopy and Kinetics</td>
<td>6</td>
</tr>
<tr>
<td>Interactions and Recognition in Biomolecular Systems</td>
<td>6</td>
</tr>
<tr>
<td>Protein Engineering</td>
<td>6</td>
</tr>
<tr>
<td>Protein Chemistry</td>
<td>6</td>
</tr>
<tr>
<td>Environmental Chemistry</td>
<td>6</td>
</tr>
<tr>
<td>Biomolecular Disease Processes</td>
<td>6</td>
</tr>
<tr>
<td>Protein Engineering</td>
<td>3</td>
</tr>
<tr>
<td>Materials for Sustainable Energy Production</td>
<td>6</td>
</tr>
<tr>
<td>Organic Chemistry 2 (TB+KA)</td>
<td>6</td>
</tr>
<tr>
<td>Fundamentals of Chemistry</td>
<td>6</td>
</tr>
<tr>
<td>Biochemistry 1 (KA)</td>
<td>6</td>
</tr>
<tr>
<td>Application Areas to Chemical Analysis</td>
<td>6</td>
</tr>
<tr>
<td>Engineering</td>
<td>6</td>
</tr>
<tr>
<td>Introduction to Forensic Chemistry</td>
<td>6</td>
</tr>
<tr>
<td>Project in Chemical Analysis Engineering</td>
<td>6</td>
</tr>
<tr>
<td>Forensic Chemistry</td>
<td>6</td>
</tr>
<tr>
<td>Thesis C</td>
<td>15</td>
</tr>
<tr>
<td>Thesis D (KB)</td>
<td>30</td>
</tr>
<tr>
<td>Chemistry</td>
<td>6</td>
</tr>
<tr>
<td>Degree Project – Bachelor’s Thesis (KA)</td>
<td>16</td>
</tr>
</tbody>
</table>

### TEACHER EDUCATION

Chemistry: General Chemistry (1–10) 15
Organic Chemistry Biochemistry Teaching Practice and Subject-specific Didactics (16–30hp) 15
Inorganic Chemistry Experiments and Teaching Practice with Subject Didactics (21–30) 15
Analytical Chemistry and Teaching Practice with Subject Didactics (31–40) 15
Chemistry: Organic Chemistry (41–50) 15
Chemistry (11–20) 15

**Physics – Natural Science**

**STAFF**

- **Director of studies:** M. Boman
- **Administrative assistant:** A. Andersson
- **Technicians:** H. Dzuho, A. Evaldsson, J.-O. Järnhed, and J. Wisbing

Courses in physics are offered as parts of the following study programmes:

- Basic Year and Semester
- Program for education in Linköping
- Physics program,
- and as Separate courses.

**BASIC YEAR AND SEMESTER.** Two physics courses (19.5 hp) are given for students without the necessary qualifications for studies in science and engineering at the university as a part of the Basic year in Linköping. In addition, a one-semester Basic education (15 hp physics) is given for students that already fulfill the most basic qualifications.

The Basic education enrolled approximately 150 students at Campus Valla alone.
Program for Education in Linköping involves a Physics profile, leading to a teaching qualification either for the later years of the compulsory school and the upper secondary school. We have given four A/B-level courses in physics (in total 60 hp points) and, in addition, two new C-level courses (30 hp). Students were also supervised when they carried out diploma work with a physics-profile.

We have also been responsible for the physics part of courses in the Naturals science profile of the program (15 hp physics).

The department was also responsible for the natural science part of the interdisciplinary course Teaching and knowledge, which is compulsory for all first-year students and given for the first time.

The department was also involved in the LiU application for the new program for education commencing in fall 2011. The application, including a physics profile, was approved by the Swedish national agency for higher education (HSV).

Physics program, leading to a Bachelor of Science in Physics. Our engagement in the physics programs primarily concerns two courses in mechanics and one course in astronomy.

Separate Courses. The course Planets, stars and galaxies was given as evening classes and/or distance courses and reached out to a broad audience, as a part of the of the IFM effort to communicate to the surrounding community (“the third university task”). The course enrolled approximately 30 students.

Basic Year and Semester
- Physics A 7.5 hp
- Physics B 12 hp
- Basic education, physics 15 hp

Programme for Education
- Teaching and knowledge 15 hp
- Classical mechanics and thermal physics 15 hp
- Wave Physics and Electromagnetism 15 hp
- Quantum physics, geophysics and astronomy 15 hp
- Teaching physics 15 hp
- Mechanics and physical seminars 15 hp
- Statistical physics and solid state physics 15 hp
- Natural science: Physics 15 hp
- Final thesis 15 hp

Physics Programme
- Mechanics I 6 hp
- Mechanics II 4 hp
- Astronomy and Geophysics 6 hp

Separate Courses
- Planets, stars and galaxies 4.5 hp

International Master’s Programmes

Applied Ethology and Animal Biology
This program deals with animal behaviour and biology from an applications perspective. Central issues are the biology of stress and animal welfare, domestication effects on behaviour, physiology of behaviour and conservation biology.

The programme is taught in association with Kolmården Zoo which sometimes is the teaching venue. Learning rests on a mix of classroom lectures, seminars and hands-on projects involving studies of animals in captive environments. All over the world, problems associated with keeping animals in captivity require increased attention and knowledge.

After completed studies, the student should be well-acquainted with theories of animal behaviour and biology, and have a close understanding of the concepts of animal welfare and conservation. Examination requires the ability to plan, implement and present a scientific investigation in the subject framework of the programme.

Master’s Programme in Molecular Genetics and Physiology, 120 ECTS
This master’s programme focuses on eukaryotic molecular genetics and physiology, with particular emphasis on how this relates to both embryonic development and adult homeostasis.

The programme is divided into a first year of courses and a second year of work on a particular research project in a laboratory setting. The courses are taught using a multitude of formats, including regular lectures, practical laboratories and seminar discussions.

The laboratory classes will utilize powerful biological model systems such as Arabidopsis or chicken to illustrate modern concepts of molecular genetics and physiology. The thesis project during the second year (diploma work) will be conducted in a research laboratory at LiU or other university, in industry or the public sector.

During the first and second year, there will be a parallel seminar course in Current Concepts in Life Sciences, involving research articles and research lectures by invited speakers. During the second year, a parallel course in thesis writing and presentation techniques will be given.

Master’s Programme in Ecology and the Environment, 120 ECTS
Students will develop a critical scientific approach to ecology and an awareness of its role in society. The programme includes training in skills in experimental design and ecological field methodology, both in the classroom and during the individual project in the second year which can be linked to current research projects at the department – e.g. in grassland and weed ecology, ecology and Biogeochemistry of shallow waters or conservation biology. Alternatively the link can be to other universities or research institutes.

This master’s programme also emphasizes the need for, and use of, mathematical models and statistical analyses for addressing complex ecological problems. Such methods serve as powerful tools to e.g. identify crop management strategies.
for effective biological control, understand life-history strategies and the risk of population extinction in a variable environment, or evaluate the preservation status of nature reserves and the impact of management schemes.

The courses cover theories in population, community and systems ecology and how they relate to current environmental problems. Examples are methods in ecology, mathematical modelling of biological systems and conservation biology.

**MASTER’S PROGRAMME IN PHYSICS AND NANOTECHNOLOGY**

Aim and Organisation. The Master’s Programme in Materials Physics and Nanotechnology educates specialists in the area of physics of novel materials. The master students are prepared for university or industry careers in materials related research and development.

The programme covers a wide range of materials including materials used in semiconductor and nano-technology, optoelectronics, biotechnical applications (biocompatibility), chemical and bio-sensors, mechanical applications such as hardness and elasticity etc.

The programme comprises four semesters. The first autumn semester consists of a larger part of compulsory courses while the two following semesters contains mainly elective courses. The fourth semester is assigned to the Master’s thesis project.

The student can choose courses among essentially four elective profiles:
- Electronic Materials and Devices
- Surface and Nano Sciences
- Computational Physics
- Organic Electronics and Sensors

The master’s thesis should be based on high quality scientific research within the area of the profile chosen by the student. This work can be performed either at Linköping University or at other universities.

**PROGRESS**

The programme started 1996 and around ten students have since then joined the programme each year. This year fifteen students entered the programme. The study results of our International master’s students have overall been good. Several of them have produced very good results and have after receiving their degree been recruited as PhD students at LiTH, KTH, CTH, LTH, KU and at universities abroad.

---

**Graduate Education**

---

**Forum Scientium**

- **Programme director**: Stefan Klintström
- **Chairperson scientific board**: Ingemar Lundström
- **Administrator**: Susann Årnfelt

Forum Scientium is multidisciplinary and the doctoral students have backgrounds within biology, chemistry, medicine, physics and technology. The research projects are located at two faculties, Faculty of Health Science and the Faculty of Science and Engineering. Forum Scientium has financial support from the faculty and from the supervisors. 2010 was the third of five years with funding also from the Swedish Research Council, 2.5 million SEK per year.

The strategic objectives are “PhD’s well prepared for their future careers through a structured doctoral programme which includes research of world class, and cooperation and multifaceted contacts with industry and society”.

During 2010, the doctoral programme Forum Scientium had around 65 PhD-students, and eleven PhD-dissertations were defended.

Since 2008, a special Forum Scientium Award exists. Forum Scientium PhDs can apply for an award providing 35% of the salary for a period of up till one year from the PhD-exam. The award aim at promoting the future career for the awardees, and to promote twinning among active Forum Scientium members. Most important is also that they should be of benefit for the active PhD-students. The awardees are called “Transformers” and during 2010 we had all together 10 transformers.

May 2010 Forum Scientium during three days visited a huge number of different research departments and companies in Cambridge, UK. The intention was as usual to find possible positions for the next step in the doctoral students’ career. The photo is from the Medical Research Council Laboratory of Molecular Biology, the department that has received most Nobel Prizes. One Forum Scientium member has so far made his postdoc at MRC-LMB. This was the third time we visited MRC-LMB and we plan to do it again.

**OTHER ACTIVITIES WERE:**
- Ten monthly meetings at Campus US and Valla
- Summer Conference August 2010
- Poster competition August 2010
• Yearly individual follow-up with each PhD-student
• Courses of high quality

and much more that can be found in the Forum Scientium Yearly Report that is published at www.liu.se/scientium/

IFM Graduate Programme

• Director of Graduate Studies: Per Olof Holtz,
• Administrator: Ingegärd Andersson

Graduate students within the graduate program at IFM, Linköping University, aims at a degree of Licentiate or Doctor of Technology or Philosophy. The graduate programme is based on partly a course part and partly a research part. The course and research parts combined will correspond to 240 ECTS points for the Doctor degree and approximately half the number of ECTS points for the Licentiate degree. The nominal time for training to the Doctor degree is four years full-time training and for the Licentiate degree approximately two years full-time training. Most students combine the graduate studies with teaching at undergraduate level (at maximum 20% of full-time), which means that the total time to provide the Doctor degree can be up to five years.

The course menu is organized jointly for the different scientific research areas at IFM. With such an arrangement, a broad menu of courses, reflecting the wide range of IFMs scientific activities, is offered (see course menu enclosed for the students at IFM during the year 10/11 or at http://cms.ifm.liu.se/edu/graduate/courses/). This broad course menu offered at IFM is an important supporting factor for the high interdisciplinary activity level at the department. The graduate students also have the possibility to follow courses given at the graduate school, Forum Scientium at IFM, at other departments at our University or at other universities in Sweden or abroad.

Each graduate student is required to write an individual study plan each year for a planning and follow-up of the progress in the graduate program. This study plan should contain a time schedule for the PhD studies, a project plan for the course requirements and research work together with teaching and other duties at the department.

Each PhD student at IFM will get a mentor when entering the graduate program. The mentor will take active part in the individual study plans. Another reason for the mentorship, is that each PhD student should have the possibility to discuss various questions related to the graduate studies with another person than his/her supervisor.

For all new PhD students, there will be an introductory day offered. On this day, both general information (e.g. department organization, environmental and safety aspects, administration routines) and specific information on the graduate program (e.g. mentorship, course requirements, teaching, doctoral reference group) will be presented.

At IFM, we have a graduate program council, which is a forum for various topics associated with the PhD studies at IFM and LiU. This council, with four meetings per year, has the following members: The Director of Graduate Studies, one representative for each scientific research area at IFM and two PhD student representatives.

PhD Courses Offered

DURING THE ACADEMIC YEAR 2010/11
• Halvledarfysik/Semiconductor Physics: Fredrik Karlsson
• Principles, Instrumentation, Methodology and Applications of Ellipsometry (PRIMA): Hans Arwin
• Materialoptik/Material Optics: Hans Arwin
• Mikrosystem och nanobiologi/Microsystems and nanobiology: Anders Elving
• Kvantdynamik/Quantum Dynamics: Irina Yakimenko
• Kem/Chemistry: Nils-Ola Persson
• Synkronstrålnings/Synchrotron Radiation: Martin Magnuson
• NMR spektroskopi/NMR spectroscopy: Patrik Lundström
- Bioethik/forskningsetik/Bioethics/research ethics: Stefan Welin/Health University
- Chemical Sensor and Science Technology (web based): Anita Lloyd Spetz
- Vakuumteknologi/Vacuum Technology: Per Eklund
- Bioteknologi avancerad kurs/Biotechnology advanced course: Carl-Fredrik Mandenius
- Biomolekylär växelverkan/Biomolecular interactions Bengt-Harald Nalle Jonsson/Anki Brrsson
- Avancerad Biosensor Teknologi med Medicinska Tillämpningar/Advanced Biosensor Technology with Medical Applications: Fredrik Winquist
- Fasta Tillståndets Fysik I/Solid State Physics I: Roger Uhrberg
- Basic management of Research Projects: Stefan Klintström/Rune Olsson
- Biomolekylära sjuksomsprocesser/Molecular Basis of Protein Conformational Diseases: Per Hammarström
- Intellectual Properties as a Business Tool: Stefan Klintström/Lena Sjöholm/Magnus Klofsten/Arne Jakobsson
- Kärnbildning och tillväxt/Nucleation and growth: Lars Hultman
- Nanofysik/Nano Physics: Plamen Paskov
- Röntgendiffraktion/X-ray Diffraction: Jens Birch/Fredrik Eriksson
- Modern biologi för icke-biologer/Modern Biology for non-biologists: Stefan Klintström
- Ytfysik/Surface Physics: Chariya Vironjanadara
- Multidimensional imaging: Daniel Filippini
- Fundamental of Ceramics: Michel Barsoum
- Teoretisk Ekologi/Theoretical Ecology: Bo Ebenman
- Halvledarbaserad komponentfysik/Semiconductor device physics: WeiXin Ni
- Bayesianiska nätverk: Med forensiska och andra tillämpningar/Bayesian networks: With forensic and other applications: Uno Wennergren/Anders Nordgaard
- Polariserat ljus/Polarized light: Hans Arwin
- Nanokemi II/Ytor och Kolloider/Nano Chemistry II (Surfaces and Colloids): Nils Ola Persson, P O Käll, L Ojämä
- Kemiska bindningar/Chemical bondings: Nils Ola Persson, Lars Ojämä
- Svepprob mikroskopi/Scanning Probe microscopy: Ragnar Erlandsson
- Fasta Tillståndets Fysik II/Solid State Physics II: Sergei Simak
- Raman spektroskop/Raman spectroscopy: Ivan Ivanov
- Partikelfysik/Particle Physics: Magnus Johansson
- Experimentell strukturnobiologi/Experimental structural biology: Maria Sunnerhagen
- Halvledarfyssik/Semiconductor physics: Peder Bergman
- Mångpartikelfysik I/Many particle physics I: Bo Sernelius
- Optoelektronik/Optoelectronics: WeiXin Ni
- Bio/nano teknologi/Bio/nano technology: Bengt-Harald Jonsson/Karin Enander
- Tunnelfilmsfysik/Thin Films Physics: Ulf Helmersson
- Plasmafysik/Plasma physics: Ulf Helmersson/Daniel Lundin
- Bioteknologi/Biotechnology: Carl-Fredrik Mandenius
- Bioteknologi, exp. tekniker/Biotechnology, exp. techniques: Carl-Fredrik Mandenius
- Vetenskaplig publicering/Scientific Publishing (prel): Per Jensen
- Proteinkemi/Protein chemistry: Uno Carlsson
- Elektrodynamic/Electro Dynamics: Bo Sernelius
- Optiska egenskaper hos halvledarbasrade nanostrukturer/Optical Properties of Semiconductor Nanostructures: Fredrik Karlsson
- Contemporary Sensor Systems: Anita Lloyd Spetz
- Biosensor Teknologi/Biosensor Technology: Fredrik Winquist
- Kvantmekanik I/Quantum mechanics I: Irina Yakimenco
- Kvantdatorer/Quantum Computers: Irina Yakimenco
- Basic management of Research Projects: Stefan Klintström/Rune Olsson
- Computational Quantum Chemistry: Patrik Norman, Lars Ojämä
- Materialtekniska analysermetoder (MTA)/Analytical Methods in Materials Science (AMMS): Fredrik Eriksson

---

### Scientific Branch of Applied Physics

#### General Information

**STEERING COMMITTEE DURING 2010**
- Prof Bo Liedberg (chairperson), prof Hans Arwin, prof Kajsa Uvdal, prof Olle Inganäs, prof Carl-Fredrik Mandenius, prof Ingemar Lundström, prof Anthony Turner and acting prof Stefan Klintström.

**RESEARCH DIVISIONS**
- Applied Optics
- Applied Physics
- Biomolecular and Organic Electronics
- Biosensors and Bioelectronics NEW
- Biotechnology
- Molecular Physics
- Molecular Surface Physics and Nanoscience

Prof Anthony Turner, one of the leading pioneers in biosensors has moved to Linköping from Cranfield University, UK. Prof Turner is setting up a new research division at Applied Physics and is organising the new Linköping Biosensors and Bioelectronics Centre (LBB).

Prof Bo Liedberg has spent one third of his time during 2010 setting up the Centre for Biomimetic Sensor Science (CBSS)
at Nanyang University in Singapore. One of the aims is to develop biosensors for tropical diseases.

Prof Anita Lloyd Spetz has been appointed as FiDiPro, Finnish Distinguished Professor at Oulu University and will work in Oulu half time during the next couple of years.

**SUMMARY OF ACTIVITIES**

The research within the Scientific Branch of Applied Physics is multidisciplinary and in many cases directed towards the area of Life Science Technologies.

There were around 20 graduate students in Applied Physics during 2010. Four students have successfully defended their PhD thesis during 2010.

Most of the PhD students participate in Forum Scientum (see separate entry) and work in projects that involves two or more divisions or departments at LiU. Forum Scientum is directed by Dr Stefan Klintström.

Staff from the Applied Physics branch teaches in several undergraduate programs, especially in Engineering Biology. The Applied Optics division have special responsibility for many of the undergraduate courses in Measurement Technology. Prof Ragnar Erlandsson is the director of undergraduate studies.

**Highlights During 2010**

**SPECIAL ISSUE OF BIOSENSORS & BIOELECTRONICS**

Special Issue of *Biosensors & Bioelectronics*, containing 101 papers, and the inaugural issue of *Advanced Materials Letters* were dedicated to the occasion of Professor, Anthony Turner’s 60th Birthday. Over a thousand delegates at the World Congress on Biosensors, held in Glasgow, UK in May 2010, joined in a celebration of his Birthday and his 30 years of contribution to the field of Biosensors. *Biosensors and Bioelectronics* has the highest ISI Impact Factor (5.43) for a research journal in the entire Analytical Chemistry category (69 journals) and the editorial team is now headquartered at IFM. IFM will also organise the next World Congress on Biosensors in Cancun, Mexico in May 2012.

**TESTING THE HEART WITH A CELL PHONE.**

Research at the Optical Devices Lab has demonstrated the evaluation on regular cell phones of tests used for monitoring of cardiac diseases. Heart failure is a serious condition that demands periodic controls at the hospital. The evaluation of the NT-proBNP test on cell phones is a promising step towards home testing of medical conditions.

**SURFACE PATTERNING FOR CELL ADHESION**

The division of Molecular Physics has developed a versatile method for preparation of patterned hydrogels which can be used to control cell adhesion. The hydrogel is a methacrylate-based poly(ethylene glycol)-containing polymer, which is completely resistant to non-specific adsorption of fibrinogen (a very “sticky” blood protein) if its thickness is greater than 5 nm. The hydrogel can be prepared on a range of substrates, and since it is easily prepared in patterns (see figure) it is well suited for diagnostic cell adhesion assays where the hydrogel can be used as a matrix for presenting selected bioactive ligands. The efficiency of these materials was tested in collaboration with the Division of Clinical Chemistry (Faculty of Health Sciences).

**SUCCESSFUL DEMONSTRATION OF WATER QUALITY ALARM SYSTEM.**

The EVENT project (Event detection in crisis management systems) ended 2010 with a successful demonstration of a system that could detect the ingress of minute amounts of sewage water into a drinking water network and raise an alarm within the framework of an internet based crisis management system. The demonstration attracted considerable media interest because of the coinciding event in Östersund where thousands of people fell ill from parasites in the drinking water.

**WHITE LIGHT ORGANIC LEDS**

Devices emitting a balanced white light has been produced by incorporating red and yellow phosphorescent molecules...
within a blue-emitting polymer matrix. The red and yellow molecules were encapsulated in protein nanowires, formed by misfolding of insulin decorated with the phosphorescent molecules. This structure helps to suppress the energy transfer processes which would otherwise have made this a faint blue OLED.

RESEARCH PLATFORM – MATERIAL OPTICS AND NANOSTRUCTURES
We combine material optics and development of ellipsometric methodology to analyze optical properties and nanostructure of bulk materials, thin layers, their surfaces and interfaces. Our main technique is spectroscopic ellipsometry which is based on changes in the state of polarization due to reflection of polarized light. Our instruments cover the spectral range 0.19–33 μm (0.04–6.5 eV) and can provide generalized ellipsometric data as well as depolarization and Mueller-matrix data.

METAMATERIALS – EXPLORING EXTENDED ELECTRO-MAGNETIC RESPONSE
Current development in materials science makes it possible to fabricate metamaterials with new properties. New software from J.A. Woollam Co., Inc. allows analysis of the dielectric ε, magnetic μ and gyrotropic ξ and ζ tensors at optical frequencies using the extended constitutive relations.

\[ D = \varepsilon \varepsilon_0 E + c^{-\kappa}\zeta H \]

\[ B = c^{-\kappa}\zeta E + \mu\mu_0 H \]

Using these features we can address materials properties of new nanostructured materials in the emerging field of metamaterials.

NATURAL PHOTONIC STRUCTURES
Natural systems offer technologically unrealized photonic structures and provide inspiration for applications that require unique optical performance. Studies of the optical properties of cuticles of several scarab beetles (loan from Swedish Museum of Natural History) to learn how nature has designed bilayer structures in progress. One interesting example is the golden beetle *Chrysina argenteola* which shows both right- and left-handed polarization depending on angle of incidence. This is illustrated in Fig.1 where the blue color at 65° and the red color at 45° for blue light correspond to right- and left-handed near-circular polarization, respectively (Gustafson, Järrendahl, Landin, Arwin).

Applied Optics

STAFF
Professor: Hans Arwin
Administrative assistant: Susann Årnfelt
Assoc. professors: Kenneth Järrendahl, Lennart Bávall, Tomas Hallberg (external)
Assist. professor: Sergiy Valyukh
Visiting scientists: Saulius Tumenas (Lithuania)
Post docs: Torrun Berlind, Iryna Valyukh
PhD students: Roger Magnusson, Christina Åkerlind

VISITING/DIPLOMA STUDENTS
Eduardo de Mayolo, Johan Gustafson

COLLABORATIONS
ARTIFICIAL PHOTONIC STRUCTURES

Gold-silica arrays were investigated in collaboration with Mikael Käll at CTH and a model describing the optical response is developed (Mendoza, Järrendahl, Arwin).

Nanostructured helical films composed of InAlN nanorods were fabricated and analyzed in collaboration with Jens Birch at LiU. Both left-handed and right-handed structures were grown which in reflected light exhibit left- and right-handed polarization, respectively (Magnusson, Arwin, Järrendahl).

ACTIVE OPTICAL ELEMENTS

Lenses with variable focus distance and beam steering devices based on nematic liquid crystals are studied. We propose a new method for developing such active optical elements which involves a non-uniform surface distribution of the anchoring energy of the liquid crystal. Advantages are that these elements have layers with uniform thickness, continuous electrodes and are driven with low voltages (S. Valyukh).

PROTEINS AND CELLS AT INTERFACES

In collaboration with Håkan Engqvist, UU, (SSF Strategic Research Center, MS’E) surfaces aimed for bone replacements are examined. To reveal the impact of activation of complement (the immune system) and coagulation, surfaces are exposed to blood plasma and antibodies. The investigation of possible applications for carbon nitrides in biological environments is continued. Blood plasma and cell studies are being performed. A protein adsorption study on hydrophobic polymers for medical applications has been initiated (Berlind).

FUNCTIONAL COATINGS

Chemically induced optical switching in thin films of Rose Bengal has been studied. BRDF measurements and Mueller-matrix ellipsometry on the white beetle Cyphochilus insulans has been performed to analyze scattering and depolarization properties (Åkerlind, Hallberg, Arwin, Landin, Järrendahl).

CELLULOSE FILMS

In collaboration with Lars Wägberg, KTH, optical properties of nano-fibrillated cellulose films and humidity induced changes are studied in situ spectroscopic ellipsometry (de Mayolo, Arwin).

SCIENTIFIC OUTPUT 2010

6 published publications, 10 reports in press and 20 conference contributions.

SPECIAL EVENT

During 2010, ICSE-V – the 5th Int. Conf. on Spectroscopic Ellipsometry was held in Albany, New York. We were well represented with coauthorship on 13 contributions: one plenary, four oral and 8 posters.

TEACHING

The Ph D course “Principles, Instrumentation, Methodology and Applications of Ellipsometry (PRIMA)” was given. Järrendahl, Båvall, Berlind and Arwin were responsible for many undergraduate courses and activities. Kenneth Järrendahl is vice chairman for the EF study board.
**Applied Physics**

**STAFF**

*Professors:* Ingemar Lundström (emeritus), Anita Lloyd Spetz (50% professor at Oulu Univ. Finland), Fredrik Winquist, Ragnar Erlandsson, Martin Holmberg (now professor at Swedish Police Academy), Helen Dannetun (leave of absence) and Pentti Tengvall (prof. at Göteborg Univ 2010)

*Acting professor:* Dr Stefan Welin Klintström (head of the division)

*Scientists:* Doc Mats Eriksson, Doc Daniel Filippini, Dr Anke Suska, Dr Mike Andersson, Dr Robert Bjorklund, Dr Ruth Pearce, Dr David Lindgren

*Administrative staff:* Susann Årnfelt and Anna Maria Uhlin

*Graduate students:* Roger Klingvall, John Olsson, Paula Linderbäck, Stephen Macken, Kristina Buchholt, Zafar Iqbal, Pakorn Prechaburana, Zhafira Darmastuti

*Research engineers:* Jörgen Bengtsson, Jeanette Nilsson, Hans Sundgren, Bo Thunér (laboratory manager), Ingemar Grahn and Agneta Askendal (retired 2010)

**GENERAL INFORMATION**

The research within the Division of Applied Physics is multidisciplinary. The members of the division are electrical engineers, physicists, chemists, biochemists and biologists. Several projects are in the areas of physics and chemistry, and physics and biology. The projects are often conducted in cooperation with other divisions within the scientific branch of Applied Physics. The research activities also include fundamental multidisciplinary research, mainly within the surface sciences. Many projects are run in cooperation with external collaborators.

The division is hosting *Forum Scientium*, a multidisciplinary doctoral student programme under the direction of Dr Stefan Klintström. Most of the graduate students at the Division of Applied Physics participate in Forum Scientium.

*Forum Scientium* has its own entry in the Activity Report, see “Graduate education”.

The division also participates in two VINNOVA-graduate schools: *Forum Securitatis*, a graduate school in security research and *AgoraLink*, an agora for Medical and Life Science Technologies in Linköping.

Professor Ingemar Lundström, emeritus since May 2008, is reemployed by LiU (to 50% of full time) to participate in externally funded research projects and act in other university based activities. He is, among other things,

- Chairperson of the steering committee of Linköping Centre for Life Science Technologies
- Chairperson of the scientific advisory board of Forum Scientium
- LiU member of working groups within New Tools for Health (Hälssans Nya Verktyg)

Prof Lundström and Prof Winquist are both moving their activities to the new division Biosensors and Bioelectronics. Both are still involved in projects run by S-SENCE as described below.

Besides his engagement at LiU Ingemar Lundström has served as Chairman of the Nobel Committee for Physics, among other things.

**RESEARCH OVERVIEW**

The research within the Division is conducted in collaboration with most of the other Divisions within the Scientific branch Applied Physics and often within the larger programs described elsewhere. This means that some activities are more extensively described at other places in the Activity Report. The research areas which are further described below are:

- Optical Devices Lab
- Chemical Sensor Science
- S-SENCE
- New Tools for Health
- Materials in Medicine

**COLLABORATIONS**

The division has a number of collaborations with Swedish and foreign universities. These are mentioned in the project descriptions below.

**RESEARCH**

**Optical Devices Lab**

Under the leadership of Doc. Daniel Filippini this group’s most important achievements during 2010 has been:

- Demonstration of NT-proBNP evaluation using HDR imaging on regular cell phones operated as light sources and image detection platforms.
- The development of a new 3D fast micro prototyping systems capable of configuring arbitrary positive, negative and suspended geometries, as well as sealing to substrate and connections with service areas.

Dr. Daniel Filippini’s group works on optical chemical sensing methods and devices. One important area of the group’s activity is chemical sensing for ubiquitous platforms such as consumer electronic devices. The other main research focus is micro fabrication methods for disposable optics and fluidics.

Present activities concentrate on the migration of optical spectroscopies and surface plasmon resonance imaging to cell phones aided by disposable microsystems.

**Heart failure monitoring**

We have demonstrated NT-proBNP evaluation, a key parameter for decentralized heart failure monitoring, using standard cell phones as controlled light sources and advanced image acquisition platform (P. Prechaburana, et al., Biosensors & Bioelectronics).

The implementation of high dynamic range (HDR) imaging showed the possibility to duplicate the resolution of NT-proBNP detection, bringing the evaluation of commercial tests with cell phones within the diagnostics range.
3D microstructure fabrication
Further progress in the above area requires more sophisticated disposable sensing devices customized to operate on cell phones. Therefore the Filippini group is directing its efforts towards microfabrication. During 2010 we have demonstrated a new fast prototyping method for fully defined 3D microstructures compatible with optical and sensing uses (P. Preechaburana, D. Filippini, Lab. Chip).

The development of this system has been supported by LfIT and Carl Trygger foundation grants, and we have been able to demonstrate: 3D configuration of positive, negative and suspended microstructures, sealed spaces and microstructures embedded within extended service areas.

The micro fabrication platform is a refined mask-less micro projection lithography system (MPLS) implemented as a complementary DMD light source through the epi-fluorescent path of a routine microscope. The system enables fast and accessible fabrication of 3D microsystems of varied characteristics and only requires the most common photolithographic materials: SU-8 and S1818.

The figure shows a collection of results obtained with this platform.

Further progress in the development of this micro prototyping system will require the incorporation of nano structuring and the extension of the integration capabilities to larger areas.

**CHEMICAL SENSOR SCIENCE**
The research group of Prof Anita Lloyd Spetz runs cross disciplinary projects over several scientific areas within IFM.

**Graphene sensors.**
Monolayer graphene was epitaxially grown on SiC in the group of Prof Rositza Yakimova, Material Science Div. Preliminary results showed ultra low detection limit, less than 10 ppb of NOx. The graphene sensor research is supported within FunMat and AFM – Strategic Faculty Grant in Advanced Functional Materials.

**Sensors with smart electronics**
A collaboration has been started with Saarland University in Saarbrücken, Germany. Smart electronics and data evaluation is developed to increase the information from SiC sensors. Cycling of the sensor operation temperature and smart data evaluation showed preliminary interesting results, like simultaneous quantification of both NO and NOx in a mixture of synthetic exhaust.

**FunMat**
Lloyd Spetz is the deputy director of The VINNOVA VINN Excellence center FunMat, presented elsewhere. The activities are concentrated around development of MAX materials, which are conducting ceramics with industrial applications such as coatings for cutting tools, electrical/mechanical contacts and chemical gas sensors. The MAX material Ti3SiC2 is found to grow epitaxially on SiC and is developed as ohmic contact to SiC as part of the strive to raise the allowed operation temperature of FET- SiC sensors to at least 700°C.

**SootSensI, Soot sensors for efficient combustion and low emissions**
SootSensI & II, coordinatated by Prof. Anita Lloyd Spetz is an MNT ERA – Net programme with 8 partners in 4 countries. The aim of the project is to develop a soot sensor based on thermophoresis, i.e. keeping the sensor surface colder than the surroundings and thus increase the sensitivity. In this way it is possible to detect small amounts of soot, e.g. after the particulate filter in diesel exhausts. Testing has been performed in stationary diesel engines at Volvo in order to show proof of concept.
**SIC BASED AMMONIA SENSORS FOR CONTROL OF SNCR**

This project, funded by Värmeforsk, involves several industrial partners, (Tekniska Verken, SenSiC AB, Vattenfall and Alstom Power Sweden AB) and concerns development of a SIC based ammonia sensor system to control SNCR (selective non catalytic reduction), i.e. injection of ammonia (or urea) in hot flue gases in order to efficiently reduce nitrogen oxide gases leaving only nitrogen and water.

**Multifunctional Biosensors**

In this project financed by VR, multifunctional bio- and chemical sensors based on wide band gap materials are developed through material growth (Prof Rosita Yakimova), biofunctionalization (Prof Kaja Uvdal), and device development (Prof Anita Lloyd Spetz). Also synthesizing of nanoparticles for sensing layers (Prof. Per-Olov Käll) and modelling (Prof. Lars Ojamäe) is performed. A workshop was held in June 2010 at Linköping University with participants from India, USA, Singapore, Romania and Sweden supported by a VR/SIDA grant.

**FET sensors within CeNano**

A grant by CeNano, IFM, contributes to the research on MAX material high temperature contacts, mainly Ti$_3$SiC$_2$, for SIC FET sensors. Characterization on the nanoscale of the contact material is performed within this project. See also FUNMAT elsewhere.

**S-SENCE**

The S-SENCE group, headed by associate professor Mats Eriksson, is a research group within bio- and chemical sensor science and technology. Mats Eriksson is also a member of the management group of Security Link, a new (2010) strategic research effort at LiU, focusing on technology and methodology for civil security applications.

The “Event detection in crisis management systems” (EVENT) project, a collaboration with Saab AB, Tekniska Verken i Linköping AB and the municipality of Linköping, has been a good example of a so called triple-helix project. A network of electronic tongues were monitoring a pilot version of a water distribution network, providing information about the water quality to a crises management system in real-time. After problems with the drinking water in Östersund the EVENT project attracted considerable attention in media.

“Microelectrode arrays for drinking water quality monitoring” is a new project which is running during 2011–2013. Via this project the group is also a partner in the newly established Linköping Biosensors and Bioelectronics Centre (LBB).

The “BugiT” project has developed a sensor network system for monitoring and identification of insect attacks in the field, which will help farmers to optimize insect control. In the project “Instant method for the determination of cadmium”, cadmium in cereal products will be measured by stripping voltammetry. In collaboration with the Health University at LiU, a project concerning the use of an electronic nose as a diagnostic tool for KOL and heart diseases is running. Prof. Fredrik Winquist participates in a project on sensing amylase in saliva as a stress marker, which is described in detail in the section about the LBB centre mentioned above.

**NEW TOOLS FOR HEALTH**

**Computer Screen Photo-assisted Techniques**

CSPT is used for the development of diagnostic methods based on color indicators (porphyrins) for volatile organic molecules like amines and alcohols. Presently the research aims at the development of a method to detect emissions from (precursors to) pressure ulcers. This work is a collaboration with Departments of Biomedical Engineering and Medicine and Health (HU), ACREO in Norrköping and the University of Rome Tor Vergata.

The goal is to create a smart fabric for the visualization of “hot spots” for an early detection of precursors to pressure ulcers. The development of CSPT itself, for example to be used with cell phones and dedicated optical microstructures, is performed by Dr. Daniel Filippini and his research group within the Optical Devices Lab at the Division of Applied Physics.
**Salivary amylase as a general health marker**

The goal for this activity is to develop a simple-to-use, reliable and reproducible detection method for salivary amylase activity based on sensing strips for electrochemical or optical evaluation. The method should be used in home based tests as a general health marker related both to physical and psychological stress.

Studies have been performed, in collaboration with the Health University, where several interesting correlations between general health conditions and salivary amylase activity have been found. The development of a simple test method for amylase activity is now expanded through a LIST project run by Prof. Fredrik Winquist and Dr. Peter Garvin (HU) called “Salivary amylase as a stress marker”.

A second (small) clinical study in collaboration with the Heart Centre at HU elucidates the connection between salivary amylase activity of patient with heart failure in different stages. The hope is to be able to use salivary amylase as an endogenous biomarker in home based monitoring of heart failure patients.

**Materials in Medicine**

Prof Pentti Tengvall, executive person in the Materials in Medicine research program, received a new professorship at Gothenburg University where he is currently leading the doctoral programme BIOSUM, an interdisciplinary research school established 2008 by University of Gothenburg and Chalmers Technical University.

---

**Biomolecular and Organic Electronics**

**STAFF**

*Professor:* Olle Inganäs,  
*Associate professor:* Fengling Zhang, Niclas Solin  
*Postdocs:* Christian Müller, Tang Qun (–Feb), Lintao Hou, Mattias Andersson, Kristofer Tvingstedt, Koen Vandewaal

*Graduate students:* Jens Wigienius (–June), Viktor Andersson, Anders Elfwing, ZaiFei Ma, Fredrik Bäcklund (March–), Zheng Tang (Aug–)  
*Visiting students:* Zhongqiang Wang.

*Administrators:* Mikael Amlé  
*Research engineer:* Bo Thunér  
*Diploma students:* Jonas Bergquist, Chorpure Thinprakong, Yu-Te Hsu

**SUMMARY**

Research in biomolecular and organic electronics is focused on the development of polymer electronics, particularly polymer photovoltaics, and the combination of biological macromolecules with synthetic conjugated polymers for supramolecular materials assembly.

A PhD thesis on conjugated polyelectrolytes for supramolecular selfassembly and sensing was presented by Jens Wigienius.

We published 25 papers during 2010.

**BIOMOLECULAR ELECTRONICS**

Microscopy and spectroscopy has been used to follow the growth of protein or polypeptide based nanostructures incorporating conjugated polyelectrolytes from solution.

We have developed methods for the synthesis of hybrid materials formed between proteins and inorganics and organics. The hybrid materials are formed by heating a suitable protein precursor in aqueous acid; the proteins then self-assemble into amyloid fibrils. The bio-molecule thus determines the shape of the self-assembled object, whereas the function is determined by a proper choice of functionalization agent. We have made such amyloid-like materials carrying metallic, magnetic, luminescent and other functions in or on the nanowires.

We can also prepare hybrid materials that incorporate phosphorescent organometallic molecules. These amyloid-like structures were successfully incorporated into polymer blends, allowing us to fabricate white light emitting devices.

Novel biomaterial structures for neural stem cell research has been constructed to investigate mechanical keys to cell differentiation.

**ORGANIC ELECTRONICS**

Charge transfer state spectroscopy has been extended to many new polymer/fullerene systems. Distinctions between the charge transfer state seen in photoluminescence and that seen in electroluminescence enable analysis of recombination routes in these systems.

A new combination of thermal and optical methods has been used to deduce the phase diagram of binary blends of polymer and fullerene acceptor in polymer solar cells. We have also followed the dependence of phase behaviour on polymer molecular weight.

A new and blue polymer from Chalmers gave a 6% power conversion efficiency in polymer solar cells. We have developed optical models for this material, and elaborated the processing, in order to understand the correlation of nanostructure and device performance.

Novel low bandgap polymer improve voltage from polymer solar cells, with light absorbed deep into the infrared. Poor optical absorption limit the photocurrent in these materials. Also studies of molecule/molecule blends show improving power conversion efficiency.

Electrochemical transistors in fibre format has been developed using new fibre substrates, one of them (spiber) coming from genetic engineering of a spider silk protein. The other one was natural silk from Bombyx mori, and both materials are easily coated with the soluable and metallic polyelectrolyte PEDOT-S. These studies have also underlined that binding
between conjugated polyelectrolytes and proteins is modulated by the charge of each species.

TEACHING
Teaching in the undergraduate curriculum included the undergraduate courses Microsystems and nanobiology (TB), Materials and Nanotechnology(TB),

COLLABORATIONS
Within European projects with Freiburg, Germany, Åbo Akademi, Finland and ECN, the Netherlands. With Chalmers University for polymer materials, and with Lund for spectroscopy.

With prof. J. Widengren at KTH for fluorescence correlation spectroscopy.

With Karolinska Institutet for evaluation of cell interfaces.

We participate within the SSF research centre for organic bioelectronics, OBOE.

Funding in the field of printed organic electronics and organic nanoelectronics comes from SSF, through the program OPEN 2008–2013. For polymer photovoltaics, the Swedish Energy Agency finances 5 different projects.

HIGHLIGHTS
Electrochemical transistors on silk fibres
A metallic conjugated polymer coated on a fibre from the silkworm Bombyx mori is used to build electrochemical transistors. These have some similarities to standard transistors, but are based on redox processes in the conjugated polymer, also depending on ion transport and therefore very slow.

The low voltage and possibility of making woven logic, as well as the ease of integration into biological environments, makes these devices candidates for addressing and multiplexing signals to neurons at electrode/neural interfaces.

White light organic LEDs
White light via electroluminescence from conjugated polymers and organometallic molecules organized with help of protein nanowires formed by self assembly.
Biosensors and Bioelectronics

STAFF
Professors: Anthony Turner and Fredrik Winquist
Emeritus Professor: Ingemar Lundström
Consultant: Dr Claes Nylander
Managing Editor: Dr Alice Tang
Administrative staff: Anette Andersson

GENERAL INFORMATION
Biosensor and Bioelectronics is a new Division within the scientific area Applied Physics. It was established in November 2010, when Prof Anthony Turner moved to LiU from Cranfield University in the UK, where he has been working on biosensors and bioelectronics for over 30 years. Besides setting up this research department he has also taken the initiative to form the Linköping Biosensors and Bioelectronics Centre (presented separately in this report) in order to establish LiU as an international centre for research in this area, by building on its extensive network of international universities and industries.

Professors Ingemar Lundström and Fredrik Winquist have joined the Division and are undertaking several ongoing and forthcoming projects within the new department.

The new team will be seeking close collaborations with other groups within LiU while maintaining close contacts with outstanding international academic and industrial research groups.

EU Marie Curie Fellowship IFF254955: Stimuli-responsive Zipper-like Nanobioelectrodes.

This new International Incoming Fellowship (Marie Curie) was transferred with Professor Turner to IFM and will fund Dr Ashutosh Tiwari until March 2013.

Engineering of stimuli-responsive advanced materials at the nano levels has found striking applications in both the strategic and civil sectors. Some of the most promising functional materials are those that have the ability to alter shape or texture in a controlled way in response to an external stimulus. Nanobioelectrodes are an emerging vehicle resulting from the smart integration of nanobiotechnology and nano-materials. Due to their ultimately small size, high surface area and simulation capacity, they are becoming a versatile platform for making novel nanobiosensors.

The current programme is focused on the fabrication of simple-to-use, inexpensive and ultra-sensitive devices, which are highly selective, sensitive and stable. Thus, the fundamental goal is a novel bioelectrode with self-control abilities for advanced applications (e.g. switchable bio-catalysis). Zipper-like polymers are being used to construct nanobioelectrodes with a number of advantageous properties. Novel methodologies include molecular self-assembly, monitoring of dynamic-phase transition and bio-catalytic analysis and characterisation.

The programme builds on a previous Fellowship: Smart-MIP (Modulated Catalysis by Smart Molecularly Imprinted Polymers), awarded to Dr Songjun Li, who continues to work at Cranfield University under Professor Turner’s supervision.

EU Network for Initial Training in Chemical Bioanalysis ITN264772: CHEBANA
Professor Turner is the Principal Investigator for this new Marie Curie Initial Training Network (ITN), commencing December 2010 for four years and being carried out in collaboration with Cranfield University in the UK and ten other European partners.

CHEBANA provides a European hub for research and training in the fast developing field of Chemical Bioanalysis with co-supervised PhD theses, postdoctoral training, workshops and summer schools to help furnish highly specialised experts.

Chemical Bioanalysis aims to retrieve selective information out of complex biological systems. Sensors, probes and devices are the future tools of medical diagnostics, environmental monitoring, food analysis and molecular biology. CHEBANA provides interdisciplinary research training for both early-stage and experienced researchers and focuses on the most important techniques in the field: electrochemistry, fluorescence and mass spectrometry. Eleven excellently qualified academic partners, along with one of Europe’s leading diagnostics companies participate in the network.

Moreover, joint research projects between the partners will include the following four overlapping areas:

• Sensor development for the detection of small analytes
• Monitoring of biomolecular interactions
• Analysis of cellular function
• Development of diagnostic tools

Production of molecularly imprinted nanoparticles
This grant to Professor Turner funds a PhD student, Alessandro Poma, until 2012. The work is principally carried out in the UK under Professor Turner’s supervision and in collaboration with Professor Sergey Piletsky as local supervisor. Molecularly imprinted polymers (MIPs) are prepared by polymerising self-assembled molecular complexes formed between a target (template) molecule and functional monomers in the presence of a cross-linker and are promising substitutes for antibodies
for use in diagnostics, therapeutics, imaging and separations. This project focuses on the particular issues associated with the large scale manufacture of such “plastic antibodies” and the implications for the performance of the synthesised materials. In contrast to conventional bulk MIPs, those created as nanoparticles exhibit improved properties by facilitating surface imprinting strategies, thus improving the template binding kinetics and affinity distribution and therefore the overall performance of the recognition process.

Moreover, through the formation of MIP nanoparticles in situ with immobilised template, it may be possible to significantly reduce the amount of target molecule used for imprinting and enhance epitope imprinting of proteins.

**Artificial enzyme electrodes**

Under an ongoing programme of collaboration with the University of Florence, where Professor Turnier is a Visiting Professor, quasi-monodimensional polyaniline nanostructures for enhanced molecularly imprinted polymer-based sensing have been developed and reported. The approach opens up possibilities for creating artificial enzyme electrodes using catalytic polymers in conjunction with amperometric detection.

**Enzyme immobilisation in SU-8 films**

A long-standing collaboration with Professor Nico de Rooij at the Ecole Polytechnique Fédérale de Lausanne has recently resulted in a novel method for enzyme entrapment in SU-8 microfabricated films for glucose micro-biosensors. This approach facilitates the integration of biological components in conventional microfabrication processes.

**Minimally invasive glucose sensing**

Professor Turnier is working with Pelikan Technologies Inc (Palo Alto, USA) to develop proprietary approaches to near-painless sample acquisition and glucose monitoring for use by people with diabetes. The technology uses an electro-magnetic sampling engine together with electro-chemical detection.

**Electrochemical nano-immunosensor**

In a collaborative PhD project with the National Physical Laboratory in the UK and Argento Ltd, novel electrochemical immunoassays are being explored for applications in developing countries. The programme is supervised by Professor Turnier and exploits silver nanoparticles as electroactive bio-labels together with a proprietary solubilisation procedure and stripping voltammetry.
Arsenate sensor for water quality testing
Work continuing under an international collaborative programme with Dr Priyabrata Sarkar at the University of Calcutta in India, has resulted in a novel electrochemical sensing systems for arsenate estimation, based on the oxidation of L-cysteine followed by amperometric detection using a disposable sensor format.

Biotechnology

STAFF
Professor (head): Carl-Fredrik Mandenius
Adjunct professor: Anders Brundin
Secretary: Anna Sundin
Research engineer: Maria Carlsson (lab manager)
Postdocs: Michael Fritzsche
PhD student: Gunnar Bergström
Master student: Cyrus Djahedi

SUMMARY
The research and education at the division of biotechnology focus on industrial applications of biotechnology. In essence, industrial biotechnology is the integration of engineering and biology for production purposes. The scientific breakthroughs of the seventies and eighties in molecular genetics, which resulted in the industrial production of recombinant proteins in microbial and animal cell cultures, are now furthered by new products such as stem cells, therapeutic antibodies and gene therapy vectors.

A number of bioengineering tools are currently exploited based on genetic, protein, metabolic, physiological and organ engineering in order to improve production capacity of proteins, metabolites, and cells. It is a prime task for the current biotechnology research to integrate and develop these tools in order to achieve and optimize new and better industrial applications.

The biotechnology division at IFM is contributing to this by inventing and developing novel analytical means that can provide better insights into the biology of industrial production systems. The cross-disciplinary environment of Linköping University furnishes unique opportunities for this. The combination of sensor technology, mathematical computation methods and production design, supports the use of new approaches that enhance the understanding and allow further optimization of the bio-industrial production systems. The integration of these topics in the curricula of the Engineering Biology program forms an important link between education and research at the division. Our PhD-study program in biotechnology is directly connected to the research of the division and is a part of the research that is highlighted below.

HIGHLIGHTS

In vitro toxicity testing
The division has during the past five years devoted substantial efforts to the study of in vitro toxicity testing with a variety of sensor and cell culture methods. A substantial part of the work has involved two EU-projects, Invitroheart and Vitrocellomics, where cardiomyocytes and hepatocytes derived from human embryonic stem cells have been exploited. Sensor methods that have been used with these cells to develop assays for in vitro toxicity testing have been based on surface plasmon resonance and multi-wavelength fluorimetry.

An overall aim with the EU-project has been to deliver reliable in vitro models that could be used by the pharmaceutical industry to replace experimental animals in (2) investigations on pharmacological toxicity and safety of compounds in the drug discovery and development processes, and (2) the testing of toxic effects of chemicals according to the new system of the Community on the Registration, Evaluation and Authorisation of Chemicals (REACH). In the pharmaceutical industry reliable in vitro cell models would contribute to replace current techniques with animal experimentation in the selection and optimisation of lead compounds and in documentation of a selected drug candidate before it enters clinical phases.

During 2010 three articles have been published that demonstrate how human embryonic stem cell derived cardiomyocytes can be used for sensor-based testing of biomarkers and drugs by SPR and fluorimetry (Andersson et al, Anal. Bioanal. Chem., 2010; Andersson et al, J. Biotechnol., 2010; Fritzsche and Mandenius, Anal. Bioanal. Chem., 2010). The figure below illustrates the application on an SPR biochip with cardiomyocytes for monitoring of cardiac troponin release.

![Figure 1: Assay principle for monitoring of release of troponin from human cardiomyocytes during drug exposure](image)

The in vitro cell studies have involved several collaborating partners: MultiChannelSystems GmbH (D), Saarland Uni-
Software sensors for bioprocess control
Software sensors are robust on-line sensors supported by mathematical models derived from the systems under study. In particular, they are useful for bioprocess monitoring due to the complexity of the biological mechanisms of the producing cells. We have used software sensors to monitor physiological signals from typical industrial cultures by combining sensors for biomass, effluent gases and key metabolites with basic mass balances and kinetic (Warth et al, Journal of Biotechnology, 2010). Fig. 2 illustrates sensor configurations investigated.

Biomechatronic Design in Biotechnology
In collaboration with IEI at LiU we carry out continuing studies on the industrial development and design process of complex biotechnology instruments and devices. During 2010 the subject was highlighted in one of the leading biotechnology journals, Trends in Biotechnology (Mandenius and Björkman, 2010). The paper covers new applications with stem cell manufacturing and artificial organ bioreactors. Work has also been devoted to a new book to be published during 2011 (Mandenius and Björkman, Wiley, New York) where broader approaches are taken on the subject.
Molecular Surface Physics and Nano Science

STAFF
Professor: Kajsa Uvdal
Postdocs: Xuanjun Zang, Z.Hu, Caroline Skoglund
PhD students: Cecilia Vahlberg, Maria Ahren, Linnéa Selegård, Linnéa Axelson, Natalia Abrikossova
Diploma students: Andreas Skallberg, Emanuel Larsson, Fredrik Backman
Technical staff: Bo Thunér
Administrative staff: Anna Maria Uhlin

GENERAL
The division of Molecular Surface Physics and Nano Science is a division at Applied Physics IFM, active in the field of Nanomaterial and Molecular thin film physics and spectroscopy. Our main focus is on surface modification for sensing/biorecognition and nanoprobe for biomedical imaging.

Bio-specific binding phenomena at solid surfaces are investigated. Design and characterization of new and improved nanoprobe for imaging are performed. Equipment used are X-ray Photoelectron Spectroscopy (XPS), Near Edge X-ray Absorption Fine Structure (NEXAFS) Spectroscopy, Infrared Absorption Spectroscopy (IRAS), Surface Plasmon Resonance (SPR), Dynamic Light Scattering (DLS), Transmission Electron Microscopy (TEM) and Magnetic Resonance Imaging (MRI). Super small particles i.e. particles with very small volume, with unique physical and chemical properties, have a high potential in biomedical imaging and future biosensing applications. We are designing biocompatible nanoparticles based on rare earth metal oxides. These are very promising as positive contrast agent (Patents) in MRI. Powerful equipment available at IFM, in house experience of life science technology and molecular physics as well as close collaboration with CMIV (Center for Medical Image Science and Visualization) facilitate progress in the field of novel nanomaterial design for bio medical imaging. We are now investigating protein nanoparticle interaction processes and are studying cell responses in collaboration with pharmacology HU. Preliminary studies within applied MRI are initiated together with Karolinska Institutet, Stockholm.

EDUCATION
The division has delivered three advanced level courses in the Engineering Biology program (Industrial Biotechnology, 6 hp; Bioprocess design, 6 hp; and Bioprocess manufacturing, 6 hp) and examined several diploma work theses in biotechnology.

COLLABORATION
During 2010 the division had fruitful collaborations with the following companies and institutes: Cellartis AB (S), Pharmacelsus GmbH (D), Multi-Channel-Systems GmbH, Reutlingen (D), Presens GmbH, Regensburg (D), AstraZeneca R&D, Möln达尔 (S), Saarland University (D), Charité University Hospital, Berlin (D), ECVAM Joint Research Center, Ispra (I), University of Pittsburgh, Penn (USA), IBET, Oeiras (P) Bodenkulturuniversität, Vienna (A), Karolinska Institute, Stockholm (S), Sahlgrenska University Hospital (S).

Figure 4: Bioreactor producing recombinant GFP

Measurement, Monitoring, Modelling & Control (M&C)
Measurement, monitoring, modelling and control (M&C) are critical issues for successful application of biochemical engineering. The recent interest in M&C methodology from regulatory authorities, e.g. FDA and EMA, as well as the International Conference on Harmonisation (ICH) further underscores its industrial relevance, especially for the pharmaceutical and biopharmaceutical manufacturers, but also for academic researchers and educators. Prof Mandenius is the chairman of the M&C group of the European Federation of Biotechnology. The group develops network activities in Europe on M&C issues. During 2010 an expert workshop on “M&C and Process Analytical Technology for Biopharmaceuticals” was organized in Bologna. The will soon be available (Glassey et al, Biotechnology Journal, in press). A position paper on M&C education was recently published (Bracewell et al, Biotechnology Journal, 2010).
We are studying functionalization of wide band gap material surfaces to be used for multifunctional bio- and chemical sensors. This is done in collaboration with Applied Physics and Material Science.

Research based on the use of synchrotron radiation is of main importance for our research group and is conducted at MAX II at MAX-lab, which is a Swedish national laboratory in Lund. MAX II is a third generation electron storage ring for synchrotron radiation. High resolution X-ray photoelectron spectroscopy (XPS) and Near Edge X-ray Absorption Fine Structure (NEXAFS) spectroscopy are the techniques that we are using at these synchrotron facilities.

TEACHING
A yearly course in Surface Science (TFTB35) which is an Undergraduate profile courses, 4th year for students on the programmes Chemical Biology and Engineering Biology, is conducted in our research laboratories. The students obtain hands on experience in using powerful techniques and equipment in surface science. The projects and molecular systems chosen are closely related to issues in biomolecular surface modification research.

THE PHD PROGRAMME
The PhD students within the division of Molecular Surface Physics and Nano Science are enrolled in the graduate school Forum Scientium.

HIGHLIGHTS
Nanoparticles for biomedical imaging
In this project we are designing and characterizing rare earth nanoparticles to optimize the contrast in magnetic resonance imaging (MRI). This project includes material design and synthesis, characterization, surface modification, biofunctionalization and signal optimization followed by tagging for targeting purposes.

The synthesis of the material is done in close collaboration with Inorganic Chemistry, IFM. The MR imaging optimization is done in cooperation with the Center for Medical Image Science and Visualization (CMIV) at the medical faculty and University Hospital. We have shown that the relaxation properties of this contrast agent have an enhancing capability with respect of MRI signal, compared to the commercially available ion based Gd-DTPA contrast agent. With this new contrast agent the aim is to obtain higher resolution, tissue specific images and cell- and molecular imaging.

Knowledge obtained with in the project will contribute to the understanding of drug delivery targeting. Our goal is to improve the contrast to enable high resolution imaging for e.g. early diagnosis of neurodegenerative diseases and cancer. This is a true interdisciplinary project, combining Physics, Chemistry, Biology and Medicine.

The material developed has high potential as a positive MR contrast agent. We have initiated and established a spin off company Spago Imaging AB, 2007.

Design of biospecific peptides
One fundamental part of the biosensing research is devoted to the design and synthesis of new recognition molecules and to their immobilization on surfaces. Molecules mimicking neurotransmitters, important for the cell signaling system for the G-protein coupled receptor, are in focus. These neurotransmitter inspired molecular systems are designed, synthesized and evaluated by means of molecular orientation, binding strength to substrate, packing density etc. Our focus now is on the principles of coordination of signal substances, selectivity processes and bio-recognition. Platform used is self assembly and thiol chemistry followed by stepwise coupling sequences.

Synchrotron light is used for X-ray Photoelectron Spectroscopy (XPS), Near Edge X-ray Absorption Fine Structure (NEXAFS) and X-ray Circular Dichroism (XCD) studies of amino acids, peptides and related molecules at the national facility MAX-lab, Lund. Adsorbates of neurotransmitter derivatives such as Dopamine- and Noradrenaline and the precursor Tyrosine are investigated, preliminary results are obtained on model systems mimicking selective/specific receptor sites.

Detailed information of the molecular orientation is obtained, by using different photoelectron take off angles and by varying the direction of polarisation of the incoming light relative to the supporting surface.
We have now, in collaboration with P. Norman, Computational Physics, Linköping University and U. Ekström, VU University Amsterdam obtained theoretical calculations, verifying the experimental based assignments and molecular orientation.

Furthermore, the interaction between pure and mixed monolayers, of synthetic peptides derived from the 2nd and 3rd intracellular loops of the α2A – Adrenergic receptor, with G-protein is investigated.

RESEARCH COLLABORATIONS
M. Engström and H. Gustavsson Center for Medical Image Science and Visualization (CMIV) S. Svensson, T Bengtsson and C. Skoglund Pharmacology, M Griffith, Nanomedicine, Health University Linköping, PO Käll Inorganic Chemistry, Prof, Rositza Yakimova, Prof. Anita Lloyd Spetz, Applied Physics, K. Deppert, Lund University, J Kehr, Karolinska Institutet Stockholm, Max Lab Swedish national laboratory in Lund, A Sadreev, Theoretical Physics, Institute of nonlinear behaviour, Krasnoyarsk, Russia. Industry partners Astra Zeneca Södertälje, SPAGO Imaging AB Lund.

THE CENTRE IN NANO SCIENCE AND TECHNOLOGY (CENANO) is an organization within Linköping Institute of Technology (LiTH) at Linköping University. The mission of CeNano is to strengthen and support the competence within nano science and nano technology at LiTH. This is made by gathering researchers with nano activities at LiTH in the centre and by acting for increased collaborations and common projects in the nano realm. CeNano also acts for development and coordination of the graduate and undergraduate education in this scientific area. K. Uvdal is the director of CeNano.

Sensor Science and Molecular Physics

STAFF
Professor: Bo Liedberg (head of division).
Lecturers: Fredrik Björnfors, Thomas Ederth, Karin Enander.


Technical staff: Bo Thunér.

Administrative staff: Pia Blomstedt, Anna Maria Uhlin.

SUMMARY
The division of Sensor Science and Molecular Physics conducts fundamental and applied research in three closely related fields of biologically inspired surface and nanoscience: biosensing and biochip technology; molecular/polymer thin film physics and spectroscopy; and nanoscale physics/chemistry.

We are developing new and improved sensor principles for real time detection of biospecific binding phenomena at solid surfaces using surface plasmon resonance (SPR), plasmonic nanoparticles, quartz crystal microbalance (QCM) and electrochemical (EC) transducers. The division is also involved in the development of new technology and hardware for parallel bioanalysis using microarrays and miniaturized devices. The transducer and microarray oriented projects are conducted in collaboration with the division of Applied Physics and Swedish industry.

The fundamental part of the biosensing and biochip research is devoted to the design and synthesis of surface active compounds and new biorecognition molecules. Polypeptide as well as carbohydrate recognition molecules are synthesized and evaluated using the above mentioned transducer platforms. We are also working with de novo synthesized helix-loop-helix polypeptides and minimized sequence peptides for microarrays.

A significant portion of the research utilizes solution self-assembly techniques to produce novel surface architectures and materials. Ethylene glycol monolayers forms the base for our investigations, and through a fruitful combination of surface vibrational spectroscopy and quantum chemical ab initio calculations we have improved the understanding of the mechanisms that influence the phase behaviour and orientation in such layers.

An interesting approach for nanoscale patterning on planar substrates using an AFM tip as a paintbrush has been exploited jointly with Institute of Physics (IOP), Vilnius, within a SI-supported program (The Visby program). The technique is often referred to as “dip-pen nanolithography” (DPN) and it has been used to introduce monomolecular patterns, “nano-arrays”, with a line width of less than 100 nm.

A new project on nanoparticle plasmonics also has been initiated. Nanoparticles of gold and silver of different size and shape have been synthesized by inorganic chemists at IFM. We are particularly interested in using them for studies of metal-enhanced optical phenomena including, for example, metal enhanced extinction (MEF) or metal-enhanced fluorescence (MEF). We are currently interacting with the School of Materials Science and Engineering, Nanyang Technological University, Singapore, on a new set of nanoprisms (triangular) particles for colorimetric and MEF applications. The plasmonic research relates also to our activities on helix-loop-helix polypeptides for controlled aggregation of gold nanoparticles (NPs) into functional entities. The plasmonics work is a part of an SSF supported initiative on Nano sensing for medical diagnostics, imaging and drug screening (NanoSense).

The division was involved in two Integrated EC projects within FP6, which were terminated during 2010: 1) Advanced Nanostructured Surfaces for the Control of Biofouling, “AM-BIO”, in which our part concerns the development and in situ characterization of nanostructured surfaces. 2) HealthCARE
by Biosensor Measurements and Networking, “CAREMAN”, where we contributed within microarraying and plasmonics. We are since January 2010 participating in the Marie Curie Initial Training Network SEACOAT.

The Molecular Physics group is also involved in a new initiative on Regenerative Medicine headed by Professor May Griffith. New laboratories for polymer science and peptide chemistry have been designed at IFM. Our role in the project is to prepare new materials and molecules and to provide advanced tools for the characterization of the developed materials and implants.

HIGHLIGHTS

DPN, nanoarrays and nanobrushes.

Ramunas Valiokas, Bo Liedberg; PostDoc: Olof Andersson, PhD students: Emma Ericsson, Thomas Rakickas. We have developed DPN to generate nanoscale molecular patterns for templated growth of hydrogel nanobrushes. A typical example of such brushes is shown below for a 3x3 array before and after immobilization and regeneration of fluorescent quantum dots.

![Image](image-url)

Figure 1. a) Nanoarray composed of hydrogel nano-brushes generated by free-radical polymerization of methacrylates on a DPN-generated SAM template. b)–f) shows fluorescence images after successive immobilization and regeneration of the nanobrush chip. Scale bars are 1.5 μm.

Electrochemistry for surface analysis and energy conversion

Fredrik Björefors. In a fuel cell, chemical energy is directly converted to electric energy. This conversion often results in a high yield and, if hydrogen is used as the fuel, only harmless water and small amounts of heat are obtained as byproducts. The chemical environment inside a fuel cell is, however, quite aggressive, and stresses the electrode material (i.e. the bipolar plate) that collects the current from the electrochemical reactions. One idea to circumvent this is to implement new ceramic materials as protective coatings on the fuel cell electrodes. Such materials, for example, have excellent corrosion protection properties while still maintaining a sufficiently low contact resistance. The idea behind this project is to employ electrochemical techniques and other tools for surface analysis to develop, test, and implement ceramic materials in fuel cell applications. The activities are financed by the SSF-program Strategic mobility, and operated together with the private company Impact Coatings (Linköping). For example, amperometry and electrochemical impedance spectroscopy are employed to analyze the stability and corrosion properties of metallic and ceramic thin films deposited on bipolar plates. In other projects, those techniques are also used for analysis of conducting polymers and surface immobilized gold nanoparticles (together with Assoc. Prof. Nate Robinson, IFM, and MSc. Anders Lundgren, Chalmers, respectively).

Novel hydrogel chemistries for biomaterials, biosensing applications and biofouling research

Thomas Edertl, Bo Liedberg; PostDocs: Olof Andersson, Tobias Ekblad. PhD students: Emma Ericsson. We have developed a range of strategies and protocols for preparing structured hydrogel thin films, for example in patterns or multicomponent layers. These are based on oligo(ethylene glycol) methacrylates which are mixed with other types of building blocks to vary the chemistry of the films. The hydrogel network is generated by UV-induced radical polymerization and can be used to modify the surface of organic films, polymers and glass. The technology is referred to as Self-Initiated Photografting and Photopolymerization (SIPGP). These materials are now utilized in biochip and biosensing applications, as model substrates for fundamental protein adsorption studies and for marine biofouling applications. Evaluation of the haemocompatibility of a number of such surface modifications, Fig. 2, confirmed that none of the hydrogel surfaces activated the coagulation system to any great extent, and also were resistant to platelet adhesion, suggesting that these coatings have unusually high blood compatibility and are suitable for demanding biomaterials applications.

![Image](image-url)

Figure 2. Time-lapse images from imaging of coagulation experiments using polystyrene controls (top two rows) and a series of hydrogel coatings. Blue color indicates low-density fibrin network and red/yellow indicates high-density fibrin network.
Structure and interaction studies of hIgG-Fc
Erik Martinsson. PhD student: Daniel Kanmert. The Fc part of IgG molecules, IgG-Fc, is involved in many immunologically important activities in the body involving, e.g., interactions with complement and receptors on phagocytic cells. We have characterized different so-called alternatively folded states of human IgG-Fc (especially of subclass 4), obtained by heating or acidification. It was found that the alternatively folded protein is associated with oligomer formation, displays high chemical stability and is even able to form amyloid structures, Fig. 3. This is of particular interest since parts of IgG (mainly from light chains) are known to be involved in some misfolding diseases (amyloidoses).

In cooperation with Thomas Skogh and colleagues at IKE, Faculty of Health Sciences, we are also studying IgG-Fc interactions of relevance to rheumatoid arthritis. We have recently designed an immunoassay (ELISA) for the IgG variant of rheumatoid factor, autoantibodies specific for IgG-Fc. Recombinant glycosylated hIgG-Fc molecules of all subclasses were produced in *Pichia pastoris* and used as antigens in the assay. Samples from early rheumatoid arthritis patients were then analyzed in order to find specificity patterns of IgG-RF that could, potentially, be useful for diagnostic and prognostic purposes. Most notably, it was found that IgG-RF to a great extent was directed towards hIgG2-Fc in these patients.

Supramolecular chemistry and plasmonics
Bo Liedberg. Karin Enander. PhD students: Robert Selegård, Erik Martinsson. We have previously demonstrated how gold nanoparticles coated with helix-loop-helix polypeptides can be used for protein sensing. In this context, so-called “click” coupling chemistry is now being developed for highly flexible particle modification. This chemistry will be used in combination with families of ligands with different analyte affinities, thus extending the dynamic range of quantification in the particle-based biosensor assay.

When fluorophores are placed close to metallic nanoparticles (NPs) or structured metallic surfaces, the fluorophores interact with the electrons in the metal. This interaction significantly modifies the spontaneous emission of photons from the fluorophores which gives rise to enhanced fluorescence intensity, faster radiative emission and less photobleaching. This phenomenon is known as plasmonic-enhanced fluorescence.

The distance between NPs and fluorophores is a crucial parameter for the plasmonic enhancement effect. If the fluorophores are placed too close to the NPs, the emission is quenched and if they are placed too far away, no effect is seen. The optimum distance is generally between 5 nm and 30 nm, Fig. 4. We are using polyelectrolyte multilayers in order to control the distance between fluorophores and NPs and find the optimum distance where maximum enhancement can be obtained.

**Figure 3.** Transmission electron micrograph of amyloid fibrils formed from hIgG4-Fc after incubation during 20 h of the protein sample at 37°C. Scale bar: 500 nm

**Figure 4.** Illustration of the distance dependence of plasmonic-enhanced fluorescence for a fluorophore near a metal nanoparticle

Self-assembled monolayers – experiments and theory
Ramunas Valiokas, Alexander Onipko, Lyuba Malysheva, Yurij Klymenko, Bo Liedberg. PostDoc: Alex Kapitanchuk. PhD students: Hung-Hsuan Lee, Tomas Rakickas. The synthesis and assembly of functionalized thiols and disulphides are key activities for the molecular physics group. The research is conducted in close collaboration with the division of chemistry and with scientists from the Institute of Physics, Vilnius. A broad range of samples have been synthesized and characterized with vibrational spectroscopy for future applications in our bio-oriented research programs.

We are also heavily involved in studies aiming at improving the understanding of structural properties of self-assembled monolayers (SAMs). This work combines experimental and theoretical efforts and a significant portion of that research concerns the use of *ab initio* quantum chemical methods for studies of oligo(ethylene glycol) SAMs. *Ab initio* modelling was performed for isolated molecules by using density functional theory (DFT) with non-local gradient corrections and an elaborated basis set.
Tethered lipid bilayer formation on mixed self-assembled monolayers
Ramunas Valiokas, Bo Liedberg. PostDocs: Martynas Gačutis, Zivile Ruzele. PhD student: Hung-Hsun Lee. One of the research activities in self-assembly concerns design and optimization of biomimetic model systems. As an example, we have developed a molecular system for surface-tethering lipid bilayers. This system consists of a mixed self-assembled monolayer (SAM) with controlled surface concentration of alkyl chain anchors, which are embedded into the bilayer. The properties of this system was investigated with respect to the concentration and structure of the tethers, before proceeding to fusion of small unilamellar vesicles to form supported bilayers. This work paves the way for micro- and nano-structured molecular architectures for analysis and mimic of complex cell membrane assemblies. Figure 5 shows schematically how the bilayer is tethered to the surface SAM via alkyl chains on PEG spacers.

Molecular interactions with bilayer membranes
Thomas Ederth, PostDoc: Patrik Nygren. Beside the use of peptides to control biological processes, there is also an interest in peptides from a materials science point of view; as supramolecular building blocks, for increased biocompatibility or for specific recognition of surfaces. In collaboration with Bengt-Harald Jonsson (division of Molecular Biotechnology), we investigate how de novo designed cationic peptides can be constructed to alter their conformation from random-coil in solution to, for example, α-helix or β-sheet as they are electrostatically attached to negatively charged membranes. By establishing design principles which permit control of the secondary structure of these peptides, we foresee the implementation of functions such as activation of specific catalytic activity at the membrane, or the the introduction of specific functions beyond mere lysis upon attachment to selected membranes, which would open entirely new possibilities for attachment of markers or performing operations on membranes.

In collaboration with Karin Ollinger (IKE, Faculty of Health Sciences), we investigate how the stability of model lysosome membranes are affected by the presence of lysosomotropic detergents and other membrane components specific to lysosomal membranes. Lysosomes are vesicular organelles found in virtually all eukaryotic cells and are involved in macromolecule turnover and thus contain numerous hydrolytic enzymes, digesting unwanted material in the cell. Lysosomes are also involved in apoptosis; the lysosomal membrane is permeabilized in response to cell death stimuli, although the mechanisms behind this are incompletely understood.

Surface Engineering for Antifouling – Coordinated Advanced Training, SEACoAT
Thomas Ederth, Bo Liedberg. PostDocs: Luigi Petrone, PhDs: Vetra Yandi, Pitsiri Sukkaew. SEACoAT is a Marie Curie Initial Training Network, where six universities and two companies are collaborating to understand biointerfacial processes involved in the colonisation of surfaces by marine fouling organisms. This will inform the future development of new, environmentally-benign materials and coatings for the practical control of marine biofouling. The principal objective is to discover which nano- and micro-scale physicochemical properties of surfaces influence the adhesion of fouling organisms. The network involves research in three complementary, interdisciplinary themes: surface engineering, surface analytics and bioadhesion. These themes are directly reflected in our activities within this project. We are, for example, developing synthetic routes for preparation of anti-fouling polymer coatings, and preparing a range of self-assembled monolayers for bioadhesion studies, including newly synthesized oligosaccharide building blocks for SAM applications. Coatings are thoroughly investigated using state-of-the art surface analytical techniques, and their interactions with common marine biofoulers are investigated in close collaboration with other partners within SEACoAT.

Barnacles are particularly pervasive foulers, causing a significant increase in drag due to their relatively large size, hard-calcareous form and gregarious nature. To improve our understanding of barnacle settlement and colonization, we have developed methods to study the dispersal stage of barnacles, the cyprid larvae, and their interactions with model surfaces. As the cyprid explore a surface to assess its suitability for settlement, it probes the surface with a foot-like antennule, leaving a “footprint” of adhesive glue on the surface. We have developed methods to follow the cyprid exploration and footprint deposition in real
Lipid membrane nanotube architectures

Johan Hurtig A project concerning control of directional growth of intercellular nanotubes through micropatterned substrates as well as nanosurgical extraction of cell material was established in the end of 2010. The investigation of intercellular nanotubes is based on an interdisciplinary approach between microfluidic sample handling, micropatterned substrates and sensitive detection technologies to probe a new eukaryotic cell-cell communication strategy. This will be implemented through single-molecule detection and manipulation with a combination of laser-induced fluorescence and confocal microscopy, providing powerful tools to analyze the minute amount of analytes present in a nanotube cargo.

Figure 7. Micromanipulation and optical position of microbeads for attachment to an intercellular nanotube followed by laser surgery.

Regenerative medicine

May Griffith, Ebo de Muinck, Bo Liedberg. PostDocs: Li Buay Koh, Jaywant Phopase. PhD students: Abeni Wickham, Mattias Tengdelius. We are currently building up a laboratory for biomaterials and polymer chemistry to support the cross-faculty initiative on Regenerative medicine. The initiative I-GEN is funded by LiU/LITH and the County of Östergötland. At Molecular Physics, IFM, we are developing new materials, molecules and patterning technologies for the development of novel implants for cornea replacement and heart tissue regeneration.

COLLABORATIONS


Bo Liedberg has been on sabbatical 2010 at Nanyang Technological University, Singapore, hosts Prof’s Freddy Boey and Bertil Andersson.

INTERACTION WITH INDUSTRY AND SOCIETY

The division interacts with numerous companies within several of the thematic areas outlined above including GE Healthcare – Biacore Division, Uppsala, AstraZeneca, Söder-tälje, RGB Technologies AB, Linköping, Modpro AB, Uppsala, Optisense, the Netherlands, Optiqua, Singapore.
Biology

General information

Chairman: Professor Per Jensen

Biology covers all aspects of life science, from subcellular molecular processes, via organisms to whole ecosystems. Basic scientific challenges in the area concern the way in which genetic instructions influence the development of organisms which interact and constitute a complex biological system. This is knowledge which is strongly requested from society. It influences a wide range of societal issues from the use of gene technology for altering and affecting the function of various organisms, to questions of animal welfare in modern farming and the management of species and ecosystems for biological conservation purposes.

The scientific branch Biology has about 50 persons employed in total, of which about 20 are PhD-students. To organize and lead the activities, the branch has a steering committee, which includes all professors and other main PhD-supervisors. This group meets every month and is responsible for matters concerning budget, research, PhD-education and organization.

The scientific branch of biology is organised in three different divisions, headed by the following persons:

- Ecology (professor Per Milberg and associate professor Karin Tonderski)
- Molecular biology (associate professor Johan Edqvist)
- Zoology (associate professor Jordi Altimiras).

Within ecology, emphasis is on community and population ecology, including conservation biology. Wetland ecology is also studied in a number of international cooperative projects. Another important research area is vegetation ecology. Here, methodology and temporal trends have been studied in areas such as phenotypic plasticity and seed dormancy. In Molecular genetics, research is carried out in two groups, headed by associate professor Johan Edqvist and professor Cornelia Speta-Wiklund, both focusing on plant molecular biology. In zoology, research is mainly focused on developmental aspects of cardiovascular control systems, on domestication effects on behaviour in chickens, and on comparative olfaction research. The staff is also heavily involved in undergraduate teaching in all subjects covering the biological education programs.

The scientific branch has had an excellent success rate in external funding over the last couple of years, and important grants were also obtained 2010. For example, researchers from the branch were awarded a 5-year excellence grant for strong research environments from Formas. Professor Per Jensen and prof Cornelia Speta-Wiklund hold contract funding from LiU, each comprising a guaranteed 2.2 million SEK per year in faculty support.

Research facilities include the research chicken house (“Wood-Gush”) and the hatchery (“Kruijt”), along with state-of-the-art molecular lab facilities.

The scientific branch Biology was instrumental in planning and organizing a popular science day, with parallel sessions containing lectures in biology, chemistry, physics and mathematics. The theme was “Expand reality”, as a tribute to the slogan of LiU. The lectures attracted in total about 1000 attendants, mostly school teachers and high school students.

The biology branch has a wide-ranging collaboration with groups and labs in different places of Sweden and abroad. For example, cooperation in both teaching and research is maintained with groups in Bolivia, The Netherlands and Great Britain. Furthermore, the cooperation with Kolmården Zoo has continued and produces both research results and teaching collaboration.
Division of ecology

STAFF

Professors
Jan Landin (emeritus)
Per Milberg (Head of division)

Associate professors
Karl-Olof Bergman, Anders Hargeby
Karin Tonderski

Junior lecturer
Kjell Carlsson

Other teaching staff (part time)
Johan Bergstedt, Lars Westerberg

PhD-students
Hristina Bodin, Karin Johannesson
Håkan Lättman

Administrative staff
Anna Sundin (Administrator)
Ingevald Abrahamsson (Engineer)

RESEARCH AND PHD TRAINING

Our emphasis is on community and population ecology, including conservation biology and plant ecology (mainly grasslands and forests). In addition, one group focuses on ecosystem ecology, especially nutrient cycling in wetland ecosystems.

The group led by assoc. prof. Karl-Olof Bergman and prof. Per Milberg has studied the saproxylic beetle fauna and lichen flora on old oaks (Quercus spp.) with the aim was find a spatial scale at which density of old oaks best explained the presence of species in a landscape. Finding such a spatial scale is important for conservation of biodiversity in oak-rich landscapes.

Detailed knowledge about species ecology is necessary for successful conservation of them. One study focused on the habitat requirements at different scales of three species of red-listed burnet moths. The study went from the smallest scale of individual host plants to analysis of the occurrence pattern in the south of Sweden.

Another study in the group was a collaboration with several researchers in Europe and focused on identification of general patterns in how species with different dispersal abilities and different degrees of habitat specializations respond to habitat fragmentation. A large dataset on butterflies were used in the study.

Monitoring of species is an important part of detecting environmental changes. One study tested a novel method of monitoring of butterflies. In Sweden, monitoring of butterflies focus on semi-natural grasslands and our study tested a more landscape-based approach including the whole landscape.

Bergman and Milberg have also used butterflies and vascular plants to study the effect of past landuse, exploiting the rich information available on economic maps from the 1870s and 1940s. For example, the flora and butterfly fauna on clearcuts in forest is much affected by landuse in the 1870s.

A more theoretical ecology analysis aim at understanding aspects of biodiversity and stability in ecosystems, and to use this to analyse and predict biological consequences of changes in landscape structures.

The group working on nutrient transport (led by Assoc. prof. Karin Tonderski) is working with methods for identification of sources to phosphorus transported in streams and rivers, using stable oxygen isotopes. This is done in cooperation with SMHI, the County Administration in Linköping and Tübingen University, Germany. This group also works with a fingerprinting approach to identify the main sources of stream particulate matter in agricultural areas.

In cooperation with SLU, Uppsala, and Halmstad University the function of wetlands as sinks for phosphorus losses from agricultural areas is investigated. This involves both detailed studies of sedimentation and phosphorus removal in individual wetlands, and studies on a regional scale.

Zygaena filipendulae, a species inhabiting grasslands.

Part of the research in conservation biology focuses on the structure of oak landscapes as habitats for threatened species.
Research on nutrient transport focus on tracing the sources of phosphorus transported in agricultural streams, and on quantifying the efficiency of wetlands as sinks for this nutrient.

In 2009, a study on structural ecosystem shifts in the shallow lake Tåkern was initiated by Assoc prof. Anders Hargeby. He also works with studies on local adaptive changes that follow from such shifts, and their functional consequences, using the fresh water isopod (*Asellus aquaticus*) as model organism.

**COOPERATION**

Our projects involve cooperation with a number of universities and research institutes around the world, e.g. University of Lund, Sweden; SLU (Uppsala, Alnarp, Umeå), Sweden; Halmstad University, Sweden; SMHI, Sweden; University of Bergen, Norway; Oklahoma State University, USA; Towson University, USA; Middle Tennessee State University, USA; University of Madrid, Spain; Haremaya University, Ethiopia; University of Ballarat, Australia. These projects concern both practical and theoretical research in ecology and environmental science.

**EXTERNAL ACTIVITIES**

Our staff presented research for students and teachers from secondary schools in the county at the Popular Science Day, arranged by IFM. We have also been involved in presentations for the public arranged by the university, and have guided study visits from primary and secondary schools. Our staff acts as one of several LiU partners in a new multidisciplinary secondary school profile education, with the theme sustainable development, that will start at Folkungagåsksalan in Linköping. We also serve as expert advisors to the County Administration, the Environmental Protection Agency and the Swedish Board of Agriculture, and as Technical advisor to Sida’s project BioInnovate, supporting Biotechnology in East Africa.

---

**Division of molecular genetics**

**STAFF**

*Professor: Cornelia Spetea Wiklund*

*Associate Professors: Johan Edqvist, Head of division*

*Post.doc: Azeez Beebo*

*PhD students: Monika Malmbecker Edstam, Patrik Karlsson, Lan Yin, Daniel Graf-Wimark*

**RESEARCH AND PHD TRAINING**

In the Molecular Genetics division, research is focused on plant molecular genetics. The research performed by the two groups headed by Johan Edqvist, and Cornelia Spetea Wiklund are focused on understanding lipid transport proteins, and photosynthetic regulation, respectively, using *Physcomitrella patens, Arabidopsis thaliana* and *Medicago truncatula* as model systems.

The group of Cornelia Spetea Wiklund (Plant Genetics and Photosynthesis Group) uses a functional genomics approach in *Arabidopsis* to identify and functionally characterize putative proteins from the chloroplast photosynthetic (thylakoid) membrane. These membranes can undergo compositional and structural changes to provide functional flexibility in response to light fluctuations. Main goal of this project is to study thylakoid solute transporters from *Arabidopsis*: (i) the ATP/ADP carrier, (ii) the thylakoid phosphate transporter, and (iii) one K+ channel. Furthermore, important progress was made in the study of a phosphate transporter from *Arabidopsis* root plastids.

A new project was initiated related to photosynthetic studies in the natural accessions of *Arabidopsis thaliana* (Fig. 1).

![Fig. 1. Three widely used Arabidopsis natural accessions in functional genomics research, grown under hydroponic conditions. Photo taken by Lan Yin.](image)

Important advances were made this year in a project aimed to study the mechanism of photosynthesis improvement during arbuscular mycorrhiza symbiosis in a model legume (*Medicago truncatula*). (Fig. 2)
The research in the group headed by Johan Edqvist (Lipid Transfer Protein (LTP) group), is focused on function, structure and evolution of the non-specific lipid transfer protein (ns-LTP). The nsLTPs are small, basic proteins characterized by a tunnel-like hydrophobic cavity, capable of transferring various lipid molecules between lipid bilayers. During 2010 we have also initiated a project on the regulation of mRNA-splicing in plants. Johan Edqvist is also involved in a research project concerning the genetics of land race crops, seed bank propagation and agricultural history, working with a 19th century seed collection belonging to Nordiska Museet.

HIGHLIGHTS
The Photosynthesis group has elucidated the role of the thylakoid ATP/ADP carrier in the repair of the photosynthetic machinery during light stress (Published in Plant Physiology). In addition, a homology modeling study combined with site directed mutagenesis and heterologous expression has revealed key amino acid residues in the function of the first thylakoid phosphate transporter (Published in Biochemistry). In addition two book chapters and one review on thylakoid membrane transporters and the role of thylakoid lumen in plant cell signaling and regulation have been published.

COOPERATION
Individual external collaborations
- Cornelia Speta Wiklund – Bengt L. Persson (Linnaeus University, Kalmar), Benoit Schoefs (Université de Bourgogne, Dijon), Eva-Mari Aro (Turku University), Wayne Versaw (Texas A&M University), Maarten Koornneef (Max-Plank Institute).
- Johan Edqvist-Tiina Salminen (Åbo Akademi University), Peter Mattjus (Åbo Akademi University), Matti Leino (Nordiska Museet), Magnus Eklund (SLU)

Collaborations within LIU
- Cornelia Speta Wiklund – Alexander Vener (IKE Cell Biology), Bengt Persson (IFM Bioinformatics).

EXTERNAL ACTIVITIES
The Photosynthesis group has participated with a total of six posters at International Conferences, and 2 invited talks at Swedish and non-Swedish Universities.

SPECIAL EVENTS
We have been the host for one week project by Gymnasium elever from Berzelius school. The project in the Photosynthesis Group was to study the effects of high light stress on photosynthesis in three natural ecotypes of Arabidopsis thaliana.

Division of zoology

STAFF
Professors: Mats Amundin (adjunct professor), Per Jensen Mathias Laska
Associate professor: Jordi Altimiras (head of division)
Assistant professors: Thomas Østholm, Jennie Westander (adjunct), Lina Roth, Dominic Wright
Junior lecturers: Eva Mattson, Örjan Lönnvik

Post doc: Vivian Goerlich

PhD-students: Annelie Andersson, Beatrix Eklund, Magnus Elfwing, Pernilla Foyer (FHS). Markus Jöngren, Anna-Carin Karlsson, Isa Lindgren, Daniel Nätt, Josefín Starkhammar (LU), Anders Wiren

Administrative/Technical staff: Ingvald Abrahamsson (Engineer), Leila Bektic (Animal Technician), Ida Gustafson (Research Technician), Anna Sundin (Administrator), Daniel Wennergren (Research Technician)

RESEARCH AND PHD TRAINING
Research in Zoology involves the study of fundamental and applied aspects of animal biology, with special emphasis on the physiology and behaviour of birds and mammals. The division includes three research groups: the Sensory and Behavioural Physiology Group led by Matthias Laska, the Animal Biology Group led by Mats Amundin, and the AVIAN Behavioural Genomics and Physiology Group, a merging of the ethology lab led by Per Jensen, the physiology lab led by Jordi Altimiras and the new genomics lab led by Dominic Wright.

Research in the Sensory and Behavioral Physiology Group focuses on odor structure-activity relationships, that is, on determining the properties of stimulus molecules that are critical for the interaction with an olfactory receptor and thus for the odor quality they evoke. A second research topic concerns cor-
relations between chemosensory performance and neurobiological and genetic properties such as the size of olfactory brain structures or the size of the olfactory receptor repertoire. With both topics, a comparative approach including human subjects and a variety of mammalian animal models is employed.

HIGHLIGHTS

The Division continued to grow steadily during 2010, with a substantial increase in its members, research funding and publications (16 articles in peer-reviewed journals and one book chapter). Dominic Wright was awarded a LiU FoAss, which will allow him to carry on his research on a full time basis on the genetic basis of complex traits in chickens using genome-wide techniques and QTL mapping. Annelie Andersson defended her licentiate thesis in the spring on infanticide and welfare of wild boars in enclosures and Isa Lindgren defended her PhD thesis in the fall on the role of beta-adrenergic receptors on the structure and function of the fetal heart. She is currently an NIH postdoctoral fellow at the Johns Hopkins School of Medicine.

Together with other researchers at LiU and SLU Per Jensen and Jordi Altimiras founded a Strong Research Environment in Animal Welfare financed by FORMAS for the next 5 years.

Josefin Starkhammar, PhD, student in Professor Amundin’s group, used ELVIS in a study of beam steering in a white whale, Delphinapterus leucas at Sea World, San Diego. The whale is being trained to station in front of the screen, grab a bite plate with its teeth and track a moving target with its sonar beam.

Research in Behavioural Genomics and Physiology attempts to dissect complex behavioural and physiological traits using modern genetic methods. Although not restricted to it, most of the group’s research focuses on junglefowl and modern chicken breeds selected for farming purposes such as egg productivity or meat yield with the goals of improving poultry welfare and understanding the genetic basis of animal domestication.

Research in the Animal Biology Group focuses on the study of communication and sonar in marine mammals at Kolmården Djurpark. In collaboration with the Electrical Measurement Department at Lund’s University, Mats Amundin continues the implementation of ELVIS (Echolocation Visualization and Interface System), a dolphin-human interface. A second area of work at Kolmården involves the census of harbour porpoises in the Baltic Sea using porpoise click loggers (C-POD), a 5 year LIFE Plus project called SAMBAH (Static Acoustic Monitoring of the Baltic Harbour porpoise; www.sambah.org) coordinated by Mats Amundin.

Chicks of the advanced intercross line (F8) between White Leghorn layers and junglefowl

Josefin Starkhammar holds the bite plate used by whales to drive ELVIS
The SAMBAH LIFE Plus project coordinated by Mats Amundin is ready to deploy 300 C-PODs in a systematic grid, and then keep them in operation for 2 years. Data from the loggers will be used to calculate population densities, total abundance, distribution and habitat preferences.

Matthias Laska and one of his students were able to demonstrate that human males are significantly more sensitive to the sperm-attractant odorant bourgeonal than human females. This is the first report ever to find human male superiority in olfactory sensitivity (Olsson and Laska 2010. Chemical Senses 35, 427-432).

**Bourgeonal**

Bourgeonal, the first molecule to which males show a higher olfactory sensitivity than females

In collaboration with Per Jensen’s group and Peter Konradsson’s group (IFM Chemistry), they also showed that chickens have individual body odors.

They used a combination of behavioral assays including so-called “detective mice” and chemical analyses to demonstrate that secretions of the uropygial glands of the birds differ systematically between individuals which may have important implications for their behavior (Karlsson et al. 2010. Journal of Experimental Biology 213, 1619-1624).

Dominic Wright continued the work on the large-scale advanced intercross line between wild-derived and domestic chicken strains. Genotypic and phenotypic data from the AIL cross are now being analyzed. Using an earlier version of this cross, it was shown that the genetic architecture of domestication traits is remarkably similar to many other domesticated plants and animals, with traits being controlled by linked modules which affect many different aspects of the domestication phenotype (Wright et al. 2010. Molecular Ecology 19:5140-5156).

Per Jensen, together with colleagues in Uppsala, published a Nature-paper on selective sweeps associated with domestication of chickens. This work identifies many loci which have been selected during domestication and will provide an important database for further identification of genes and mutations (Rubin et al. 2010. Nature 464, 587-591). The group has published a number of papers on the role of particular loci in domestication related behaviour of chickens, for example the PMEL17 gene and the region surrounding AVPR1a.

**COOPERATION**

The Sensory and Behavioral Physiology Group has a long-standing collaboration with the Instituto de Neuro-Etologia of the Universidad Veracruzana in Xalapa, Mexico. Pia Katrine Latvedt and Jenny Larsson, students of the International Master’s Programme in Applied Ethology, performed the experimental part of their thesis work in Mexico and collected data on chemosensory performance in spider monkeys. The same group is also collaborating with the Centre for Research in Animal Behaviour at the University of Exeter, England, where Nellie Linander and Marie Holmbergh, also students of the International Master’s Programme in Applied Ethology, performed the experimental part of their thesis work in England and collected data on chemosensory performance and learning capabilities in honeybees.

Master’s student Nellie Linander gearing up to collect bees during her project performed at the Centre for Research in Animal Behaviour at the University of Exeter, England

The same group is also collaborating with the Department of Neurobiology at Yale University in New Haven, Connecticut, and is involved in a joint project on the phenotypical characterization of Alzheimer’s disease model mice.

From left to right: Dra. Laura Teresa Hernandez Salazar, Pia Katrine Latvedt, Jenny Larsson, and Professor Matthias Laska.
The AVIAN group is a member of the newly formed centre of excellence for animal welfare science. The center brings together scientists from LiU and SLU in joint effort to explore positive emotions and life-time experiences in relation to welfare.

The same group is also closely linked to the LiU centre for neurobiology, which comprises groups from both the medical and technical faculties involved in neurobiology and behaviour.

Furthermore, Per Jensen and his students collaborate with researchers at the veterinary school in Oslo on a project on emotional reactions in chickens.

Jordi Altimiras has ongoing collaborations with Maastricht University Hospital in the Netherlands, University of North Texas (USA) and Universidad Mayor de San Andrés in Bolivia.

Mats Amundin is collaborating with LU, Sea World San Diego, the US Navy, the Swedish Board of Fisheries, the Swedish Environmental Protection Agency, Aarhus University, the Finish Ministry of Environment, Danmarks Miljøundersøgelser, Fjord & Baelt Center, Denmark, and Loughborough university, UK.

EXTERNAL ACTIVITIES
Members of the division have been involved in external lecturing and committee advising. The division has been visible several times on national TV, radio and in several newspaper articles on various subjects relating to the research conducted. Per Jensen was invited speaker at conferences in Great Britain, Holland and Norway. Matthias Laska was invited speaker at conferences in Japan, USA, and Germany.

SCIENTIFIC BRANCH OF

Chemistry

General information

STEERING COMMITTEE
Prof. Bengt-Harald “Nalle” Jonsson (chairman), Assoc. prof. Stefan Svensson, Prof. Uno Carlsson, Prof. Per Hammarström, Prof. Peter Konradsson, Prof. Ingemar Kvarnström, Prof. Lars Ojamåe, Prof. Per-Olov Käll, Prof. Maria Sunnerhagen.

The e-mail address to the head of the branch is: nalle@ifm.liu.se

RESEARCH DIVISIONS OF CHEMISTRY
- Protein Chemistry
- Molecular Biotechnology
- Organic Chemistry
- Physical Chemistry
- Inorganic Chemistry
- Organic Analytical Chemistry

SUMMARY OF ACTIVITIES
The research branch of Chemistry, cover all traditional areas of chemistry. The major research programs Protein Chemistry, Molecular Biotechnology and Organic Chemistry all have a strong focus on Molecular Life Science and Chemical Biology.

Research activities in Analytical Chemistry, Inorganic Chemistry and Physical Chemistry are led by senior staff, often in co-operation with other researchers in the department and with other research programs at the University.

20 PhD students have been enrolled and 3 PhD Dissertations were defended at the department during 2010.

The research in the different research divisions are presented in the following sections.

Protein Chemistry

STAFF
Professors: Uno Carlsson, Per Hammarström
Associate professors: Lars-Göran Mårtensson, Magdalena Svensson

Post-doc: Sofie Nyström

PhD students: Ina Berg (graduated in 2010), Karin Carlsson
(graduated in 2010), Daniel Sjölander (graduated in 2010), Patricia Wennerstrand, Maria Jonsson.

Administrator: Susanne Andersson

ACTIVITIES

The general objective of our research in protein chemistry is to understand different important aspects of the protein folding process. This also includes misfolding and related diseases as well as conformational changes associated to protein-protein interactions and protein adsorption to solid surfaces.

A major goal of protein engineering is the design of stabilized protein variants for use in many applications. In this project we use several strategies based on experience from our folding studies to stabilize the structure of our model protein carbonic anhydrase. Engineered proteins with varying stability and different surface structure are also employed to study the interaction with solid surfaces, a phenomenon that is very important in many biotechnological applications.

Molecular chaperones. Folding in vivo is for many proteins assisted by several protein factors such as molecular chaperones. Although proteins can fold spontaneously the chaperones suppress aggregation during folding and increase the yield. In our research we aim to gain insights into the mechanism of chaperone function that is essential for the understanding of the folding mechanism and prevention of misfolding.

Misfolding diseases represent a large collection of diseases. This group includes for example the prion diseases Creutzfeldt-Jakob disease and mad cow disease; the amyloid diseases such as Alzheimer’s disease and familial amyloidotic polyneuropathy (Skeleffeäsjukan). All these diseases are connected to a specific protein that misfolds into alternate conformations and often forms aggregates. We are working with proteins involved in all of the mentioned folding diseases. Our objectives are also to inhibit the formation of the toxic species of amyloid and prion diseases by using different strategies including small-molecule binding and interactions with molecular chaperones.

Thiopurine methyltransferase (TPMT) is a polymorphic enzyme and a key enzyme in treatment of childhood leukemia and inflammatory bowel diseases such as Crohn’s disease. TPMT is one of the few classical examples of pharmacogenetics where the dosages of medical drugs are directly dependent on the polymorphism of the enzyme.

In collaboration with Department of Clinical Pharmacology at University Hospital in Linköping mutants of different variants are engineered and biophysically characterized, using a repertoire of techniques such as enzyme activity measurements, circular dichroism, fluorescence and differential scanning calorimetry.

In parallel we are also screening conditions to crystallize the various variants.

Fig II: Structures of Thiopurine methyltransferase (TPMT) with cofactor SAH (red)

Protein-protein interactions are intrinsic to virtually every cellular process. We are studying the interaction of the cellular receptor tissue factor (TF) with the coagulation factors VII (FVII) and X (FX) that is the key step in the initiation of blood clotting and thrombus formation. The information output from this project will directly be used in drug design of therapeutical agents that can intervene in the association process of FVII and FX to TF.

β-sheet propensity of amino acids is investigated also using Tissue Factor (TF) as a model protein to better understand how to rationally stabilize β-sheet containing proteins. In addition, the stabilizing effects of additives are investigated to find biopharmaceutical formulations that will prolong the shelf-life of proteins.

Protein-surface interaction. Little is known about the direction and specificity of protein adsorption to solid surfaces, a knowledge that is of great importance in many biotechnological applications. Site-directed fluorescence probing has successfully been employed to resolve in what direction a protein binds to silica nanoparticles. A continuation of this work is now in progress where attempts are made to reorient the adsorption direction of the protein. The strategy is by protein engineering to change the surface charge of the protein in specific regions to be able to direct the adsorption.

Fig I. Amyloidogenic proteins studied in the Hammarström lab. All with totally different native sequence and fold which nevertheless ultimately misfold into cross-beta-sheet structure of amyloid fibrils. The central image is a transmission electron micrograph of lysozyme amyloid fibrils taken at 80,000 fold magnification.
Molecular Biotechnology

**STAFF**
Professors: Bengt-Harald “Nalle” Jonsson, Maria Sunnerhagen
Assistant Professors: Ann-Christin Brorsson, Patrik Lundström, Martin Karlsson

Post-docs: Janosch Hennig, Lotta Tegler
PhD students: Cecilia Andrésen, Anna-Lena Göransson, Jutta Speda, Linda Helmors, Sara Helander, Alexandra Ahlner, Annica Johnsson
Administrator: Susanne Andersson

**ACTIVITIES**
The research activities in molecular biotechnology are focused on detailed characterizations of protein structure and dynamics at the molecular level. The role of protein interactions for understanding a variety of biological functions are addressed in different projects. The results which are gleaned from our studies of these fundamental biological phenomena are also utilized in projects, which aim at efficient diagnosis and novel strategies for treatment of some human diseases.

**The protein misfolding disease ALS:** The mis-folding and intracellular aggregation of the protein superoxide dismutase is strongly coupled to the neurodegenerative disease ALS. To find the molecular basis for ALS we perform a detailed characterization of the structural and dynamical effects of a large set of different ALS-associated mutations in the gene for CuZnSOD. Therefore, we have used chemical cross-linking, analytical ultra-centrifugation and hydrogen/deuterium-exchange experiments to unravel the effects of the mutations on the dynamics of the protein.

**Functionalization of nanoparticles by peptide design:** Earlier studies have given us a firm knowledge about the structure of and dynamics in proteins upon adsorption to solid surfaces. Recently we have unraveled fundamental principles that govern the formation of helical structure on silica nanoparticles, which is important in the development of devices that interact with biological systems.

**Alzheimer’s disease:** The aim of this project is to perform detail studies of the molecular origins of Alzheimer’s disease (AD) and of systemic amyloidosis (SA). The aggregation process of the amyloid β peptide (associated with AD) and lysozyme (associated with SA) is studied by using *Drosophila melanogaster* as a model organism, in parallel with biophysical studies. The challenge is to identify and characterize toxic species as well as to study the influence of cellular factors on the toxicity. This knowledge will then be used to test the effect of anti-aggregation agents in vitro as well as in vivo.

**Biogas Enzyme mining:** Enzymes are biological catalysts that find their use in a large number of biotechnological applica-

tions and enzyme based industrial processes are expected to increase in the near future. One central concern in order to realize the promise of industrial biotechnology is then to find new enzymes that are active and stable at the conditions of interest. In this respect microorganisms are an ideal source of novel enzymes since they can survive and propagate in many environments. However, to be able to screen full microbial communities for new enzymes methods that are independent of pure culturing need to be developed. We are currently working on the development of such methods to mine for new enzymes in methanogenic microbial communities in experimental biogas reactors.

**Bacterial and immunological responses in infectious disease.** The human Ro52 protein is an autoimmune target in Sjögren’s disease, and involved in the production of fetal antibodies in pregnant mothers. We have characterised the interaction of the disease-related antibodies and are currently characterizing the subdomains of Ro52 and their interactions on a molecular level.

Our most recent results show that patient autoantibodies that hinder ubiquitination interfere with the E2-binding surface of the E3-active RING domain of Ro52. Taken together with our previous studies, we can now propose an action model for the entire Ro52 protein (Fig III, below) MexR is a DNA-binding protein that regulates the expression of the *Pseudomonas Aeruginosa* efflux pump, and a target for antibiotic resistance mutations leading to multi-drug resistance. We have described the biophysical and molecular basis for resistance and are currently evaluating their implications on structure.

![Fig III An action model for the entire Ro52 protein](image-url)
Structural biology in cancer development and protection. The oldest characterized oncogene, c-Myc, houses a series of fatal hotspot mutation sites leading to increased tumor development. We have characterized the structural properties of the transactivation domain which, surprisingly, adopts a molten globule structure, perhaps a prerequisite for its high-affinity binding to a range of biologically important target proteins. A range of protein interactions are currently being screened on a structural level.

Regulation of kinase activity. Eph proteins are involved in developmental processes such as cell migration, angiogenesis and axon guidance and in the adult organism they have been implicated in certain cancers. The crystal structure of the kinase domain of EphB2 as well as those of other Eph proteins suggests that the ground-state cannot be catalytically active. Our working hypothesis is that a low-populated “excited” state is responsible for catalysis and we have shown that the protein exchanges between the ground-state and something else on the millisecond time-scale. We are currently using NMR spectroscopy and x-ray crystallography to further study the interplay of structure and dynamics for this unusual mode of enzyme regulation.

Synthesis of potential protease inhibitors: Proteases are enzymes capable of restructuring peptides and proteins by specific hydrolysis and are therefore powerful mediators for health and disease. There are five different classes of proteases, classified according to the most significant functional group in the active site of the enzyme. Design and synthesis of inhibitors and screening for efficient and selective inhibitors of key proteases have become an attractive and powerful course for new drug development. This is an area of fundamental importance to the pharmaceutical industry. Structure based drug design has been used in the search for potent and selective drug candidates. An important part of this is to find the minimum necessary chemical features for binding to a particular protease. Methods for screening of potential inhibitors are available and it is possible to screen large libraries of single compounds to identify lead compounds. Design and synthesis of inhibitors have been studied against the following proteases: HIV-1 protease, Hepatitis C protease, Malaria parasite proteases, Thrombin and β-Secretase (Alzheimer’s disease). The research projects are done in collaboration with the University of Stockholm, BMC, Uppsala and Medivir AB, Huddinge.

Fig IV: General chemical structure of functionalized oligothiophene derivatives.

Synthesis of potential protease inhibitors: Proteases are enzymes capable of restructuring peptides and proteins by specific hydrolysis and are therefore powerful mediators for health and disease. There are five different classes of proteases, classified according to the most significant functional group in the active site of the enzyme. Design and synthesis of inhibitors and screening for efficient and selective inhibitors of key proteases have become an attractive and powerful course for new drug development. This is an area of fundamental importance to the pharmaceutical industry. Structure based drug design has been used in the search for potent and selective drug candidates. An important part of this is to find the minimum necessary chemical features for binding to a particular protease. Methods for screening of potential inhibitors are available and it is possible to screen large libraries of single compounds to identify lead compounds. Design and synthesis of inhibitors have been studied against the following proteases: HIV-1 protease, Hepatitis C protease, Malaria parasite proteases, Thrombin and β-Secretase (Alzheimer’s disease). The research projects are done in collaboration with the University of Stockholm, BMC, Uppsala and Medivir AB, Huddinge.

Organic Chemistry

STAFF
Professors: Peter Konradsson, Ingemar Kvarnström
Associate professor: Stefan Svensson
Assistant professor: Peter Nilsson
Senior researcher: Åsa Rosenquist

Post-doc: Andreas Åslund, Jeffrey Mason, Marcus Bäck, Anders Dahlgren


Administrator: Susanne Andersson

ACTIVITIES
Synthesis of functionalized oligothiophene derivatives with specific optical and electronic properties: By combining the features of polymers and the electro-optical properties of conjugated molecules, conjugated polymers suitable for a wide range of applications, such as solar cells, displays and biosensors are created. Our research is mainly focused on creating well-defined oligothiophene derivatives through rational chemical design (see fig. IV, and highlights)

As a first instance we are synthesizing oligothiophenes that can be utilized as tools for studying biological and pathological process. The aim of these projects are mainly to provide molecular tools that can be used for real time in vivo imaging of biological events from the nanoscopic level (biomolecules and cells) to the macroscopic level (organs and body). Secondly, we are also investigating if similar molecular scaffolds can be utilized as therapeutic active agents towards distinct pathological processes.

Furthermore, we are developing electro-active oligothiophene derivatives that can be combined with defined biological template molecules, such as amyloid fibrils, to generate materials that can be implemented within research areas such as nano-bioelectronics. Through a multidisciplinary collaboration with other researchers at IFM and ITN, we are aiming at develop novel materials that can be used for electronic release of pharmaeuticals, and devices that can stimulate and record cellular activity in complex environments.
**Physical Chemistry**

**STAFF**  
Professor: Lars Ojamäe  
Post-docs: Mathias Kula, Maria Lundqvist, Annika Lenz

**ACTIVITIES**  
The research projects concern computational-chemistry studies of nanostructures, functionalized nanoparticles, dye-sensitized metal oxide solar cells, electron transfer processes, heterogeneous catalysis, and water and hydrogen bonding phenomena. We thereby apply quantum-chemical computations and molecular-dynamics simulations using national supercomputer facilities to address these fundamental issues in surface science and atmospheric chemistry.

Nanoparticles exhibit many unique properties. We model crystallites of materials such as ZnO, TiO₂, RuO₂, and Gd₂O₃ and quantum dots of GaN, which are of interest in applications ranging from nanomedicine to optoelectronics. In particular we design novel nanocompounds by functionalising metal oxide nanoparticles using organic adsorbates. One such example is the dye-sensitised solar cell, where organic molecules are chemisorbed at a nanostructured metal-oxide surface (ZnO, TiO₂). Catalytic reactions at metal-oxide surfaces (RuO₂) are also studied, where we are developing ab initio MD methods that are useful for elucidating the mechanisms of surface-catalyzed reactions.

![Fig V: A self-assembled monolayer (SAM) of MPTMS on a ZnO surface.](image)

Another research theme concerns hydrogen bonding, where we are elucidating the phase transitions and proton-ordering phenomena involving water clusters, liquid water, ice and clathrate crystals.

These investigations are of importance for understanding for example the properties of liquids, environmental processes occurring in the atmosphere, and CO₂ emission from the tundra.

---

**Inorganic Chemistry**

**STAFF**  
Professor: Per-Olov Käll  
Post-doc: Fredrik Söderlind

**ACTIVITIES**  
The research in inorganic chemistry at IFM is mainly focused on colloidal synthesis and characterisation of (i) magnetic metal oxide nanoparticles (e.g. Gd₂O₃, GdFeO₃) for magnetic resonance imaging; (ii) wet synthesis of noble metal nanoparticles (e.g. Au, Ag) for use in medical imaging and diagnostics; and (iii) chemical or electrochemical synthesis of semiconducting nanoparticles, e.g. ZnO, CuO, Cu as sensing material in gas sensing studies (e.g. O₂, NOx, CO, H₂, MeOH). The above projects are pronounced interdisciplinary with collaboration partners both within and outside IFM.

(i) Several of the rare earth metals are strongly magnetic and at least one of them, gadolinium, is a unique because it combines a high magnetic moment with a very high cross-section for thermal neutrons, implying that Gd(III) containing nanocrystals are potentially interesting both as contrast agent in magnetic resonance imaging (MRI) and neutron capture therapy (NCT). We have found that small nanocrystals of cubic Gd₂O₃ and orthorhombic (perovskite) GdFeO₃ (3–5 nm) coated with diethylene glycol seem to produce significantly shorter T₁ relaxation times than the conventional gadolinium containing chelates normally used in examination of patients. A possible explanation of the effect is the higher density of magnetic active ions in a nanoparticle compared to that of a bulky chelate with a single magnetic ion at its centre.

(ii) A recently initiated project is aimed at the synthesis of noble metal nanoparticles (Au, Ag) of various sizes and shapes for surface plasmon enhanced fluorescence for bio imaging applications. We are also synthesizing core-shell nanoparticles with a magnetic core and a shell consisting of a noble metal, or silica, that can be functionalized with bio-active molecules, e.g. peptides.

(iii) A third project is aimed at the synthesis of semiconducting ZnO, CuO and Cu nanoparticles for gas sensing applications, e.g. O₂, NOx, MeOH.
Organic Analytical Chemistry

STAFF
Associate Professor: Roger Sävenhed

ACTIVITIES
Research in Analytical Chemistry is focused on the application of different analytical techniques related to technical, environmental, medical and forensic projects.

We participate in projects regarding the regional and large-scale distribution of natural and anthropogenic compounds in the environment.

Chemical methods are developed for the analysis of technical products in relation to an artificial nose and an artificial tongue.

Sophisticated analytical instruments are employed in the different studies e.g. GC-FID, GC-ECD, GC-MS, CE-DAD, HPLC-UV and HPLC-MS.

CHEMISTRY-HIGHLIGHTS
I. Maria Sunnerhagen has been appointed as professor in structural biology.

II. Peter Nilsson has achieved an ERC starting grant (1.5 million Euro for 5 years) and was also awarded FFL-4 (Future scientific leaders, 10 million SEK) from the Swedish Foundation for Strategic research (SSF).

III. Martin Karlsson has received a VR-grant for an appointment as a research fellow in a collaborative project between an industrial partner and LiU. He is now building an independent research group.

IV. The research groups of Peter Nilsson showed that the application of the luminescent conjugated polyelectrolytes (LLCPs) could be utilized to gain novel mechanical insights regarding prion strain interactions (Fig VI). The article "Prion strain interactions are highly selective" was published in J. Neuroscience (2010). Nilsson KP, Joshi-Barr S, Winson O, Sigurdson CJ. J. Neuroscience 2010;8:12094-12102.

V. In 1992 Uno Carlsson and coworkers demonstrated for the first time that a folding catalyst (prolin isomerase or cyclophilin) could also act as a chaperone, which is protecting a folding protein from aggregation and other side reactions (P-O. Freskgård, N. Bergenhjem, B-H. Jonsson, M. Svensson and U. Carlsson, Science 258 (1992) 466-468. This finding was later debated, but has now after 18 years been definitely proved (see fig VII).


VI. The research groups of Peter Nilsson, Stefan Thor and Per Hammarström, showed the application of the anionic luminescent conjugated oligothiophene, p-FTAA as amyloid imaging agent in model systems of human amyloidoses, such as Alzheimer’s disease in transgenic Drosophila Melanogaster (figure VIII). The article “Efficient imaging of amyloid deposits in Drosophila models of human amyloidoses” was published in Nature Protocols (2010). Berg I, Nilsson KP, Thor S, Hammarström P. Nat Protoc. 2010;5(5):935-44.

Figure VI: Fluorescence images showing that protein aggregates associated with distinct prion strains can co-exist independently in the brain of a single host. Protein aggregates having a red LCP spectrum is associated with murine sheep scrapie (mSS), whereas a green LCP spectrum is observed from protein aggregates originating from murine chronic wasting disease (mCWD).

Figure VII: Flattened 3D-micrograph of amyloid distribution in whole Drosophila brain of 10-d-old double expressing A11-42. Drosophila line [C155-Gal4/UAS-A11-42; UAS-A11-42]. DAPI is stained blue and p-FTAA is stained green. Scale bar indicates 200 μm. Arrows indicate amyloid deposits, and the filled arrowhead indicates an area of background fluorescence.
VII. To better understand the electronic relaxation properties of gadolinium oxide nanocrystals Gustafsson, Käll, Söderlind et al. undertook ESR (Fig. IX) and magnetic studies of nanoparticles of Gd$_{2}$Y$_{1-x}$O$_{3}$, $0.2$ $x$ $1$, prepared by a combustion method.

![Fig IX](image)

An interesting observation is that the magnetic Curie-Weiss constant $\theta$ showed its maximum magnitude for $x = 0.9$ (not for $x = 1$). A similar observation of non-linearity with $x$ was made for the EPR signal intensity which exhibited a maximum for $x = 0.75$. A possible explanation for the observed “anomalies” is that the distribution of diamagnetic Y and paramagnetic Gd may not be completely statistical over the two crystallographic sites in the RE.O$_{3}$ structure. (Work accepted by J. Phys. Chem. C.)

VIII. Recent results on the structure of liquid water by a collaboration of scientists from Stockholm, Stanford, Tokyo, Hiroshima and Linköping (Lars Ojamäe) were highlighted in the magazine New Scientist (Fig X).

![Fig X](image)

Rescue fruit flies from Alzheimer’s disease-related tissue damage

Rescue of Drosophila eye morphology. Scanning electron micrographs of eyes of flies expressing a toxic Aβ protein alone, or in combination with a small protein molecule (Affibody) which prevents damage of the eye tissue. Scale bar = $100 \, \mu$m in main pictures and $20 \, \mu$m in inserts.

Working with genetically engineered fruit flies Luheshi, L.M. and Broorsson, A. C. et al (2010) PLoS Biol $8$, e1000334 have developed a fly equivalent of Alzheimer’s disease to produce a toxic Aβ protein. The Aβ producing flies were crossed with a second line of flies genetically engineered to produce a protein molecule (Affibody). The study revealed that the Affibody can abolish the toxic effect of the Aβ protein when co-expressed in the fruit flies. This rescue effect can be visualized in the eye of Drosophila where the structure of the eye is highly disrupted in flies expressing the toxic Aβ protein but restored in flies expressing the toxic Aβ protein together with the Affibody molecule.
Material Physics

General Information

Research Divisions and Professors

Functional Electronic Materials
Weimin Chen, Head
Irina Buyanova

Nanostructured Materials
Magnus Odén, Head
Bo Jansson (Adjunct from SECO Tools AB)

Plasma and Coatings Physics
Ulf Helmersson, Head
Nils Brenning (Adjunct from KTH, Stockholm)

Semiconductor Materials
(Formerly Materials Science)
Erik Janzén, Head
Peder Bergman
Per-Olof Holtz
Leif Johansson
Rosita Yakimova (Emeritus)
Bo Monemar (Emeritus)
Satoshi Kamiyama (Adjunct from Meijo Univ.)

Surface Physics and Chemistry
Mats Fahlman, Head
William Salaneck (Emeritus, honorary Nanjing)
Koong-An Chao (Emeritus)

Surface and Semiconductor Physics
Roger Uhrberg, Head
Göran Hansson (Prefect of IFM)
Wei-Xin Ni

Thin Film Physics
Lars Hultman, Head
Jens Birch
Esteban Broitman
Joseph E Greene (Adjunct from Univ. Illinois)
Ivan Petrov (Adjunct from Univ. Illinois)
Michel Barsoum (Adjunct from Drexel Univ.)

Steering Committee
Lars Hultman (Head), Erik Janzén (Deputy Head), Weimin Chen, Mats Fahlman, Ulf Helmersson, Magnus Odén, and Roger Uhrberg.

Larger Research Programmes

- Strategic Faculty Grant (SFO) in Materials Sci.
- ERC Advanced Grant (Hultman)
- ERC Starting Grant (Rosén)
- EU-Epitaxial Graphene EPiGRAT (Janzén et al.)
- EU- GaN HEMT MANGA/EuSiC (Janzén et al.)
- VR Linnaeus Center LiLi-NFM (Hultman et al.)
- VR SiC Material för Power electronics (Janzén)
- VINNEX Center FunMat (Hultman et al.)
- Nordic Research Center SIMARC (Chen et al.)
- SSF Coordinated Grant in Materials Science MultiFilms (Odén et al.)
- SSF Nano-N (Holtz et al.)
- SSF Strategic Res. Center MS2E (Hultman et al.)
- SSF project: III-nitrides for UV and high frequency applications (Janzén et al.)
- The Linköping Center for Nanoscience and Nanotechnology CeNano (Hultman, Chair)
- LG Innotek (Janzén et al.)

Summary of Activities

The Material Physics Area is the largest research unit of the Faculty and is internationally recognized as a strong research environment. It engages 150 persons, including over 50 PhD students.

The research is of a basic experimental character, but direct collaboration with industry is essential in many projects. Theoretical modelling is a natural part of many projects.

The research activities include growth of a variety of material structures with different techniques, mainly PVD, CVD and sublimation-based. The materials studied span a broad field, such as metallic thin films, semiconductor materials, nanostructures, and organic structures.

We operate several advanced laboratories; mostly in clean room environment. The characterization techniques include electron microscopy (SEM, TEM, FIB, EELS, PL, CL) and surface studies (ARUPS, STM, AFM, XRR, ERDA), partly at external synchrotron radiation facilities, but also extensively optical, transport and magnetic resonance techniques. Collaboration with foreign laboratories is typical for all research groups; in fact most published papers have international co-authors.

Education

The researchers are heavily involved in teaching on the basic and advanced level in physics, materials science, and nanotechnology (>30 courses). ~10 courses for PhD students are also given each year.

Prof P O Holtz is Director of the Graduate Education at IFM and in the Government AFM.

Prof. L I Johansson is Director for undergraduate teaching in Physics at IFM. He is also Director of the Master Education in Materials Physics at LiTH.

In 2010, we published 7 licentiate and 1 PhD theses.

Technology Transfer & Public Interaction

Our research has generated high-tech industries like Norstel AB in Norrköping, producing SiC substrates, Epigress AB in Lund, producing SiC growth systems, and Impact Coatings AB in Linköping, developing PVD-processes and equipment for functional and decorative thin films.
Several patent applications were filed in 2010. The spin-out company Cyclops AB was founded to develop a novel SiC epitaxial tool.

Assoc. Prof. Robinson was invited to present a paper describing paper an all-plastic (metal-free) light-emitting device employing graphene at the Nobel symposium on Graphene in Saltsjöbaden (Stockholm) in May. The original publication in the journal ACS Nano was one of the 20 most downloaded articles in 2010, and the invention was also featured in Ny Teknik and The Economist.

HIGHLIGHTS 2010
We are part of the Linköping Univ. Fund Raising Campaign; www.liu.se/expanding_excellence.

We became hosts for the new EC Erasmus-Mundus graduate school for Material Science and Engineering (DocMase)

**The Semiconductor Energy and Environmental Materials Initiative (SENMAT)**
Yakimova and Syväjärvi, www.liu.se/senmat) makes production-oriented research of new materials and applications based on SiC, AlN, and graphene. The Fast Sublimation Growth Process (FSGP) of fluorescent SiC for a white LED in general lighting was commercialized with El Seed Corporation, Japan. The High Temperature Graphene Process demonstrated a world class epitaxial graphene evidenced in a publication in Nature Nanotechnology.

The **Senmat** research was high-lighted in Swedish Television and mentioned in the Annual Meeting speach by Björn O. Nilsson, President of IVA and during the Nobel prize award celebrations. We arranged a special graphene session at IEEE SENSORS 2010 Conference and the LIU-spinout company SenSiC demonstrated a sensor based on the graphene produced by us.

A metal-free polymer light-emitting device with a graphene electrode emits light from both sides of the device. This research was a collaboration between Umeå Univ., Linköping Univ. and Rutgers Univ. See doi:10.1021/nn9018569.

The building of a laboratory for a new FEI Titan transmission electron microscope was started in 2010. It is a monochromatized instrument with double spherical aberration correction and a fast EELS spectrometer. Photo: Thomas Lingefelt; Drawings: Tham & Videgård Arkitekter
Functional Electronic Materials

STAFF

Professors: Weimin Chen, Head of Division
Irina Buyanova

Visiting scientists and post-docs (>1 month):
Daniel Dagnelund (June 2010–), Alexander Fionov,
Vladimir Kalevich, Inna Kulakova, Alexander Levanov,
Qijun Ren, Evgeniya Tveritinova, Deyoung Wang,
Xingjun Wang, Yury Zhitnev, Weihang Zhou

PhD students: Jan Beyer, Shuha Chen, Daniel Dagnelund
(–May 2010), Yuttapoom Puttisong

Administrative/Technical staff: Lejla Kronbäck, Arne Eklund

SUMMARY OF ACTIVITIES

In the Functional Electronic Materials Division, we conduct scientific research on electronic, magnetic and optical properties of semiconductor materials and nanostructures. The materials systems under study in 2010 include: (i) advanced spintronic materials based on II–VI and III–V semiconductors; (ii) novel photonic materials based on dilute nitrides; (iii) ZnO-based materials and nanostructures; and (iv) self-assembled InAs/GaAs nanostructures. The research has been carried out mostly through a close collaboration with many groups worldwide. Our aim is to obtain a better understanding of fundamental physical properties and a good control of materials properties, and to fully explore functionality of the studied materials for applications in future generation micro- and nanoelectronics and photonics, spintronics, as well as in potential multifunctional devices and systems.

In the area of spintronic semiconductors, we have continued and extended studies of our recently discovered room temperature spin-filtering in a non-magnetic semiconductor Ga(In)NAs. The focus has been on (i) understanding and optimization of our recently discovered defect-engineered spin filtering effect in Ga(In)NAs quantum and nano structures at room temperature; (ii) studies of spin loss at GaAs/GaNAs interfaces during spin injection at room temperature.

For dilute nitrides like Ga(In)NAs and Ga(Al,In)NP, the presence of harmful residual defects is still one of the major obstacles preventing the materials from practical applications in photonics and optoelectronics. In 2010, we have continued our experimental efforts to identify point and interfacial defects that are responsible for deteriorating optical quality of the materials.

In the area of ZnO-based materials, several topics were addressed. We have continued our studies of exciton dynamics and exciton-photon coupling in ZnO nanostructures, e.g. nano rods and tetrapods. We have also initiated an investigation of spin dynamics in ZnO.

In 2010, we have conducted detailed studies of spin-dependent properties of self-assembled InAs/GaAs QD, QD molecules and rings. Special attention was paid to room-temperature spin generation, spin injection and spin detection, which are relevant to applications in spintronics.

There have been on-going research efforts on spin-sensitive local probe microscopy/spectroscopy. The aim is to develop a variety of advanced spin-sensitive scanning probe microscopies (SPM), such as spin-polarized scanning tunneling microscopy/spectroscopy, and to apply them to studies of nano-magnetism and spin detection and manipulation on the nano- and atomic scale in novel electronic and magnetic materials and nanostructures.

We have also been actively involved in the education program for undergraduate students. During the year, the courses in “Semiconductor Technology” (TFY369) and “Perspectives on Physics” (TFM12) were given.

HIGHLIGHTS

Reliable determination of efficiency of room-temperature spin injection and spin loss across a GaNAs/GaAs interface – The first case for a semiconductor heterointerface at room temperature

Recently discovered effect of spin-filtering and spin amplification in GaNAs enabled us to circumvent the limitation of spin relaxation imposed on efficiency of semiconductor spin detectors at room temperature and to reliably obtain detailed information on the degree of spin loss during optical spin injection across a semiconductor heterointerface at room temperature. Spin polarization of electrons injected from GaAs into GaNAs was found to be less than half of what was generated in GaAs by optical orientation. We showed that the observed reduced spin injection efficiency was not only due to spin relaxation in GaAs, but more importantly due to spin loss across the interface due to structural inversion asymmetry and probably also interfacial point defects. (Appl. Phys. Lett. 98, 012112 (2011)).

On the origin of suppression of free exciton no-phonon emission in ZnO tetrapods

ZnO is one of the most promising materials for future ultraviolet optoelectronic, sensing and spintronic devices, which can be easily synthesized in a large variety of interesting morphologies. Here, we addressed a puzzling issue on the free-exciton (FX) emission in ZnO nanostructures. The intensity of the no-phonon line in ZnO tetrapods was found to be largely suppressed as compared with LO phonon assisted transitions. From spatially resolved cathodoluminescence (CL) studies, this suppression was shown to strongly depend on structural morphology of the ZnO tetrapods and became most significant within areas with faceted surfaces. A model based on re-absorption due to multiple internal reflections in the vicinity of the FX resonance was suggested to account for the observed effect. (Appl. Phys. Lett. 96, 033108 (2010))
Figure 1: (a) An SEM image of a single tetrapod. (b) Room-temperature CL spectra measured at the P1, P2, and P3 positions of the tetrapod shown in (a), together with a typical CL spectrum from the reference bulk ZnO.

**COLLABORATIONS**

We have active scientific cooperation with many international groups, including several on-going exchange programs sponsored by (i) the Swedish Research council (VR) and Swedish International Development Cooperation Agency (SIDA) through a Swedish Research Link program (Fudan University, China); (ii) the Swedish Institute through two Visby programs (Moscow State University, Russia; Inst. of Semiconductor Physics, Ukraine, and A.F. Ioffe Physico-Technical Institute, Russia).

**OTHERS**

Daniel Dagnelund defended his doctoral thesis “Magnetooptical studies of dilute nitrides and II–VI diluted magnetic semiconductor quantum structures” on May 7, 2010.

---

**Nanostructured Materials**

**PERSONNEL**

Professors: Magnus Odén, Bo Jansson
Assistant Professors: José Manuel Córdoba
Naureen Ghafoor, Mats Johansson
Fredrik Söderling
Post-doc: Clara Grönhagen

PhD students: Mohamed Ballem, Emma Johansson
Axel Knutsson, Lina Rogström, Jianqiang Zhu
Jennifer Ullbrand, Rickard Forsén, Niklas Norby
Torkel Stenqvist, Robert Pilemalm
Susanne Sveen

Diploma students: Klara Kemmer, David Dilner

Administrative and Technical Staff: Therese Dannetun, Karl-Olof Brolin

Visiting researcher: Edwin Escalera 2010

**GENERAL INFORMATION**

The division of Nanostructured Materials was established April 1, 2007 as a response to several research centers being granted at that time (i.e. Vinnova-FunMat, VR-LiLi-NFM, and SSF-MSF5E). In 2009 SSF granted the group an additional Material Science program called MultiFilms and 2010 an Erasmus-Mundus graduate school, DocMase, with support from EC for 20 students was added. Naturally most of the Nanostructured Materials group’s research activities are related to these centers and programs.

The scientific aim of the group conforms to the material science paradigm: understanding of the synthesis, microstructure evolution, and material properties of nanostructured materials of industrial interest.

**RESEARCH PROGRAMS**

**Hard coatings**

The thermomechanical properties of nanostructured reactive arc evaporated ceramic materials are studied in model systems that include a miscibility gap. Special interest is paid to the kinetics of the decomposition process in hard coatings and how it is influenced by the environment. Here we use high energy SAXS, and DSC as tools to in situ study the formation of nm-sized particles within the solid solution. STEM and 3D-atom probe in combination with phase field and ab-initio calculations are used to further advance the understanding. In addition the microstructure evolution of alloyed cathode surface is also studied.

**Mesoporous materials**

Synthesis of several types of pore structures with a variable pore size (30–300 Å) based on micelles and how to use these mesoporous materials as chemical microreactors. Of special interest is to use these frameworks to synthesize nanoparticles with extremely narrow size distributions.

**Engineering materials**
Application based research on surface behavior related to tribology at elevated temperature and brazing.

**HIGHLIGHTS**
2010 was the year when Nanostructured materials first graduated students. L.Rogström, A. Knutsson, J. Zhu, and E. Johansson all graduated with a licentiate degree.

- Evidence of age hardening in Ti$_{0.5}$Al$_{0.5}$N/TiN multilayers during metal machining.
- Reactive arc evaporated ZrAlN shows a thermally stable nanocrystalline structure which exhibits age hardening.
- ZrSiN exhibits nm-sized segregation during growth offering means for in situ interfacial design of nanocomposites.

- Nanoparticles of Co, Co$_3$O$_4$, Fe$_3$O$_4$, and ZrO$_2$ with an unprecedented size precision (4±0.4nm) have been synthesized using a mesoporous frameworks as hard templates.
- We have calculated and confirmed experimentally an enormous effect of composition on the elastic properties of TiAlN.

Microstructure evolution simulation during spinodal decomposition of TiAlN including elastic property effects. Arrows indicate local stress state.

- Including elastic anisotropy in a phase filed model for the microstructure evolution in metastable TiAlN.
- Developed a new concept for improved thermal stability through intelligent alloying of quasi binary metal nitrides that involves an unexpected decomposition path.

**COLLABORATION**
- Dr J. Almer, U. Leinert, and Dr J. Ilavsky, Advanced Photon Source, Argonne National Laboratory, USA.
- Prof. W. Clegg, Cambridge University, UK.
- Dr J. Molina, IMDEA Materials, Spain.
- Prof. F. Mucklich, Saarland University, Germany.
- Dr J. Rosenholm, Åbo Akademi, Finland.
- Prof. M. Anglada, Universitat Politècnica de Catalunya, Spain.
- Industrial partners such as SECO Tools, SAPA Technology, Sandvik Tooling, Ionbond, and Element Six.
Plasma & Coatings Physics

STAFF
Professor: Ulf Helmersson
Adjunct professor: Nils Brenning
Assistant professor: Daniel Söderström
Research engineers: Petter Larsson, Sankara Pillay

Post-doctors: Kostas Sarakinos, Daniel Lundin, Iris Pilch
PhD-students: Mattias Samuelsson, Montri Aiempanakit, Asim Aijaz, Daniel Magnfält,

Administrative assistant: Mikael Amlé,

Master students: Chung-Chuan Lai, Bo Lu, Magnus Karlsson, Viktor Johansson, Rickard Gunnarsson, Aspurah Staney (KTH)
Student consultant: Viktor Brodin

INTRODUCTION
The Plasma & Coatings Physics group is a division at the Department of Physics, Chemistry and Biology (IFM), Linköping University, Sweden. Our overall goal is to contribute towards addressing challenges of contemporary materials science and technology through the synthesis of novel films and nanomaterials. To realize this goal, we employ innovative processes which allow for the generation of plasmas with unique properties as well as control of the material synthesis at the atomic level. Through a combination of advanced experimental and theoretical tools we seek to understand the process-plasma-material interactions and gain insight into the knowledge-based synthesis of functional films and nanomaterials.

SCIENTIFIC HIGHLIGHTS IN 2010
HiPIMS – plasma properties
The transport of charged particles in a HiPIMS discharge is of great interest when optimizing this thin film deposition technique with respect to deposition rate and control of the ion acceleration. Our group carried out a study where the internal plasma currents were resolved in time as well as in space during process. From the measurements a phenomenological model was constructed describing the evolution of the current density in this pulsed plasma, see Figure 1. The core of the model is based on three different types of current systems, which characterize the operating transport mechanisms, such as current transport along and across magnetic field lines. There is a gradual change between these current systems during the initiation, build-up and steady-state of a HiPIMS plasma.

These experimental results on the plasma dynamics are essential input to ongoing HiPIMS computer modeling, which aims to predict and optimize the composition, energetics and direction of the material flux from the source to the growing film.

HiPIMS – increased film density
When the microstructural appearances of films deposited by HiPIMS are compared to those of conventional sputtering, they are often described as more smooth and dense. However, actual comparisons of the film densities for the two deposition methods are seldom performed. A systematic study of densities comparing films from eight different metals deposited by HiPIMS and conventional sputtering has been performed. When comparing the two methods it was confirmed, for the first time, that the film grown using HiPIMS show a significant increase in density. This increase, for the individual metal, was found to correlate to the degree of metal ionization of the particular element as calculated using a newly developed global plasma model.


HiPIMS – reactive sputtering
In the field of reactive sputtering we have worked with several materials. Here are some examples:
We studied the behavior of reactive sputtering of Al, Ce, and Ti using HiPIMS in an Ar-O₂ atmosphere as well as in DCMS. It was found that for some cases, the hysteresis may be completely avoided. In other cases, the system is not free from hysteresis even with HiPIMS. However, the hysteresis is reduced and there is an optimum pulsing frequency which minimizes hysteresis. The relationship between the pulsing frequency and the hysteresis behavior has been explained on the basis of the gas rarefaction during and the limited target oxidation between the power pulses. The elimination/suppression of the hysteresis in HiPIMS has facilitated the growth of stoichiometric and transparent Al₂O₃ at relatively high deposition rates over a wider range of experimental conditions as compared to DCMS.
with core-shell structures, of a wide range of materials. The efficiency of the method (i.e. to get as many particles per kWh as possible) and the control over particle sizes and shapes has been greatly improved. We have synthesized copper nanoparticles both in the shape of spheres (Figure 3) and cubes (Figure 4). The results indicate a very fast growth with many particles in a short time, and with a fairly good size distribution. Note that the particles have not passed any type of filter.

![Figure 2](image2.png)

**Fig. 2.** (a) Discharge voltage, (b) mass deposition rate and (c) O2 partial pressure as a function of the O2 flow during reactive HiPIMS of the Al target at pulsing frequencies of 1, 2 and 4 kHz. The process characteristics of the reactive DCMS process are also plotted for reference.

![Fig. 3](image3.png)

**Fig. 3.** SEM micrograph of spherical copper nanoparticles.

Experiments with core-shell structured nanoparticles were also initiated during the year. This work is still in its early stage, but the experiments show very promising results. The idea is to synthesize nanoparticles in situ or seed our plasma reactor with ready-made particles and coat them in several steps to get a core-shell structure.

A patent application describing our novel process was finished and filed during the spring 2010.

![Fig. 4](image4.png)

**Fig. 4.** SEM micrograph of cubic copper nanoparticles.

We have also studied the growth of carbides in a reactive environment. In this case, TiC was grown using a gas mixture of argon and acetylene with a titanium target. The results show that when using HiPIMS the process window is widened and its stability increased as compared to the conventional sputtering process. Also the film properties are improved in that the formation and growth of carbide is promoted in the HiPIMS process, and the normally encountered difficulties in the process are avoided.

**Nanoparticles**

During the year, the plasma method for synthesizing nanoparticles (particles with sizes in the range of a few to hundreds of nanometers) – started in 2009 – was developed further. The method allows us to synthesize advanced nanoparticles, e.g.
**AWARDS 2010**

- Daniel Lundin received the Yearly Teaching Award, voted by the students of Applied Physics at LiU.

**INVITED LECTURES GIVEN DURING 2010**

- K. Sarakinos, “HiPIMS: a tool of synthesizing new functional thin films and coatings”, Department of Physics, University of West Bohemia, November 2, 2010, Plzen, Czech Republic.
- D. Lundin, “Plasma Applications in Material Science”, University of Greifswald, August 16–27, 2010, Greifswald, Germany.
- D. Lundin, “The role of ions in magnetron discharges”, Department of Physics, University of West Bohemia, November 2, 2010, Plzen, Czech Republic.

**ACADEMIC AND INDUSTRIAL COLLABORATION PARTNERS**

(outside the department) in on-going projects or joint publications in 2010:

- Prof. J.T. Gudmundsson and co-workers, Science Institute, University of Iceland.
- Dr. T. Kubart and co-workers, Uppsala University.
- Prof. H. Kersten and co-workers, Kiel University, Germany.
- Prof. M.A. Raadu, KTH, Stockholm.
- Prof. J.E. Greene, University of Illionois, USA.
- Dr. M. Lattemann, Forschungszentrum Karlsruhe GmbH, Germany.
- Prof. W. Möller and co-workers, Forschungszentrum Dresden-Rossendorf, Germany.
- Drs. E. Rezuginia, Anne Lise Thomann and Pascal Brault, Université d’Orléans, France.
- Prof. J. Boettiger and co-workers, Aarhus University, Denmark.
- Dr. H. Ljungcrantz, Impact Coatings AB, Sweden.
- Prof. J. Bradley, University of Liverpool, UK.
- B. Stevens and Prof. S. Barnett, Northwestern University, USA.
- Drs. J. Alami and G. Erkens, Sulzer Metaplas GmbH, Germany.
- Prof. T. Minea and co-workers, Université Paris-Sud, France.
- Prof. J. M. Schneider, and co-workers, Materials Chemistry, RWTH Aachen University, Germany.

**Semiconductor Materials**

**STAFF**

Professors: Erik Janzén, Per Olof Holtz, Leif Johansson, Peder Bergman, Rozitsa Yakimova (emerita), Bo Monemar (emeritus).


Visiting scientists: Hyunchol Cho, Japie Engelbrecht, Tomoaki Hatayama, Yeong Deuk Jo, Dares Kaewket, Jun Kajita, Seok Min Kang, Pawinee Kangtakai, Hashim Raza Khan, Moonseong Kim, Wei-Jung Lai, Georgios Manolis, Rui Masuda, Evgenii Moskalenko, Shakila Bint Reyaz, Einar Sveinbjörnsson, Fumiharu Teramae, Qing Xiang Zhao.
**PhD students**: Supaluck Amloy, Franziska Beyrer, Ian Booker, Patrick Carlsson, J-Tai Chen, Mihails Cubarovs, Daniel Dufåker, Saida Muniza Faraz, Andreas Gällström, Chih-Wei Hsu, Valdas Jokubavičius, Ahsan Ullah Kashif, Arvid Larsson, Stefano Leone, Anders Lundskog, Björn Magnusson, Daniel Nilsson, Susanna Stammbach, Remigijus Vasiliauskas, Chao Xia, Mengyao Xie, Milan Yazdanfar.

**Others**: Chun-Xia Du, Philip Hens, Tihomir Iakimov, Sergey Lebedev, Rickard Liljedahl, Petra Reimers, Pontus Stenberg.

**Administrative/Technical staff**: Eva Wibom, Kerstin Vestin, Sven Andersson, Roger Carmesten, Arne Eklund.

**SUMMARY OF ACTIVITIES**

The research activities in the Semiconductor Materials Division cover a broad spectrum, dominated by basic research. The projects are mainly funded by external agencies, partly with direct industry collaboration. There is a strong international cooperation within most research projects. The present research program can be divided into the following partly overlapping areas:

- Preparation and characterization of epitaxial films and bulk material of semiconductors with chemical vapor deposition (CVD), and sublimation techniques, with a strong emphasis on SiC and III-nitrides. The characterization includes surface and interface properties, structural properties, optical properties and transport properties.
- Investigation of properties of dopants and defects in a large variety of semiconductors, including structural as well as electronic properties. The latter covers bulk, surface and interface defects, with several techniques including laser spectroscopy and magnetic resonance.
- Preparation and investigation of the electronic properties of semiconductor quantum structures and nanostructures such as heterostructures, quantum wells, quantum wires and dots, and superlattices, with various spectroscopic techniques in several material systems.
- Studies of the electronic structure of III-nitride materials including defects and H-related properties.
- Fabrication and characterization of graphene on SiC.
- Development of GaN and AlGaN/GaN HEMT structures for high-frequency power devices and Al-rich AlGaN heterostructures for laser diodes (LDs) and light emitting diodes (LEDs) in the UV (≤400 nm) and deep UV (D4V, <300 nm) spectra regions.
- Fabrication and characterization of TiO2.
- Simulation, design and fabrication (with the collaboration with FOI) of RF and microwave power transistors based on SiC and GaN.

Research activities in this division during 2010 have produced ~50 papers published in high quality international journals, ~36 conference proceedings papers with peer review and 4 review articles/book chapters. During the year 12 invited talks were given by the staff at international conferences or symposia.

The researchers of the division are well cited in international journals, the SCI citations of papers cited for the researchers in the division cover about 18500 ISI citations since 1975.

The budget for research in our division was about 36.5 MSEK during the period 100101–101231, excluding equipment grants. The major part of this budget comes from external sources. The faculty support for research was about 8.6 MSEK for the year. External grants originate mainly from VR, the Swedish Strategic Research Foundation (SSF), Swedish Energy Agency and EC. In addition there is a strong support from and intimate cooperation with several industries, mainly Norstel AB and Aixtron AB, and with the Defense Research Institute FOI.

The Division was during 2010 engaged in several European research projects and Nordic project:
- Manga and EuSiC are two large-scale joint multinational initiatives of leading system houses and research laboratories in Europe aiming at the development of independent and state-of-the-art capability in GaN HEMT technology. The goal of EuSiC is to develop high quality European GaN-Wafer on SiC substrates for space applications and to create an independent European supply chain for space technology.
- MANSiC– A FP6 project for promoting and structuring a Multidisciplinary Academic-Industrial Network through the heteropolytype growth, characterization and application of 3C-SiC on hexagonal substrates.
- NORLED– The N-Inner project with partners from Sweden, Denmark, Germany and Norway develops an innovative and industrially feasible white LED technology for general lighting.
- LG-Innotek– The project, which is sponsored by LG Innotek and the State of South Korea, strives to develop uniform epitaxial layers for power device material on 4” wafers using the chlorinated epitaxial process that has been studied here for several years.


The Division is very active in teaching and has the responsibility for about 20 undergraduate and graduate courses at IFM.

**HIGHLIGHTS**

*Phosphorus ionization energy in 3C-SiC.*

Phosphorus is an important alternative to the nitrogen shallow donor in all polytypes of SiC. Its ionization energy in the cubic 3C-SiC polytype was determined accurately, 48.1 meV, by means of analysis and comparison of the donor-acceptor pair spectra of P-Al and N-Al pairs in this polytype. (J. Appl. Phys. 108, 063512 (2010)).

*Identification of a complex defect between a carbon antisite-vacancy pair and a third neighbour carbon vacancy in 4H- and 6H-SiC.*

The E14 EPR center is commonly detected in some types
of high-purity semi-insulating (HPSI) 4H- and 6H-SiC and seems to play an important role in carrier compensation processes and hence the SI properties of the materials. Enhancing the signal by electron irradiation and proper annealing enabled detailed EPR studies of the center in both 4H and 6H polytypes. Combining EPR studies and ab initio supercell calculations led to the identification of the defect as a complex between a carbon antisite-vacancy pair and a third neighbour carbon vacancy. Annealing studies and calculations of the migration energy barriers also suggested a model for the formation of the defect, by the migration of the silicon vacancy at low temperatures, and the transformation of the defect to a divacancy at higher temperatures. (Phys. Rev. B 82, 235203 (2010)).

Bistable defects in low-energy electron irradiated n-type 4H-SiC
Metastable defects in low-energy electron-irradiated SiC were studied using deep level transient spectroscopy. Metastable defects may be introduced during irradiation. Such defects react differently, are in an electrically active configuration or not, depending on the applied bias and the thermal history of the sample. Several types of metastable defects are present in n-type 4H-SiC: the M-center, EB-centers and EH3 and they may partly transform into each other during annealing. All bistable defects, studied up to now, were completely annealed out at 800 °C, thus mobile species, like carbon interstitials, may take part in the annihilation process. The origin of these metastable levels is likely attributed to carbon related complex defects, since the energy for displacing the Si in SiC is not reached during our electron irradiation. (Phys. Stat. Solidi RRL 4, 227-229 (2010))

High growth rate of 4H-SiC epilayers on on-axis substrates with different chlorinated precursors.
In 2009 promising results were demonstrated by using the chloride-based CVD on 4° off-axis and on-axis substrates with a growth rate below 30 μm/h. This year growth rates of 100 μm/h could be achieved. (Cryst. Growth Design, 10 5334 (2010)).

Chloride-Based SiC Epitaxial Growth toward Low Temperature Bulk Growth.
A great advantage of chloride-based chemistry is the feasibility of growing at very low temperatures (1300 to 1400 °C compared to 1600 °C). At such low temperatures 4H-SiC epitaxial layers could be grown on 8° off-axis substrates with two different precursors approaches (SiH4 + C2H2 + HCl and MTS).
The gas phase chemistry is different; MTS is more efficient to grow high quality homo-epilayer on 8° off-axis substrates at 13 μm/h. (Cryst. Growth Design 10, 3743 (2010)).

Chloride-based CVD of 3C-SiC epitaxial layers on 6H(0001) SiC.
At low temperatures on 6H-SiC Si-face on-axis substrates, using the SiH4 + C2H2 + HCl chemistry, very high quality single-domain 3C-SiC layers could be grown under C-rich surface preparation and Si rich growth conditions. If nitrogen was added during the growth single-domain 3C-SiC could be deposited. (Phys. Status Solidi RRL 4, 305 (2010)).

Optimization of a concentrated chloride-based CVD process of 4H-SiC epilayers.
The benefit of the chlorinated chemistry was tested under unusual growth conditions, such as under a concentrated gas mixture (i.e. at very low carrier gas flow) tested on different off-cut substrates. A very low carrier flow (1/10 of the standard value) CVD process was developed on different off-cut substrates. A detailed study of the gas dynamics in the reaction chamber, setting different flows, pressure, reaction chamber heating and process parameters was performed. Growth rates up to 50 μm/h and excellent thickness uniformity on a 30 mm diameter wafer area were achieved. (J. of Electrochem. Society 157, H969 (2010)).

Mg-doped Al0.85Ga0.15N layers grown by hot-wall MOCVD with low resistivity at room temperature.
We reported on the hot-wall MOCVD growth of Mg-doped AlGa-N layers with an Al content as high as x = 0.85. After subjecting the layers to post-growth in-situ annealing in nitrogen in the growth reactor, a room temperature resistivity of 7 kΩ cm was obtained, indicating an enhanced p-type conductivity compared to published data for AlGa-N layers with a lower Al content of x = 0.70 and a room temperature resistivity of about 10 kΩ cm. Despite the semi-insulating character of such Mg-doped high Al-content AlGa-N layers at room temperature, they could still perform as efficient p-transport layers in deep-UV light-emitting diodes, as a very thin layer (< 10 nm) is needed. The enhanced p-type conductivity is believed to be due to reduced compensation by native defects achieved by growth conditions enabled by the distinct hot-wall MOCVD system (Phys. Status Solidi RRL 4 (2010) 311).

Fig. 1. (a) SEM images of GaN nanotube grown at 500 oC on sapphire and (b) high density of GaN nanotubes grown on sapphire substrates with a 5 nm thick Au film.
Growth of GaN nanotubes by halide vapor phase epitaxy

GaN nanotubes are one of the building blocks which are of high interest in the field of functionalized nanostructures and there are several interesting applications based on GaN nanotubes such as solution-based transistors or highly sensitive nanotube molecular sensors. In this project, we are investigating low temperature growth (480–520 °C) of GaN nanotubes using halide vapor phase epitaxy (HVPE) on c-oriented AlO,
and Au coated Al2O3 substrates. By varying the growth process parameters, we have shown that the shape and density of the structures can be controlled. The grown nanotubes are about 1 μm long with a diameter of typically 200 nm, see Fig. 1.

The nanotubes are spontaneously nucleated at droplets of Ga or, when using Au coated Al2O3, on droplets of Au/Ga alloy. The experimental results within this project suggest that this approach with pre-patterned Au coated Al2O3 substrates has the potential for fabrication of well-organized nanotubes with a high density. (Nanotechnology 22, 085602 (2011))

Epitaxial graphene

High temperature sublimation method has been applied to produce high quality 1 ML and 2 ML epitaxial graphene on SiC substrates of different polytypes (6H, 4H and 3C-SiC) and doping (N-type and Si). Graphene has been grown on Si- or C-side depending on the purpose. Record low carrier concentration has been measured. Ultrahigh sensitive gas sensors have been demonstrated. Prof. Rositza Yaminova has suggested and organized a special session on graphene based sensors at the 2010 IEEE Sensor Conference. (Nature Nanotechnology 5 186 (2010). The graphene research was highlighted several times in Swedish technical paper Ny Teknik, Swedish Radio and Swedish Television.

Fig. 2. (a) LEEM image of a monolayer graphene grown on SiC (0001); the field of view [FOV] is 50 μm and the electron energy is Evac –0.5 eV. (b) LEEM image illustrating the graphene surface after Li deposition. (c) LEEM image recorded after annealing the sample to 320°C.

Fig. 3. The π band around the K point recorded from (a) monolayer graphene, (b) after Li deposition and (c) after annealing at 250°C. (d) Schematic drawing of the 2D Brillouin zone of graphene and the direction of scan.

Epitaxial graphene on 6H-SiC, Li intercalation.

We have demonstrated an intercalation process of Li in monolayer graphene on SiC(0001). Our results show that Li atoms penetrate through the graphene as well as the carbon buffer layer and intercalate at the SiC/buffer layer interface. The process starts immediately after deposition, see Fig. 2. The Li atoms bond to Si atoms in the uppermost Si-C bilayer and creates a dipole layer at the interface that induces a ca. 2 eV shift of the SiC core levels. The Li atoms do at the same time transform the carbon buffer layer into a second graphene layer. After Li deposition three π-bands are observed at the K-point, see Fig. 3. After annealing when a more even Li distribution and intercalation is obtained two distinct π-bands appear at the K-point. Li gives rise to electron doping and lowers the Dirac point (ED) by 0.25–0.5 eV depending on coverage. (Phys. Rev. B. 82, 205402 (2010))

Nano-scale 3D band structure imaging (E,k,k) on graphene and intercalated graphene

An X-ray Photoelectron emission microscope (XPEEM) equipped with a hemispherical energy analyzer is capable of fast acquisition of momentum resolved photoelectron angular distribution patterns in a complete cone. We applied this technique to observe the 3D (E,k,k) electronic band structure before and after Li intercalation. For the 0 ML sample no π-cones (bands) were detected close to the Fermi level, see Figs. 4(a–b), while after Li deposition and heating clearly resolved π-cones appear at the K-points in the BZ, see Figs. 4(c–d). After Li deposition on the 0 ML graphene sample less wrinkles/cracks were observed to form on the surface after Li deposition and heating (compared to on 1 ML samples). The observed deterioration in quality of the graphene upon Li intercalation may be connected to an explanation why the efficiency in fuel cell reduces with usage. (New J. Phys. 12, 125015 (2010)).

Fig. 4. Photoelectron angular distribution patterns (E,k,k) collected from 0 ML graphene at an initial state energy of (a) 1.2 eV and (b) 0.2 eV below the Fermi level, using a photon energy of 35 eV. (c)–(d). Patterns collected from the 0 ML graphene sample after Li deposition and heating at 350°C at the same initial state energies as in (a)–(b), respectively.
Doping mechanisms in InN

Control of doping in InN and related alloys remains one of the most challenging issues on the way to develop the potential of these materials in new advanced photovoltaic and light emitting device applications. In a collaborative effort with the growth teams at Ritsumeikan University (Prof. Y. Nanishi), University of Monpellier (Prof. O. Briot), National Taiwan University (Prof. L.-C. Chen) and Cornell University (Dr. W. J. Schaff) we performed comprehensive studies on the possible doping sources in MBE and MOVPE InN films with different surface orientations. We have identified a doping mechanism unrelated to dislocations, previously thought to be responsible for the unintentional n-type conductivity. We established the major role of H for the unintentional n-type doping in MBE and MOVPE InN (Appl. Phys. Lett. 96, 081907 (2010)) and found enhanced concentrations of H in the near surface regions of epitaxial InN films, that may have significant implications for the surface electronic properties. Our new findings suggest strategies to influence bulk and surface H concentrations in InN epitaxial films.

Exciton fine structure of C3v-symmetry quantum dots: Symmetry lowering and elevation

It is predicted that C3v-symmetric semiconductor quantum dots (QDs) are ideally suited as sources of polarization entangled photons. A detailed analysis of the excitonic fine structure for symmetries lower and higher than C3v provide the methodology to experimentally detect the symmetry of quantum states by the spectral features of exciton complexes. Photoluminescence measurements (PL) and computations of InGaAs QDs reveal surprising effects of symmetry elevation. These results are expected to have an impact on the development of QD based devices for quantum information processing. (Phys. Rev. B 81, 161307 (2010)).

Phonon coupling to excitonic transitions in single quantum dots

Quantum dots (QDs), often referred to as “artificial atoms”, enables confinement and manipulation of individual charge carriers with applications in quantum information processing. In this work, extremely light intense InGaAs QDs are used to investigate the coupling between the confined carriers and crystal vibrations. LO-phonon replicas of various exciton complexes are resolved for the first time in the photoluminescence spectra, and it is demonstrated that a single hole strongly modulates the probability of emitting a phonon. These results shine light onto the unavoidable interaction between the QD and its solid state environment, i.e. a process differentiating a single QD from a real isolated atom. (Phys. Rev. B 82, 205421 (2010)).

Si based RF Power Amplifier and ZnO devices

RF power amplifiers designed in Cadence and get fabricated by IBM semiconductor and ST Microelectronic semiconductor foundries. The amplifier chip is characterize at LiU and Swedish Defense Research (FOI). The research is performed in collaboration with NED Engineering University in Karachi, Pakistan. ZnO based Schottky and PN-diodes are designed by TCAD simulations utilizing physical models and parameters of semiconductors. We optimized device performance by TCAD simulation tools. (J Comput. Electron 9, 79 (2010)).

Manga & EuSiC

Manga and EuSiC are two large-scale joint multinational initiatives of leading system houses and research laboratories in Europe aiming at the development of independent and state-of-the-art capability in GaN HEMT technology. Manga program is a continuation of the KORRIGAN program with dedication to build up a European supply chain of GaN HEMT technology. LiUs participation within Manga is material development with focus on interface properties between the SiC substrate and the nitride epilayer and to improve the thermal dissipation. The goal of EuSiC is to develop high quality European GaN-Wafer on SiC substrates for space applications and to create an independent European supply chain for space technology. Linköping University will grow HEMT structures on 3” wafers, partly supplied by the Swedish SiC substrate manufacture Norstel, which will then be processed at the European process house, United Monolithic Semiconductor, UMS in Germany.

Industrial Research Project with LG Innotek

During 2010, a large collaborative effort between Semiconductor Materials and LG Innotek was started. The project, which is sponsored by LG Innotek and the State of South Korea, strives to develop uniform epitaxial layers for power device material on 4” wafers using the chlorinated epitaxial process that has been studied here for several years. For this purpose LG Innotek will place a new commercial CVD reactor at LiU that can effortlessly handle 4” wafers. The full project is anticipated to last for 3 years split into three stages. In total the research funding to the Semiconductor Materials group is worth 20 MSEK not counting the CVD reactor. Researchers from LG Innotek are here at LiU to learn the fundamentals of CVD and to study the chlorinated chemistry.

SSF project: III-nitrides for UV and high frequency applications

This joint effort between Linköping University and Chalmers, supported by industry, aims at developing an III-nitride (III-N) technology that allows for the fabrication of

- laser diodes and light emitting diodes as sources for coherent and incoherent UV and DUV radiation.
- advanced High Electron Mobility Transistors (HEMTs) to be used in high-power, high-frequency applications with performances significantly exceeding those of today’s technologies, thereby enabling exploitation of III-N based systems in several ICT application areas such as: High density data storage, Biological sensor system, Solid State Lighting, Tools for the microelectronics industry, Wireless communication and Radar systems. This will be accomplished by combining a set of unique capabilities.

LiU has developed a novel technique for growth of high quality wide band gap (WBG) materials, known as “hot-wall CVD”, which is very suitable for preparing the high quality Al-rich AlGaN heterostructures needed for emission in the UV/DUV as well as the InAlN/GaN heterostructures useful for both UV and HF applications. Defects in WBG materials are another focus area of LiU, which will be very valuable in the project.

Chalmers has many years of experience and expertise from high level research on semiconductor based light
emitting devices and HF electronics as well as well-developed techniques for fabrication of WBG devices.

NANO-N
A SSF consortium
Nitride based quantum dots and wires for optoelectronic applications

A nano consortium
The NANO-N consortium, one out of five new consortia, is financed within the NANO-X program by SSF during the period 2006–2011. The focus for NANO-N is towards nano structures made of the wide band gap semiconductors: GaN/AlN/InN based quantum wires and dots.

The organization of our NANO-N consortium at present
• Consortium leader: Prof. Per Olof Holtz
• Senior researchers: Prof. Erik Janzen, Prof. Jens Birch, and Prof Lars Ojamäe
• Industry/institute mentors: Jan Andersson, Susan Savage, Tersita Kvarnström, Qin Wang, Acreo, Kista and Steven Savage, FOI, Linköping
• Junior researchers: Fredrik Karlsson, Mattias Kula, Urban Forsberg, Maria Lundskog, Ching-Lien Hsiao, Reui-San Chen
• PhD students: Anders Lundskog, Chi-Wei Hsu, Supaluck Amloy, Justinas Palisaitas, Muhammad Junaid

The Nano-N consortium
The NANO-N consortium is financed within the NANO-X program by SSF. In this consortium, the focus is towards fabrication and optimization of light emitting GaN/AlN/InN based quantum dots. The unique concept is based on nitride pyramidal structures, fabricated by means of selective area growth in a MOCVD reactor. On a patterned substrate, the GaN growth will only occur in the etched holes, which subsequently will evolve into pyramids. Subsequently, the pyramids are covered by a thin InGaN quantum well and finally with a GaN layer on top. In the peak of the pyramid, the thin InGaN well will form a quantum dot. The pyramidal growth offers a unique controllability what concerns the density, positioning and the dimensions of the dots and consequently also the emission energy. Such deterministic dots have considerable advantages for light emitter applications. An example of a well defined excitonic emission from a single InGaN quantum dot in the peak of a pyramidal structure is shown in Fig. 5. Also structural characterization of the pyramidal quantum dots is carried out. The pyramidal structures are characterized by HRXRD, TEM and AFM. High accuracy cuts of the pyramidal structures have been performed by means of focused in beam (FIB). This opens the possibility to gain information on the cross section of the pyramids. It has been of particular importance to study the thin InGaN well, which is the basis for the quantum dot in the peak of the pyramid.

In parallel with the experimental work to optimize the pyramidal dots properties, theoretical investigations are performed by means of quantum-chemical computations, where different issues as prompted by the experimental investigations are addressed. The simulations are performed for successively larger quantum dots in order to gain information on quantum confinement and electronic structure. Also the more complicated dot-in-pyramids structures are calculated. Subsequently, theoretically predicted results on the optical absorption and emission are compared to the experimentally results achieved on (In)GaN/GaN quantum structures.

MANSIC – The RTN MANSIC (www.mansic.eu) is a Marie Curie project which promotes the European collaborative platform. Mansic is devoted to research on cubic SiC. The main idea is to develop conditions for bulk growth of 3C-SiC starting from 6H-SiC substrates in order to avoid well known problems of using Si substrates. Mansic project involves groups with expertise in growth, characterization and devices. We have studied the initial stage of homoepitaxial growth of 3C-SiC and homoepitaxial growth of 6H- SiC on nominally on-axis 6H-SiC substrates. Different sublimation growth conditions of 3C-SiC approaching a bulk process have been investigated with the focus on appearance of macrodefects. As a part of the Mansic plans, we organized and hosted Winter School on Epitaxy to Bulk Growth (PAM3) in January 2010.

Fig. 5. Micro-PL spectrum of a single InGaN quantum dot in the peak of a pyramidal structure.
NORLED – Northern Light Emitting Diode Initiative
(M Syväsjärvi, R Yakimova).
NORLED (www.ifm.liu.se/norled) is a project funded by Nordic Energy Research. During 2010 the project has demonstrated room temperature photoluminescence from doped SiC layers, which are the base for an innovative white LED for general lighting. The project also arranged a session at Sveriges Energising which is Sweden’s largest scene for discussion of energy and climate related activities and gathers more than 2000 participants. A proposal by NORLED was accepted for a session on energy saving wide band gap materials at the next European MRS conference. The project initiated research collaboration with Japan, funded with 46 MSEK by NEDO (Department of the New Energy and Industrial Technology Development Organization) which actively undertakes the development of new energy and energy-conservation technologies.

COLLABORATIONS
We have active collaboration with more than 30 research groups and industries in Europe, USA, Asia, Australia and Africa.

Surface and Semiconductor Physics

STAFF
Professors: Göran Hansson, Head of Department
Roger Uhrberg, acting Head of Division
Wei-Xin Ni

Post- Docs: Jacek Osiecki, Amir Karim

Ph.D. students: Bouchaib Adnane, Johan Eriksson,
Hafiz Muhammad Sohail

Adm/Techn. staff: Kerstin Vestin, adm. asst., Karl-Olof Brolin,
research eng., Chun-Xia Du, senior research eng., Ph. D.

ACTIVITIES
The research within the division of Surface and Semiconductor Physics concerns the following fields. Firstly, basic studies are made of the electronic and atomic structure of semiconductor surfaces, either clean or with well-characterized overlayers. Foreign atoms on a surface may result in a large variation of ordered atomic structures, i.e. surface reconstructions. Physical properties like metallic or semiconducting surface conductance may depend on what reconstruction is formed. Various physical properties are studied by a range of different techniques. The most important one is photoelectron spectroscopy from which one can obtain a complete determination of the surface electronic structure. These studies are performed at the synchrotron radiation facility, MAX-lab in Lund, Sweden. Another important technique that we use is scanning tunneling microscopy (STM) that provides information about the atomic structure of the different surfaces. A variable temperature STM (Omicron) in our lab at IFM is the major instrument used for these studies. Over the period of several years we have also built up an experience in theoretical studies of various systems. We find the capability to do both experimental and theoretical studies quite important. It gives us the advantage that we can approach a problem from both the experimental and theoretical side to obtain a complete picture of the electronic and atomic structure.

Within this field, the division was supported by the Swedish Research Council (VR) as Roger Uhrberg has one research grant for studies of the atomic and electronic structure of semiconductor surfaces.

Secondly, there are studies, development and application of silicon-based molecular beam epitaxy (MBE), which is a crystal growth technique to produce advanced semiconductor structures for fundamental physics and device studies. We have also built up competence and process capability for the development of some device modules like SiGe-heterojunction bipolar transistors (HBT) for applications in optoelectronics and rf technologies. Erbium doped structures for light emission at 1.55 μm have been studied and processing of cavity structures for Er-doped laser structures has been done using Focused Ion Beam (FIB), however without achieving stimulated emission.

We are extensive users of the synchrotron radiation facility MAX-lab in Lund and over the years we have built up experimental equipment at two different beam lines. One of us, Uhrberg, is the spokesperson for one of the beam line applications that were submitted to KAW for the coming MAX IV synchrotron radiation facility. A detailed application has been prepared for a beam line for angle-resolved photoelectron spectroscopy (ARPES) and spin-resolved ARPES. The beam line is planned for the 1.5 GeV ring at MAX IV.

COURSES
The division has during the year been responsible for the following undergraduate courses for students within the Engineering Programs and the International Masters Program on Material Science: TFY438 Optoelectronics (Ni), TFYA25 Physics of Condensed Matter, part II (Uhrberg). The Ph. D. course Solid State Physics I was given by Uhrberg.

HIGHLIGHTS
1) The clean Si(001) surface has a well-established structure of tilted Si-dimers that form a c4x2 reconstruction, see Fig. 1. This reconstruction affects the binding energy of the Si 2p core-level of the atoms in the near surface layers. By applying high-resolution core-level spectroscopy in combination with calculations of the core-level shifts, we were able to make a one-to-one identification of surface core-level shifts with the unique atoms down to the fourth layer. The Si 2p core-level spectrum in Fig. 2 is extremely well resolved and represents the state of the art in core-level spectroscopy on semiconductor surfaces. The spectrum is decomposed into various spin-orbit split Si 2p components. Each component could be identified with a certain near surface atom down to the fourth layer (see Fig. 1) based on theoretical core-level shift obtained using the Wien2k code.
2) Following the earlier success in fabricating Si/SiGe/Si(Ge-dot) hetero-junction phototransistors and three-terminal Ge(dot)/SiGe-quantum-well(QW) channel MOSFET photodetectors in the near infrared (0.85–1.55 μm) range with high photoreponse and low dark current, the group continues its effort in making lateral transport detectors with MBE grown coupled Ge-dot/SiGe-QW heterostructures incorporated in the active region for absorption and detection in the mid-infrared (4–12 μm) range for the enhanced performance. The peaked photoreponse was measured with the incident infrared radiation at ~10 μm (photon energy = 0.123 eV).

In order to optimize the device design, the optical transitions in the MBE-grown self-assembled Ge/Si dot structures were studied in detail using photo-luminescence excitation (PLE) and selective photoluminescence (SPL) measurements. The temperature- and power-dependence of the excitation properties together with the results of six-band k·p calculations support the assignment of the observed two PLE peaks to spatially direct and indirect transitions collected from two different SiGe dot populations defined by the monitored detection energy for both PLE and SPL.

3) Many SiGe- or Ge-based electronic and photonic devices require making the growth on an intermediate fully relaxed SiGe (or Ge) layer (so-called virtual substrate) that is free of threading dislocations. However, it is hard to obtain a density of the threading dislocations below 106 cm-2 by many developed virtual substrate techniques.

Fig. 1. Top and side view of the Si(001)c(4x2) surface.

Fig. 2. Normal emission Si 2p core-level spectrum (dots). A bulk (black) and six shifted surface components (gray) are used to generate the fit (solid curve).

Fig. 3. (a) PLE spectra of GeSi/Si dots acquired at different detection energies at T = 2K from a single-layer Ge/Si dot structure. (b) Schematic band-edge diagram of the GeSi-dot/Si heterojunction along the z direction with the relevant inter band transitions corresponding to the observed PLE peaks.

Fig. 4 TEM of a Ge layer on (a) a blank SiGe layer and (b) patterned SiGe templates. A bending loop of threading dislocation lines was clearly observed along the pattern edge.
We recently developed a technique to grow the Ge layer on patterned SiGe structures, such that the difference in lattice mismatch between Ge/SiGe on the ridge and Ge/Si in the open window would create a driving force to push dislocation loops moving towards the pattern edge and bend down. Dislocation-free Ge virtual substrate layers can then be produced (see Fig. 4), which is thus the technology foundation that makes a unique possibility for us to grow Ge-based heterostructures with very high crystalline quality and adjustable strain parameters for various device applications.

ASSIGNMENTS
1. Advisory committee of the 5th International SiGe Technology and Device Meeting (ISTDM-2010, Stockholm, May 24–26, 2010). Ni
2. Organizer of the EMRS Symposium on Transport and photonics in Si-based nanomaterials and nanodevices (EMRS, Nice, May 9–13, 2011). Ni
3. Scientific program committee of the 7th International Conference on Si Epitaxy and Heterostructures (ICSi-7, Sendai, Japan, May 22–26.

APPOINTMENTS
1. Prof. Wei-Xin Ni is currently an appointed associate editor of IEEE Transactions on Nanotechnology.

COLLABORATIONS
There is extensive collaboration with other groups at IFM for the characterization of MBE-grown structures, in particular the divisions of Materials Science and Thin Film Physics. External collaboration has been done with, e.g., groups at Johannes Kepler Universität (Prof. G. Bauer, Dr. T. Fromherz), Heriot-Watt University (Prof. C. Pidgeon), National Nano Device Labs in Taiwan (Drs. M.-N. Chang and J.-M. Shieh), Sichuan Institute of Solid State Circuits (Dr. K.-C. Li), Royal Institute of Technology (Dr. H. Radamson). In projects involving synchrotron radiation we collaborate with Dr. K. Sakamoto, Chiba University, Japan.

Surface Physics and Chemistry

STAFF
Professors: Mats Fahlman (Head of Division), Koung-An Chao (Emeritus), William R. Salanec (Emeritus)
Associate professors: Nathaniel Robinson
Post docs: Zekai Altun, Slawomir Braun, Xianjie Liu, Yiqiang Zhan
PhD students: Elin Carlegrim, Per Erlandsson, Linda Lindell, Sara Nilsson, Parisa Sehati
Administrative/Technical staff: Anders Evaldsson, Kerstin Vestin

SUMMARY
The division consists of three research groups: Hybrid Organic Electronic Interfaces (Fahlman, Braun, Liu, Lindell, Sehati), Organic Spintronics (Fahlman, Zhan, Carlegrim) and Transport and Separations (Robinson, Altun, Erlandsson, Nilsson). The Hybrid Organic Electronic Interfaces research is divided in four areas: fundamental study and model development of weakly-interacting organic-organic and organic-metal interfaces; interface engineering in organic electronics i.e. development of techniques for improving charge injection, exciton dissociation and stability of interfaces in organic electronic devices; transparent conducting oxides and their interaction with organic electronic materials; intrinsically conducting polymers such as PEDOT and PANi: the effect of synthesis and choice of (poly)anion on conductivity, bio-compatability and general surface properties.

The Organic Spintronics research is divided into two areas: the study and design of hybrid organic spintronic interfaces (spinterfaces) with the aim to understand and improve devices such as hybrid spin-valves and spin-polarized transistors; and the development and study of thin film organic-based semiconducting magnets such as V(TCNE)x, x~2, with the aim to understand and tune materials properties to enable efficient organic spintronic device design and fabrication.

The Transport and Separations group focuses on ionic and electronic transport in fluids and solid-state materials. One particular goal of the research is to create and understand new devices in areas such as micro- and nano-fluidics and solid-state lighting. The group develops pumps for microfluidic labs-on-chips. In addition to this work, the group studies the interface between large molecules and conducting surfaces for applications in separation processes. In addition to the work on microfluidics, studies the transport of ions and electrons in light-emitting electrochemical cells are carried out in collaboration with Umeå University and the Eindhoven University of Technology.

Collaborations with specific funding during 2010 included the EU-FP7 project on Organic Nanomaterials for Electronics and Photonics (ONE-P, Fahlman PI of LiU), the EU-FP7 project on Modelling of electronic processes at interfaces in organic-based electronic devices (MINOTOR, Fahlman PI of
LiU) and the EU-FP7 project All-carbon platforms for highly efficient molecular wire-coupled dye-sensitized solar cells (MOLESOL, Fahlander PI of LiU).

The division received additional funding from three contracts issued by the Swedish Research Council (VR) as well as funding from industrial partners and Vinnova.

The division’s involvement in the undergraduate teaching activities of the university during 2010 consisted of the courses Fysik 1 and Fysik B.

**HIGHLIGHTS**

**General**
- Substantial repair and renovation was carried out on the Scienta photoelectron spectrometer system.

- Substantial repair and renovation was carried out on the MOSES photoelectron spectrometer system.

**Emeritus professor**
- Prof. Salanek gave three invited lectures (Japan Advanced Institute for Science and Technology (JAIST), Komatsu; Opening lectures of the Inauguration of the Integrative Research Institute for the Sciences IRIS Adlershof; Humboldt-Universität zu Berlin; Department of Chemistry, Georgia Institute of Technology, Atlanta) and an invited talk (ESPMI-V Electronic Structure and Processes at Molecular-Based Interfaces, Chiba)

**Hybrid Organic Electronic Interfaces group**
- Continued development of the Integer Charge Transfer Model was carried out correlating inter- and intramolecular order and energetics at interfaces with exciton dissociation and charge transport in bulk heterojunction solar cells using P3HT and PCBM model systems.

- Carried out initial study linking details of the PCBM acceptor’s electronic structure to device performance in bulk heterojunction solar cells.

- Demonstrated the interdependence of physical and electronic structure at organic-organic heterojunctions using pentacene/PTCDA model systems.

- The group received four invited talks (LCOPV 2010 Directing Nanoscale Organization in Organic Photovoltaics: Liquid Crystals for Renewable Energy, Boulder; SPIE Photonic Devices Applications, San Diego; 217th ECS meeting, Vancouver; ESPMI-V Electronic Structure and Processes at Molecular-Based Interfaces, Chiba), one invited tutorial (ONE-P summer school, Erice) and gave one contributed talk (ASOMEA V Advanced spectroscopy of organic materials for electronic applications, Uppsala).

**Organic Spintronics group**
- In collaboration with University of Twente, demonstrated magnetic proximity effects at the hybrid CoO/FM interfaces.

- In collaboration with ISMN-CNR, Bologna, nano-structured interface engineering of spin-injecting/detecting contacts in hybrid organic spin valves have been developed and studied.

- The role of metal 3d – organic π-orbital interaction on the electronic structure, local bond order and magnetic properties were explored in the M(TCNE), M=Fe, Co, V, system.

The group received two invited talks (AVS 57th International Symposium and Exhibition, Albuquerque; Henkel Technical Meeting, Shanghai) and gave one contributed talk (SPINOS III 3rd Topical Meeting on Spins in Organic Semiconductors, Amsterdam).

**Transport and separations group**
- Assoc. Prof. Robinson was invited to present a paper describing paper an all-plastic (metal-free) light-emitting device employing graphene at the Nobel symposium on Graphene in Saltsjöbaden (Stockholm) in May. The original publication in the journal ACS Nano was one of the 20 most downloaded articles in 2010. The invention was also featured in Ny Teknik and The Economist.

- A patent application has been filed by Assoc. Prof. Robinson and Per Erlandsson for a new type of electroosmotic pump for microfluidic (e.g. handheld medical diagnostic) and other applications.

- The graphene-based light-emitting device, the electroosmotic pump, and surface studies poly-L-lysine film growth on platinum surfaces were presented at the American Institute for Chemical Engineers annual meeting in Salt Lake City, UT, the Fall meeting of the Electrochemical Society in Las Vegas, NV, and the Fall meeting of the Materials Research Society, in Boston, MA, all in the United States.

- Assoc. Prof. Robinson acted as a scientific committee member and general reviewer for the International Conference on Conducting Materials in Tunisia.
COOPERATING PARTNERS AND VISITING SCIENTISTS

The different international universities, institutes and companies with which funding were shared in projects during 2010 are listed below:

EU-FP7 ONE-P: Université Libre de Bruxelles, Université de Mons, University of Cambridge Consejo Superior de Investigaciones Científicas, Max Planck Gesellschaft zur Foerderung der Wissenschaften, Consiglio Nazionale delle Ricerche, University of Copenhagen, Chalmers University of Technology, Interuniversitair Micro-Elektronica Centrum, Rijksuniversiteit Groningen, Westfälische Wilhelms-Universität Münster, Nederlandse Organisatie voor toegepast-natuurwetenschappelijk, Universität de Strasbourg, Bergische Universität Wuppertal, Consorzio Interuniversitario Nazionale per la Scienza e Tecnologia dei Materiali, University of Nova Gorica, University College London, Technische Universität Dresden, Philips Electronics Nederland, STMicroelectronics, Merck, Scriba Nanotechnologie, Johnson Matthey, BASF, Innova and Imperial College of Science, Technology, and Medicine.

EU-FP7 MINOTOR: University of Mons, University of Twente, Interuniversitair Micro-Elektronica, University Bordeaux, Bologna University, Universidad Autonoma de Madrid, BASF, Forschungszentrum Karlsruhe and Georgia Institute of Technology.

EU-FP7 MOLE SOL: IMEC (Belgium), J. Heyrovsky Institute of Physical Chemistry of The Academy of Sciences of the Czech Republic, Ecole Polytechnique Federale de Lausanne, Max-Planck Institute for Polymer Research, SolarPrint Ltd, Greatcell Solar.

There are many other partners in co-publishing activities outside of the co-financed projects as well, e.g. ISMN-CNR (Bologna), Organic Photonics and Electronics Group in Umeå University, Nano-materials and Devices group at Rutgers University; Institute of Materials Chemistry of the Vienna University of Technology; Division of Materials Theory in Uppsala University; National Synchrotron Radiation Research Center Taiwan, Hybrid Organic Electronic Interfaces group at Sandia National Lab.

New efforts have been initiated within the Visby program scholarship (provided by Swedish Institute to Dr. O.P.Dimitriev, Institute of Semiconductor Physics National Academy of Sciences of Ukraine, visiting scientist ~6 months) to study hybrid organic-inorganic semiconductor interfaces based on cadmium sulfide wurtzite crystal.

Assoc. Prof. Fenghong Li, State Key Laboratory of Supra-molecular Structure and Materials, Jilin University, visited the division for ~2 months carrying out work in a joint project on interface engineering.

---

Thin Film Physics

STAFF

Professors

Lars Hultman, Head of Division
Jens Birch, Deputy Head
Michel Barsoum, Guest Prof., Drexel University
Joseph E. Greene, Guest Prof., University of Illinois
Ivan Petrov, Guest Prof., University of Illinois

Associate Professors/Lecturers

Valeriu Chirita (Docent)
Fredrik Eriksson (Docent)
Gueorgui Gueorguiev (Docent)
Hans Högb erg (Docent)
Martin Magnuson (Docent)
Per Persson (Docent)
Galia Pozina (Docent)
Per Sandström

Assistant Professors

Björn Alling
Per Eklund (Docent)
Ching-Lien Hsiao
Jens Jensen
Johanna Rosén (LiU Junior Researcher, Docent)

Researchers (PhD, 1st Research Engineer)

Grzegorz Greczynski,
Jun Lu
Lars-Åke Näslund

Post Docs

Manfred Beckers, Forschungszentrum Rossendorf
Carina Höglund, ESS AB
Árni Sigurður Ingason, University of Island
Petru Lunca Popa, University of Strasbourg
György Zoltán Radnóczy, MFA, Hungarian Acad. Sci.
Gunilla Wingqvist, Uppsala University

PhD Students

Martin Dahlqvist
Anders Eriksson
Hanna Fager
Amie Fallqvist
Cecilia Goyenola
Lars Johnson
Linda Karlsson
Sit Kedsongpanya
Ali Khatibi
Sergey Khromov
Hanna Kindlund
Aurelija Mockute
Junaid Muhammad
Jonas Lauridsen
Simon Olsson
Justinas Palaisaitis
Davide Sangiovanni
Susann Schmidt
Steffen Sønderby (industry PhD student)
Olof Tengstrand
Agne Zukauskaite

Administrative and Technical Staff
Inger Eriksson, Division Secretary & Linné Coordinator
Therese Dannetun, FunMat Vinnex Center Coordinator
Kirstin Kahl, AFM Coordinator
Sven Andersson, 1st Research Engineer
Karl-Olof Brolin, Research Engineer
Thomas Lingefelt, 1st Research Engineer
Harri Savimäki, Research Engineer

AIMS AND VISION
We conduct application-inspired basic research on thin films to fundamentally understand the atomistic nature of materials properties and behavior and learn how to make materials perform better through new methods of synthesis and processing. Emphasis is put on the relationships between growth from the vapor phase, microstructure, and properties of thin solid films. We thus extend the frontiers of materials and nano sciences to expand the scientific foundations for the development of materials. Our research concerns lead to unsurpassed design of new multi-functional materials for engineering, electronics, and the life sciences. Results are explored in collaboration with industry and the properties of structures unique to thin films form the basis for new and improved materials and processes in applications. We further seek to discover novel phases and structures, as well as finding new materials phenomena.

RESEARCH PROGRAM
Our research concerns the materials science and nanotechnology of thin films. It is aimed at increasing the understanding of vapor phase deposition, ion-surface interactions, and reactions in advanced materials. Specifically, we probe into the nature of epilayers, textured thin films, and nanoscale materials. Model systems include transition metal nitrides, wide-band gap nitrides, multifunctional ceramics (MAX phases; e.g., Ti$_3$SiC$_2$, Ti$_3$AlN), nanocomposites, superlattices, fullerene-like compounds, and nm-sized metallic multilayers. Several deposition techniques are covered including unbalanced magnetron sputtering, magnetron sputter epitaxy (MSE), and cathodic arc. Our materials science laboratory specializes in applying and developing methods for plasma characterization, analytical and high-resolution electron microscopy, X-ray diffraction, nanoindentation, ab initio calculations including our Synthetic Growth Concept, and multi-billion time-step molecular dynamics simulations.

External Research Funding

- Strategic Grant (SFO) in Materials Science, AFM
- ERC Advanced Grant (Hultman)
- SSF Strategic Research Center, MS.E
- VR Linnaeus Grant, Lili-NFM
- Vinnova Excellence Center, FunMat
- Vinnova Vinnmer: III-N nanostructures (Pozina)
- SSF Sabbatical Grant (Barsoum)
- SSF Ingyar Carlsson Award (Rosén + Eklund)
- VR Special Researcher (Persson)
- VR Selforganized nanostructures (Hultman)
- VR Role of Interfaces in Multilayers (Birch)
- VR Diffusion in Ceramic Films (Hultman)
- VR Design of Nanolaminated Films (Rosén)
- VR Epitaxial & nanostr cobaltate films (Eklund)
- VR Atomically resolved electr. prop. (Persson)
- VR Design of Nanostr. Materials (Gueorguiev)
- Nordforsk “PhD fuel cell electrolytes” (Eklund)
- EnergyAgency: Defects physics in GaN (Pozina)
- Carl Trygger: Defects in nanostr. GaN (Pozina)
- Carl Trygger: Ion Beam Synthesis (Jensen)
- STINT Cluster-assembled materials (Gueorguiev)
- KAW: Cs-corrected TEM (Hultman & Persson)
Undergraduate Courses Offered
TFY21 Materials Science (Hultman)
TFY40 CDIO – Computational Physics (Chirita)
TFFM40 Analytical Methods in Mtrl Sci. (Eriksson)
TFYY87 Nanotechnology (Birch)
NFYA04 Nano Scientific Project (Rosén)
TFY17 Advanced Project Appl. Phys. (Eklund, 2011)

Graduate Courses Offered
Synchrotron Radiation (Magnuson)
Ion Beam Analysis of Condensed Matter (Jensen)
Ceramics (Barsoum)
Vacuum Science and Technology (Eklund)
Electron Microscopy (Persson)
X-ray Diffraction (Birch and Eriksson)

Docent Degrees in 2010
Per Eklund
Jörg Neidhardt

PhD Theses in 2010
Carina Högglund
Jenny Frodelius Lang
Niklas Gunnarsson Sarius

Licentiate Theses in 2010
Lars Johnson
Martin Dahlqvist
Anders Eriksson

Diploma Theses in 2010
Hanna Kindlund
Sit Kedsongpanya
Elena Tajuelo Rodriguez

Special Events
• Johanna Rosén received an ERC Starting Grant.
• Per Eklund received an SSF Ingvar Carlsson Award

Scientific Highlights
• A supertoughening effect in transition metal nitride alloys has been discovered in Density Functional Theory to be induced by tuning the valence electron concentration. As a result, Ti and V ternaries are predicted to be at least as hard as the reference binaries (TiN and VN), but significantly more ductile. This unique combination of mechanical properties, potentially highly relevant for the coatings industry, is currently tested in the laboratory and represents an exciting platform for future studies.

• The step flow growth mode with ledge faceting of Ti,SiCx on off-cut SiC was determined by Helium ion microscopy. Ti(0) and Si termination from half-unit cell height steps are indicated [K. Buchholt, P. Eklund, J. Jensen, J. Lu, A. Lloyd-Spetz, and L. Hultman, submitted].

• Experimental studies (black solid lines) and Monte Carlo simulations (red dashed lines) of fluorescence lifetime are performed for colloidal ZnO nanocrystals. The percentage of excitons undergoing nonradiative decay due to surface
trapping exceeds 84% for nanocrystals with 8 nm radius, which explains the ultrafast dynamics observed in such small ZnO nanostructures. [Appl. Phys. Lett. 97, 131909 (2010)]

**Technology Transfer and Interaction with Society**

- Published Patent: Thermally Stabilized (Ti,Si)N Layer for Cutting Tool Insert (KR20100126511 A1); WO2009110829 (A1); EP2262924 A1); M. Johansson, J. Andersson, A. Flink, L. Hultman
- **ABB Corporate Research/Kantthal/Impact Coatings/SP** for applications of MAX phases
- **SECO Tools, Sandvik Tooling, Ion Bond, CemeCon**: research on wear-resistant films and PVD processes
- **Impact Coatings AB** – a spin-off by our graduate
  - H. Ljungcrantz): nanocomposites for electric contacts
- News coverage in Östgöta Correspondenten and Radio P4
- Hosted a visit by the Swedish Secretary of Research and Education (utbildningsminister) Tobias Krantz to IFM, Linköping University, 23 April, 2010.

**Scientific Branch of**

**Theory and Modeling**

The program “Theory and Modeling (T&M)” at the Department of Physics, Chemistry and Biology (IFM) includes Theoretical Physics, Computational Physics, Theoretical Biology, and Bioinformatics. The field of theory and modeling is presently in a very expansive phase. It offers new and rich opportunities to solve in realistic ways many important problems. Theory can now supplement expensive and/or time consuming experiments, replace hazardous and/or dangerous experiments and even substitute inaccessible experiments as in geophysics and astrophysics. The need for research and education in the broad field of theory and modeling is evidently great. IFM is a good place for conducting such a program, because it offers close contact with experimental activities and educational programs in engineering and science.

Another important aspect is the access to the computational facilities and expertise at the National Supercomputer Center (NSC). In particular, in 2010 a new NSC foundation level system Kappa became available for our groups (see picture). Our groups and NSC are actively involved in a new Swedish e-Science Research Centre (SeRC), supported by the Swedish Government. Another example of our collaboration with NSC is given by the Network for excellent research “MATerials Science for New Energy Technology” (MATTER), where Igor Abrikosov, Sven Stafström and Bengt Persson participate. The Network aims at solving fundamental problems and creating advanced theoretical models in rapidly developing field of energy research.

There are about fifty persons actively engaged in T&M. To organize common activities within T&M there is a steering committee, which includes Igor Abrikosov (Theoretical Physics and head of Theory and Modeling), Bo Ebenman (Theoretical Biology), Bengt Persson (Bioinformatics), and Sven Stafström (Computational Physics). Leija Kronbäck and Anna Sundin acted as administrative assistants. Members of T&M carry out innovative research. During 2010 we published 80 papers in international journals with referee system. Our papers are well cited. We gave large number of invited talks at international conferences, and we ourselves organized schools, workshops, and sessions at major international conferences, like Summer School on Computational Materials Sciences in San Sebastian, Spain, Psi-k conference in Berlin (the major conference in the field of ab initio simulations).

Scientists at T&M participate in leading national research programs. In particular, our groups are actively involved in the Interdisciplinary Materials Science Laboratory for Advanced Functional Materials (AFM), supported by the Swedish Government. We actively participate in national and international research networks. For example, we are involved in Linnaeus Strong Research Environment supported by the Swedish Research Council, in Strategic Research Center “Materials Science for Nanoscale Surface Engineering (MS2E)”. Strategic Research Centre “Multifilms”, and the “Center of Organic Electronics (COE)”, supported by the Swedish Foundation for Strategic Research. We also are part of FORMAS Strong Research Environment “Centre of Excellence for Farm Animal
Welfare Research. We participate in the European Networks “Psi-k” and “SIZEMIC”, as well as in NordForsk Networks “Coherent quantum gases-from cold atoms to condensed matter” and “Spintronics – Theory and Simulations”. We have established collaboration with many scientists leading in their research fields, in Sweden and internationally. Members of T&M are active in undergraduate and graduate teaching.

T&M represents a broad and interdisciplinary research program. To find out more about each other research we organized an annual group meeting, “Theory and Modeling Day” at Rimforsa Strand, December 16, 2010. Bioinformatics group hosted the meeting this year, which included a presentation of NSC, an invited talk by Jan Nordström, Professor in Scientific Computing at the Department of Mathematics, LiU, as well as presentations by PhD students.

## Bioinformatics

### STAFF

**Professor:** Bengt Persson,  
**Ph. D. students:** Jonas Carlsson, Joel Hedlund, Yvonne Kallberg, Fredrik Lysholm  
**Sys.adm:** Jan-Ove Järrehed  
**Administrative assistant:** Leila Kronbäck

**Ph. D. exam 2010**  
Joel Hedlund defended his thesis “Bioinformatic Protein Family Characterisation”, 10 December 2010

### RESEARCH

Bioinformatics is a fast developing field of science, devoted to the interpretation of biological information related to DNA and proteins. At IFM, the bioinformatics group was established in the autumn 2002. Our research aims at the detection of sequence patterns and relationships, which will be used to create prediction algorithms and to do functional assignments. The methodology includes genome-wide sequence comparisons, machine-learning techniques, and molecular modelling. We apply the methods on a number of biomedical problems, often in collaborations with experimental groups. We also develop bioinformatics tools and methods for large scale analyses within proteomics.

### Characterisation of protein families

We develop methods and strategies for protein family characterisation. These methods have been used for systematic classification of the superfamilies of SDRs (short-chain dehydrogenases/reductases) and MDRs (medium-chain dehydrogenases/reductases). These wide-spread super-families are occurring in close to all living organisms. Our classification method has been used as basis for a sustainable nomenclature system.

During 2010, an automated procedure has been developed to delineate families within a superfamily using hidden Markov models (HMMs). Furthermore, the HMMs are systematically tested for consistency and reproducibility. Using this technique, the MDR superfamily has been divided into 86 families, corresponding to functional entities.

### Structural calculations and predictions

We use molecular modelling techniques to study molecular interactions and sequence variations in relation to structural changes. A method has been developed to predict the effects of mutations in the p53 cancer suppressor gene. The new method uses several novel parameters combined with previously established parameters. Most important of the novel parameters is the stability measure of the mutated structure calculated using molecular modelling. For each mutant, a severity score is reported, which can be used to classify them into deleterious and non-deleterious. The method has a prediction accuracy of 77% on all mutants and 88% on breast cancer mutations on the WAF1 promoter. Thanks to the severity score calculated for every mutant, valuable knowledge can be gained regarding p53, a protein that is believed to be involved in over 50% of all human cancers.

This technique has now been generalised and applied to further protein families, showing promising results. Furthermore, web servers have been set up to give users world-wide the possibilities to predict effects on particular mutants.

### Large scale sequence analysis

A novel method for alignment of sequence data has been developed, considering the 454 data characteristics while aligning allowing the algorithm to counter the effects of plausible reading errors. Furthermore, an automated efficient BLAST pipeline has been set-up for handling and characterisation of 454 data. This pipeline has been applied in large-scale studies to find new viruses in metagenomic samples.

### ELIXIR

Bengt Persson is on the steering board for the planning for the future European infrastructure for biological information, ELIXIR, where he also is chairing the bioinformatics communities committee. The planning will be performed over the years 2008–2011, and the infrastructure should be launched in 2011/2012.

### BILS

A new distributed research infrastructure, BILS – Bioinformatics Infrastructure for Life Sciences, has been established, and after a pilot phase in 2008–2009, we are now building up this infrastructure in all six large university towns in Sweden.

### TEACHING

During 2010, we have arranged courses in bioinformatics:  
- at LiTH (TFTB29 and TFB14 autumn 2010)  
- at HU in collaboration with IBK (spring 2010)

### POPULAR SCIENCE

Bengt Persson is on the organising committee of the annual research school at the Nobel manor Björkborn, Karlskoga, for 2nd/3rd year of Swedish high school students.
Computational Physics

STAFF
Professors: Patrick Norman, Sven Stafström (head of division)
Associate professors: Magnus Boman,
Assistant professors: Gueorgui Gueorguiev, Bo Durbeej,
Mathieu Linares,
Postdocs: Jonas Björk, Zhen Sun, Sebastien Villaume
PhD students: Johan Bölin, Mattias Jacobsson,
Elham Mozaffari, Jonas Sjöqvist, Cecilia Goyenola, Olle Falklöf
Adm. Assistant: Lejla Kronbäck

GENERAL
In their work to describe electronic structure and electronic motions in molecular materials, the Computational Physics group employs a wide variety of methods including molecular mechanics and molecular dynamics for studies of structures and morphology, first principles electronic structure theory, response theory (for spectroscopic applications), QM/MM methods finite size scaling for studies of electron localization, the Landauer formalism, electron lattice dynamics and Monte Carlo methods for studies of charge transport. Most of the systems that we are studying are based on carbon. The research cuts across a range of disciplines (molecular and supramolecular electronics, photonics, materials and polymer science, device physics, photochemistry and biochemistry) with many applications in the fields of nanotechnology, optoelectronics, and organic electronics.

The Computational Physics group gives a large number of courses on graduate as well as undergraduate levels: Quantum Physics (undergraduate, Magnus Boman), Introduction to Computational Physics (undergraduate, Magnus Boman), Quantum Mechanics (undergraduate, Magnus Boman), and Quantum Chemistry (graduate, Patrick Norman and Mathieu Linares). The group has also had 4 diploma students working in the group during the year.

HIGHLIGHTS
- Characterization regarding optical properties of a dendrimer encapsulated Pt(II)-organic chromophore in THF solution at room temperature has been made. J. Sjöqvist, M. Linares, and P. Norman in J. Phys. Chem. A
- Demonstration of light-induced molecular rotor function in a protein has been reported. A. Strambi, B. Durbeej, N. Ferré, and M. Olivucci, in Proc. Natl. Acad. Sci. USA, 2010, 107, 21322.
- The electron-lattice method developed in the group of Sven Stafström has been described in two invited reviews to be published 2010 by Wiley-VCH and Chemical Society Reviews, respectively

Collaborations within LIU
- Center in Nanoscience and Nanotechnology (CeNano)
- Center of Organic Electronics (COE)
- Thin-Film Physics, IFM
- Surface Physics and Chemistry, IFM
- Organic Electronics, ITN

External activities and networks
- Secretary general, Swedish Science Research Council, secretary general from 2010 (SS)
- Board member, Nordita (SS)
- Unimolecular Electronics Center, Uppsala University
- Swedish Research Establishment
- Co-authoring the DALTON and DIRAC programs (PN)

Individual external collaborations
- H. Ågren (KTH, Stockholm)
T. Saue (Toulouse, France)
M. Bekele (Addis Ababa, Ethiopia)
K. Ruud (Tromsø, Norway)
N. Avarvari (Angers, France)
R. Rivelino, F. Brito (Federal University of Bahia, Salvador, Brazil)
M. Olivucci (Siena, Italy)

External funding
External funding is absolutely essential for the activities in the computational physics group. We are grateful for support from a number of sources including the Swedish Research Council (VR), European Commission, Foundation for Strategic Research (SSF), Swedish Defence (FMV), Carl Tryggers Foundation, and International Science Programme (ISP).

In particular, Patrick Norman is “rådsforskare” at VR and Gueorgui Gueorguiev has a VR “forskarassistent” position as well as a Swedish Foundation for International Cooperation in Research and Higher Education (STINT) project for bilateral collaboration with the Federal University of Bahia in Brazil. High performance computing resources were provided by the Swedish National Infrastructure for Computing (SNIC) and the National Supercomputer Center, NSC, at Linköping University.

Theoretical Biology

STAFF
Professors:
Bo Ebenman (head of division)
Uno Wennnergren

Associate professors:
Peter Münger
Tomas Jonsson (guest lecturer)

Postdoc:
Céline Hauzy
Tom Lindström

PhD students:
Soﬁa Berg
Alva Curtsdotter
David Gilljam
Sara Gudmundson
Nina Håkansson
Linda Kaneryd
Jenny Lennartsson
Malin Setzer
Torbjörn Sätterberg

Administrative assistant:
Anna Sundin

GENERAL
There are two research labs in the division of Theoretical Biology: Population and Community Ecology lab (PACE lab) headed by Professor Bo Ebenman and Spatiotemporal Biology lab (SPABIO lab) headed by Professor Uno Wennnergren. Present research projects include:

- The response of ecosystems to species loss: using community viability analysis to quantify the risk and extent of extinction cascades (Bo Ebenman PI)
- Using sensitivity analysis to identify keystone species and keystone links in ecosystems (Bo Ebenman PI)
- The robustness of ecosystems to an increasingly variable world: effect of climate change on the structure and functioning of ecosystems (Bo Ebenman PI)
- The response of metacommunities to habitat and species loss: the role of local and regional processes (Bo Ebenman PI)
- Ecologically effective regional population sizes (Bo Ebenman PI)
- Population growth in heterogeneous landscapes: crop management strategies for effective biological control of pests (Uno Wennnergren PI)
- Reducing the risk of spread of diseases (Uno Wennnergren PI)
- Long term strategies for preserving species in a dynamic landscape (Uno Wennnergren PI)
- Analysis and optimization of animal transport: logistics and animal welfare (Uno Wennnergren PI)

Members of the group are involved in several courses at graduate as well as undergraduate levels including courses in ecology, population ecology – theories and applications, mathematical models in chemistry and biology, and conservation biology.

SOME HIGHLIGHTS
Participation in the ESF Research Networking Programme SIZEMIC
PACE Lab members have been involved in many of the activities organized by the Research Networking Program SIZEMIC funded by the European Science Foundation. These activities include research collaborations between members of our lab and groups in Germany and UK. We have also given invited talks and poster presentations at meetings arranged by SIZEMIC in Spain and UK.

Paper published in Ecology Letters
PACE Lab members Tomas Jonsson and Bo Ebenman have together with researchers in Germany, Australia and New Zealand published the paper “Stepping in Elton’s footprints: a general scaling model for body masses and trophic levels across ecosystems”. The study is based on an extensive empirical dataset and contradicts the Eltonian paradigm stating that there is no trend between predator-prey body mass ratios and trophic level of the predator. Rather, based on the empirical data, there seem to be a systematic decrease in predator-prey body mass ratios with trophic level. The paper further addresses the implications of these findings for the current understanding of body-mass constraints on food web topology, dynamics and stability.
EXTERNAL ACTIVITIES AND NETWORKS

Participation in:
- The ESF Research Networking Programme SIZEMIC (Body-size and ecosystem dynamics: integrating pure and applied approaches from aquatic and terrestrial ecology to support an ecosystem approach). The programme is funded by the Swedish Research Council (VR) and several other national research councils in Europe. Bo Ebenman is a member of the steering committee of the programme. Sofia Berg, Alva Curtsdotter, David Gilljam and Anna Eklöf (presently a post doc at the University of Chicago) are active in two of the working groups organized by the network; “Body size and redundancy: Across system comparisons” and “Testing the generality of Elton’s Rule: Comparing aquatic and terrestrial ecosystems across environmental conditions”.
- Mathematics in the Living Environment (MILE). Erasmus/ Socrates collaboration with York University.

EXTERNAL COLLABORATIONS

- PACE Lab – Prof. Richard Law (York University, UK), Dr. Owen Petchey (Sheffield University, UK), Dr. Guy Woodward (Queen Mary University of London, UK), Dr. Mark Emmerson (University of Cork, Ireland), Dr. Ulrich Brose (Darmstadt Technical University, Germany) and Dr. Mike Fowler (Meditarranean Institute of Advanced Studies, Spain).
- SPABIO Lab – Prof. Jan Bengtsson (SLU, Uppsala, Sweden), Prof. Mikael Rönquist (Bergen University), Dr. Annie Jonsson and Prof. Bo Algers (SLU), Assoc Prof. Susanna Sternberg Lewerin (SVA), Assoc Prof. Colleen Webb (Univ of Colorado), and Dr Michael Tildesley (Univ of Edinburgh).

EXTERNAL FUNDING

Financial support has been received from the Swedish Research Council (VR), Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS), Swedish Agricultural Board, Swedish Civil Contingency Agency, and Dept of Homeland Security (DHS- USA).

Theoretical Physics

STAFF

Professors:
Igor Abrikosov (Head of T&M)
Karl-Fredrik Berggren, Bo Sernelius, Irina Yakimenko

Associate Professors:
Peter Münger, Sergei Simak, Magnus Johansson,
Lars Alfred Engström, Bruno Lindquist

Lectors:
Arkady Mikhailushkin, Eyvaz Isaev

Assistant Professors:
Mathias Boström, Leonid Pourovskii, Ferenc Tasnadi

PhD students:
Björn Alling, Christian Askä, Olga Vekilova, Marcus Ekholm, Olle Hellman, Tobias Marten, Peter Steneteg, Hans Lind

Administrative assistant:
Lejla Kronbäck

Diploma students:
Hans Lind, Hannes Svensson Frenander, Erik Welander,
Albaro Vega, Jonas Karlsson, Christopher Tholander

Visiting researchers:
Prof. Lennart Stenflo, Sweden
Katarina Kirr, Kharkiv, Ukraine
Dr. Alena Ponomareva, Moscow, Russia
Prof. Yuri Vekilov, Moscow, Russia
Prof. Antonio Ferreira da Silva, Salvador de Bahia, Brazil

APPOINTMENTS IN 2010

Irina Yakimenko was appointed professor of Theoretical Physics at Linköping University

GENERAL

The research in theoretical physics is focused on condensed matter physics/theoretical materials science, nanoscience, electromagnetic modeling, and non-linear physics. Typical projects are:
- Phase stabilities and phase transformations (I. Abrikosov, B. Alling, T. Marten, E. Isaev, S. Simak, A. Mikhailushkin, O. Vekilova, C. Askä).
- Theoretical study of materials with fast ionic conductivity for energy applications (S. Simak, O. Hellman).
- Physics of strongly correlated materials (I. Pourovskii, Marcus Ekholm).
- Nanotechnology, mesoscopic physics, ultrasmall semiconductor structures and devices in the quantum regime, quantum information, transport and quantum and classical wave chaos in microwave cavities (K.-F. Berggren, A. Sadrev, I. I. Yakimenko).
- Studies of dispersion forces in nanoscience, of the fundamental nature of the Casimir force and its temperature dependence (B. E. Sernelius and M. Boström).
- Gravitation as a Casimir interaction (B.O. Sernelius).
- Luminescence in ZnO nanorods, nanotubes and nanoparticles (B.O. Sernelius).
- Understanding Specific Ion Effects in Biology and Colloid Science through Mean-Field Theory and Monte Carlo Simulations (M. Boström).
- Dynamical simulations of defect formation and crystal growth (Peter Münger, I. A. Abrikosov, P. Steneteg).
- Nonlinear effects on energy transport in periodic and aperiodic spatially modulated systems (M. Johansson).
We participate in leading national research programs. In particular, we are actively involved in a new Swedish e-Science Research Centre and in the Interdisciplinary Materials Science Laboratory for Advanced Functional Materials, both supported by the Swedish Government. Igor Abrikosov is leading the Network for excellent research “Materials Science for New Energy Technology”. We are part of the Strategic Research Centers MS-E and “Multifilms”, both supported by the Swedish Foundation for Strategic Research. Also, we, together with Computational Physics Group, build the node “Materials Modeling” within the Linköping Linnaeus Initiative for Novel Functional Materials, supported by the Swedish Research Council. At the European level, we were actively involved in European Network Psi-k, where Prof. Abrikosov is a spokesperson for Working Group “Alloy Theory”.

The theory group gives a large number of courses on graduate as well as undergraduate levels. The teaching has a wide range of courses, including analytical mechanics, quantum theory, relativistic quantum mechanics, condensed matter physics, many-body physics, statistical mechanics, quantum information and computing, elementary particle physics, and cosmology.

**PhD examinations**

Christian Askar, “Effects of disorder in metallic systems from first-principles calculations” Dissertation No. 1299

Björn Alling, “Configurational and magnetic interactions in multicomponent systems”, Dissertation No. 1334

Tobias Marten, “Theoretical Considerations of Local Environment Effects in Alloys”, Dissertation No. 1353

**AWARDS**

Theoretical Physics PhD student Marcus Ekholm (second from the left) among winners of the students contest on Density Functional Theory (DFT) organized by one of the major contributors to the DFT development, Prof. K. Burke (UC Irvine, USA), at Summer School on Computational Materials Sciences, San Sebastian, Spain.

**HIGHLIGHTS**


We presented the theory that reveals the origin of the observed anomalous enhancement of piezoelectric response in wurtzite Sc₆₋ₓAlₓN alloys. Our first-principles calculations confirm that the 400% increase of the piezoelectric constant is an intrinsic alloying effect. The energy surface topology is found to be strongly influenced by the alloying, being elongated around the global minimum along c=a direction. The effect is particularly accentuated at intermediate compositions (see the figure below). This leads to the large elastic softening along the crystal parameter c, and raises significantly the intrinsic sensitivity to axial strain resulting in the highly increased piezoelectric constant. Our theory allows for a knowledge-based search for new materials with high piezoelectric response.
In magnetic alloys, the effect of finite temperature magnetic excitations on phase stability below the Curie temperature is poorly investigated, although many systems undergo phase transitions in this temperature range. We considered random Ni-rich Fe-Ni alloys, in which chemical order-disorder transition occurred approximately 100 K below their Curie temperature, to demonstrate from ab initio calculations that deviations of the global magnetic state from ideal ferromagnetic order due to temperature induced magnetization reduction had a crucial effect on the chemical transition temperature. We proposed a scheme where the magnetic state is described by partially disordered local magnetic moments, which in combination with Heisenberg Monte Carlo simulations of the magnetization allowed us to reproduce the transition temperature in good agreement with experiment (see the figure below).

![Image](image.png)

**KAM tori in 1D random discrete nonlinear Schrödinger model?**

[M. Johansson, G. Kopidakis and S. Aubry, EPL 91, 50001 (2010). Highlighted as “editor’s choice” by the journal].

The KAM (Kolmogorov-Arnold-Moser) theorem has fundamental implications for classical conservative many-body problems such as solar system dynamics. In simple terms, it states that most regular (quasiperiodic) trajectories are stable for any dynamical system, that can be considered as a weak perturbation of some integrable system (having as many constants of motion as degrees of freedom). The probability that a random initial condition will generate such a “KAM torus” goes to one when the perturbation goes to zero, and decreases for increasing perturbations. The remaining initial conditions become unstable due to resonances, and typically generate chaotic motion.

KAM theory becomes more complex if the number of degrees of freedom increases, due to more possible resonances, and very few extensions to infinite-dimensional systems are known. Here, we use empirical and numerical arguments to propose an extension to a physically important class of weakly nonlinear lattices with strong disorder. Solutions to the unperturbed (linear) system are then exponentially (Anderson) localized in space, limiting the number of significant resonances.

A main implication of our work, illustrated by the figure, is that such systems should exhibit two kinds of initial wave packets (intricately nested as a Cantor-like set): (i) those generating spatially localized, regular trajectories (KAM tori); and (ii) initially chaotic wave packets, spreading in space. This effect may be observable in disordered optical waveguide arrays, or with ultracold bosonic atoms.

![Image](image.png)

**Lost Heat Capacity and Entropy in the Helical Magnet MnSi**


MnSi is a very intriguing material due its peculiar magnetic properties and phase transitions. Itinerant spiral magnetization and skyrmion like magnetic ordering has been reported in MnSi. In this work the heat capacity of this compound at $B = 0$ and $B = 4$ T in the temperature range $2.5 – 100$ K has been measured, while the phonon frequencies and phonon density of states have been from first principles using the density functional perturbation theory, as well as by inelastic neutron scattering. The analysis of the experimental and theoretical data suggested the existence of negative contributions to the heat capacity and entropy of MnSi at $T > T_c$ (see figure below). This could be caused by a specific ordering in the spin subsystem of the paramagnetic MnSi.
The experimental heat capacity of MnSi at \( B = 0 \) (1) and \( B = 4 \) T (2) and the calculated phonon contribution (3).

**COLLABORATIONS**

**Collaborations within LiU**
- International Interdisciplinary Materials Science Laboratory for Advanced Functional Materials from the Swedish Government
- Strategic Centre in Materials Science for Nanoscale Surface MSE2
- Linköping Linnaeus Initiative for Novel Functional Materials
- Strategic Research Centre “Multifilms”
- Centre in Nanoscience and Nanotechnology (CeNano).
- National Supercomputer Center (NSC).

**External activities and networks**
- Swedish Physical Society (K-F Berggren, chairman, also Swedish delegate to European Physical Society Council)

Participation in:
- Swedish Research Council, Condensed Matter Physics Committee and Panel for Strategic Energy
- \( \Psi_4 \)-Network
- The European Commission project NANOCASE
- NordForsk Network “Coherent Quantum Gases – From Cold Atoms to Condensed Matter” (M. Johansson)
- NordForsk Network: Nanopintronics – Theory and Simulations (coordinator C. Canali, University of Kalmar, Sweden); I. Yakimenko node coordinator Linköping; The 2010 network meeting in Norrköping, September 22–24 was organized by the Linköping node.
- Peter Münger participates in “The Stakeholders Tune European Physics Studies’ (STEPS) initiative by the European Physics Education Network’ (EUPEN) within the SOCRATES programme.” ([www.eupen.ugent.be/](http://www.eupen.ugent.be/))

**Individual external collaborations**
- Bo Sernelius and Prof. G. D. Mahan (Penn State University, USA), Prof. Antonio Ferreira da Silva (Salvador de Bahia, Brazil), Prof. Barry Niham (Australian National University, Australia), Prof. Chris Binns (University of Leicester, England), Dr. Mike Ward, University of Birmingham, Birmingham, UK, and Dr. Astrid Lambrecht, Ecole Normale Supérieure, Paris, France
- Magnus Johansson with Dr. R. A. Vicencio and U. Naether (Universidad de Chile, Santiago), Dr. S. Aubry (CEA Saclay, France, and MPIPKS Dresden, Germany), Dr. G. Kopidakis (University of Crete, Greece), Prof. A. S. Kovalev and K. K. Ir (National Academy of Sciences of Ukraine, Kharkiv), Dr. S. Derevyanko and Dr. Y. Pylepskiy (Aston University, UK).
- Igor Abrikosov and Prof. Michel Barsoum (Drexel University, USA), Prof. L. Dubrovinsky (Universität Bayreuth, Germany), Prof. M. I. Katsnelson (University of Nijmegen, The Netherlands), Prof. Yu. Kh Vekilov (Moscow Institute of Steel and Alloys, Russia)
- Leonid Pourovskii and Prof. Antoine Georges, Ecole Polytechnique, Paris, France
- K-F Berggren and I. Yakimenko with M Pepper (Cavendish Laboratory, Cambridge, UK), London Centre for Nanotechnology, UCL and Prof. V. P. Shevchenko and PhD student V.S. Tkakunov (Kiev University, Ukraine).
- Peter Münger, collaboration with Prof. Bo Ebenman and Anna Eklöf, Theoretical Biology, IFM, on “Cascading extinctions in food webs – local and regional processes”.

**External visits**
- Peter Steneteg spent one month at Los Alamos National Laboratories, USA
- Leonid Pourovskii spent November and December 2010 at Ecole Polytechnique, Paris, France
- Magnus Johansson visited (2 weeks each): Universidad de Chile (Santiago), Aston University (Birmingham, UK), Max-Planck-Institute for the Physics of Complex Systems (Dresden, Germany), and NORDITA (Stockholm).

**Popularization of science**
- “Nobelpriset som fortfarande är en gåta” an article in *Fysikaktuellt nr 2*, May 2010 based on an interview by I. Abrikosov to C. Firs
- “Härda ytors egenskaper avslöjas med beräkningar” an article in *Fysikaktuellt nr 3*, September 2010 by B. Alling
- An interview by I. Abrikosov 10-10-05 for *Radio Östergötland* in connection to an announcement of Nobel Prize in Physics 2010
- “ESS – a chance for Swedish world class research?” (K-F Berggren), and “Ickelinjära fenomen: kan ett och och att bli tre?” (M. Johansson), *Popular Science Day, LiU*, October 20, 2010
- Editorials *Fysikaktuellt* No. 1, 3 and 4 (2010), “Swedish Physical Society 90 years” No. 2 and “Entanglement gives rise to Swedish language debate” *Fysikaktuellt No. 2* by K-F Berggren (legally responsible for Fysikaktuellt)
CeNano

The Centre in Nano science and technology (CeNano) is an organization within Linköping Institute of Technology (LiTH) at Linköping University. The mission of CeNano is to strengthen and support the competence within nano science and nano technology at LiTH. This is made by gathering researchers with nano activities at LiTH in the centre and by acting for increased collaborations and common projects in the nano realm. CeNano also acts for development and coordination of the graduate and undergraduate education in this scientific area. Included in the mission of CeNano is also exposure of the nano activities at LiTH by seminars, actions for contact establishment, taking initiative to larger projects, etc.

The board of CeNano:
- Lars Hultman, Chair
- Igor Abrikosov
- Per-Olof Holtz
- Olle Ingañas
- Per-Olov Käll
- Kajsa Uvdal, Director of CeNano

The CeNano Symposium The scope of the yearly Symposium is to inform about nano science and technology activities at LiTH and in Sweden. The intention is to bring together researchers with an interest in the nano realm to promote cross-linking between projects at different departments at LiTH. The 6th CeNano Symposium in Nano Science and Nano Technology was held December 6, 2010, Physics building at Linköping University. Projects within CeNano were presented by involved PhD students. Invited speaker this year was Professor Lennart Bergström, Materials Chemistry Dept. of Materials and Environmental Chemistry Stockholm University.

Projects supported CeNano in 2010:
- Carbon Nanofibers and Chiral Nanorods in InAlN Charaterized by Spectroscopic Ellipsometry; Arwin Hans,
- Explore the applications of GaSb nano particles embedded in polymers; Karlsson Fredrik
- Tailoring of materials properties in nanolaminate thin films; Rosén Johanna
- Epitaxially grown nanostructured ohmic contacts for high temperature stable FET sensors; Spetz Anita Lloyd
- Novel Properties of Functionalized Nanoparticles for Cell- and Molecular Imaging: Uvdal Kajsa
- Enhanced imaging of supra molecular amyloid structures by nano-synthesis; Konradsson Peter
- Optical biosensing based on functional metal nano-structures; Liedberg Bo
- ZnO nanorods: Growth and Devices for Technical and Medical Applications; Willander Magnus

- Growth and optical characterization of graphene on cubic silicon carbide; Yakimova Rosita

HIGHLIGHTS
Photonic crystals with carbon nanofibers H. Arwin, R. Magnusson IFM, R. Renhnammar CTH
Photonic crystals based on vertically aligned carbon nanofibers grown with plasma-CVD in quadratic, rectangular and random lattices were studied with ellipsometry and photonic band gaps were determined. These types of structures are optically complicated, with geometric effects both from the lattice and from individual scatterers.
**FunMat**

VINNOVA Excellence Center in Research and Innovation on Functional Nanoscale Materials

FunMat is in equal parts financed by VINNOVA, industry and the university. The Center runs between 2007 and 2016 with the mission to:

- Provide the strongest research platform for a consortium of companies in the area of advanced surface engineering, with a focus on nanotechnology for tools, components, contacts, and sensors
- Offer knowledge-based design of functional materials on the nanoscale to provide unique and improved surface properties with commensurate industrial opportunities
- Expand core R&D capabilities by enlarging and protecting the IPR base of Swedish companies in key industrial sectors.

The Center is based at IFM, Linköping University.

**Center Board Stage 2 (2009–2011)**
Lennart Karlsson, SECO Tools AB (chair)
Hans Högberg, LiU
Birgit Jacobson, CEI-Europe AB (deputy chair)
William Salanek, LiU
Åke Öberg, ABB AB

**Management team**

**Head**
Prof. Lars Hultman

**Deputy Head**
Prof. Anita Lloyd Spetz

**Research Coordinator**
Prof. Magnus Odén

**Coordinator**
Ms. Therese Dannetun

Rositza Yakimova
Per Eklund

**Partner Companies Stage 2 (2009–2011)**
ABB AB, Corporate Research
Alstom Power (start October 2010)
CemeCon AG
Ford Motor Company/Volvo Car Corporation
Impact Coatings AB
Ionbond Sweden AB
Sandvik Tooling Sverige AB
SECO Tools AB
SenSiC AB
Volvo Technology

**Senior Researchers**
Mike Andersson
Jens Birch
Robert Bjorklund
Esteban Broitman
Naureen Ghafoor
Grzegorz Greczynski
Gueorgui Gueorguiev
Hans Högberg
Anelia Kakanakova
Jun Lu
Per Persson
Galina Pozina
Johanna Rosén
Mikael Syväjärvi

**Research Engineers**
Karl-Olof Brolin
Ingemar Grahn
Thomas Lingefelt

**PhD Students**
Kristina Buchholt
Anders Eriksson
Jenny Frodelius (PhD 3/9 2010)
Zhafira Darmastuti
Niklas G Sarius, SP (PhD 26/11 2010)
Carina Höglund (PhD 28/5 2010)
Lars Johnson
Jonas Lauridsen
Nils Nedfors (Uppsala University)
Lina Rogström
Susann Schmidt
Olof Tengstrand
Jennifer Ullbrand
Jianqiang Zhu

**Post-docs**
Volodymyr Khranovskyy, Ruth Pearce

**University and Institute Collaborations**
Prof. Ulf Jansson, Uppsala University
Prof. Peter Leisner, SP

**Research Program**
- FunMat is a leading environment for problem-oriented research on nanoscale functional materials. It offers scientific competence and innovative solutions in advanced surface engineering. We develop thin film processing, advanced materials analysis, and IPR.

**Project Themes**
- Multifunctional Nanocomposites for Combined Electric and Mechanical Contacts. We develop novel coating materials for electrical contact applications. The nanocomposite MaxPhase coating materials replace gold in electrical contacts. They are tough, electrically conducting, resistant to corrosion and wear, cheap, and environmentally friendly – truly multifunctional materials.
• **Self-Organizing Nanoscale Coatings for Cutting Tools and Components**

*FunMat* generates strategic knowledge for the deposition and structure evolution of new hard coatings used in wear protection of metal machining tools. The next generation of tools must withstand yet higher mechanical and thermal loads than those of today. We explore nanostructured ceramic coatings and push the frontiers of characterization techniques as well as computational methods.

• **Low-Energy/Friction Surfaces for Components**

We explore new nano-structured carbon-based coatings, which can resist mechanical wear and have tunable surface energy. Examples of applications are rolling bearings, orthopedic implants, and hard discs. The coatings are produced in laboratory and industry magnetron sputtering systems. Expertise is provided on the growth and doping of fullerenes and graphene, characterization by nanotribology and electron microscopy as well as theoretical calculations.

• **New Nanoscale Sensor Materials & Application**

Silicon carbide chemical sensors are commercialized for applications in harsh environment at temperatures below 400 °C. Applications at higher temperatures require improved contact materials. The conducting ceramic materials developed within *FunMat* offers a unique possibility for the silicon carbide sensors as well as other challenging sensor developments. Graphene epitaxially grown on SiC is developed as an ultra sensitive gas sensor for close to room temperature operation.
• Johanna Rosén received a prestigious 5-year European Research Council (ERC) Starting Grant
• Alstom Power Sweden in Växjö is a new partner in FunMat
• Anita Lloyd Spetz was appointed as FiDiPro, Finnish Distinguished Professor at Oulu University (50% leave of absence)
• Anita Lloyd Spetz received a special support contract for research “from the Rector and Faculty Dean of LiU
• Per Eklund received a prestigious Ingvar Carlsson Award form the Swedish Foundation for Strategic Research (SSF)
• Per Eklund qualified as docent (Associate Professor) in March, and was visiting professor at the Univ. of Poitiers, France, during the summer
• We have recruited Prof. Esteban Broitman and commissioned a nanotribology laboratory with a Hysitron TriboIndenter and PicoIndenter
• Lina Rogström was a guest researcher at the Advanced Photon Source, Argonne National Laboratory, USA, in Feb–March
• Naureen Ghafoor was guest researcher at University of Illinois, USA, during May–June
• Zhafira Darmastuti is a new PhD student within Theme 5
• PhD theses presented at LiU: Carina Höglund, Jenny Fredelius Lang and Niklas G Sarius (SP)
• Licentiate theses presented at LiU: Lina Rogström, Lars Johnson, Jianqiang Zhu, and Anders Eriksson
• Studied interface, wetting, and conduction in Ti-C-Ag-based nanocomposites and the effect on contact resistance
• We published a comprehensive invited review on “The $M_{n}AX_{m}$ phases: Materials science and thin-film processing”; (Eklund et al, Thin Solid Films 518 (2010) 1851)
• Fluoro Carbide (CFx) films have been grown by reactive magnetron sputtering and modelled by ab initio calculations
• The growth mode of $Ti_{2}SiC_{x}$ on SiC with step flow and ledge faceting has been explored using Helium Ion Microscopy
• Epitaxially grown graphene on SiC was demonstrated to give response to less than 10 ppb NO.

**HIGHLIGHTS 2010**

**LiLi-NFM**

LiLi-NFM is a coordinated laboratory for interdisciplinary research on advanced materials. It is supported by the Swedish Research Council (VR) for a 10-year period until 2016 by Linnaeus Grant.

The research environment constitutes the backbone of materials research at Linköping. It consists of ~125 researchers from 9 divisions of IFM.

**Director**
Prof. Lars Hultman

**Deputy Director**
Prof. Erik Janzén

**Coordinator**
Ms. Inger Eriksson

**Research Divisions and Principal Investigators**

**Computational Physics**
Prof. Sven Stafström

**Functional Electronic Materials**
Prof. Weimin Chen, Prof. Irina Buiyanova

**Nanostructured Materials**
Prof. Magnus Odén, Prof. Bo Jansson

**Plasma & Coating Phys.**
Prof. Ulf Helmersson, Prof. Nils Brenning

**Semiconductor Materials**
Prof. Erik Janzén, Prof. Peder Bergman, Prof. Per-Olof Holtz, Prof. Leif Johansson, Prof. Bo Monemar, Prof. Rositsa Yakimova

**Surface & Semiconductor Physics**
Prof. Göran Hansson, Prof. Wei-Xin Ni, Prof. Roger Uhrberg

**Surface Physics and Chemistry**
Prof. Mats Fahlman

**Theory and Modeling**
Prof. Igor Abrikosov, Prof. Irina Yakimenko

**Thin Film Physics**
Prof. Lars Hultman, Prof. Jens Birch, Prof. Joseph E Greene, Prof. Ivan Petrov, Prof. Michel Barsoum
OBJECTIVE
Our objective is in doing basic research to fundamentally understand the atomistic nature of materials synthesis, structure, and properties. We can thus extend the frontiers of materials and nano sciences to expand the scientific foundations for the development of materials that improve, e.g., the efficiency, environmental acceptability and safety in energy generation, conversion, transmission and use.

The core activity of LiLi-NFM is within the largest and most rapidly developing area of physics research worldwide. In fact, the understanding of materials is the fundamental driving force in natural science and basic engineering research. We focus on studies on the nature of epilayers, thin films, and nanoscale materials. Here, we are in the forefront regarding materials synthesis including wide-band gap materials (SiC, AlN, GaN, ZnO), graphene, nanocomposites, superlattices, fullerene-like compounds, and organic molecular materials.

Our research concerns unsurpassed knowledge-based design of new functional materials for electronics, engineering, and the life sciences. We design material structures and explore outstanding phenomena. We also seek to discover novel phases.

STRATEGY
It is our strategy for excellence to develop and integrate theory, simulations, and experiment. The philosophy for operating LiLi-NFM contains the following elements:
- Natural science and basic engineering research
- Strategic recruitments and tenure-track plans.
- Intra-disciplinary excellence.
- Inter- and multi-disciplinary modus operandi
- Strong national & international collaboration
- State-of-the-art laboratories
- Leading computational capacity

Strategic Recruitments
- Olle Kordina
- Per Eklund
- Jens Jensen
- Mathieu Linares
- Daniel Dagnelund
- Martin Magnuson
- Henrik Pedersen
- Iris Pilch
- Fredrik Söderlind
- Gunilla Winqvist
- Daniel Söderström

SCIENTIFIC HIGHLIGHTS
Epitaxial growth of ZnO nanostructures
We have grown ZnO nano-needle assemblies with light-controlled wettability. 254 nm UV irradiation change the surface from super hydrophobic to hydrophilic. This is due to dissociative adsorption of water and oxygen on defective ZnO states. By UV light the contact angle can thus be changed from 124° to <5°. The time of transition depends on the needle diameter, but can be as fast as 5 min. Such a tunable wettability is due to the extreme surface area and small needle diameter. The controllable wettability is desirable for the micro or nano-fluid motion, and patterning during photolithography.

Fullerene-like Sulpho-Carbide (FL-CS) studied by ab initio calculations (C. Goyenola, G. K. Gueorguiev, S. Stafström, L. Hultman). Fullerene-like (FL) compounds are a new class of functional materials with outstanding mechanical properties. Sulpho carbide (CS) is studied by the Synthetic Growth Concept (SGC) developed by us. Geometry optimizations and cohesive energy results were used to compare the relative stability of precursor species for magnetron-sputtered FL-CS, such as C,S, CS2, and C2S2. The energy cost for structural defects, arising from the substitution of C by S was also evaluated. Similar to our previously synthesized FL-CN and FL-CP compounds, the pentagon, the double pentagon, and the Stone-Wales defects are feasible in CS. Graphene-like sheets in FL-CS, are expected to be shorter and more buckled than in FL-CN, yet less curved and inter-locked than in FL-CP.


Relaxed model systems with typical structures in FL-CSx: (a) Hexagon; (b) Single pentagon; (c) Double pentagon
High-Pressure/High-Temp. Polymorphism in Ta
[Ta] is a refractory metal with unique electrical, chemical, and physical properties that is used mostly as metal powder in the production of electronic components, mainly capacitors. Alloyed with other metals, Ta is used in making cemented carbide tools for metal working equipment, and in the production of superalloys for jet engine components. Phase diagrams of refractory metals remain essentially unknown. Moreover, there is an ongoing controversy over the high-pressure melting temperatures of these metals: results of diamond anvil cell (DAC) and shock wave experiments differ by at least a factor of 2. From an extensive ab initio study we discovered that the body-centered cubic Ta phase transforms to another solid phase, possibly hexagonal omega phase, at high temperature (Fig. 1). The discovered polymorphism in Ta makes a solid-solid transformation from bcc to a higher T phase, possibly the hexagonal-o phase, a viable mechanism for the observed material flow in experiments. [Phys. Rev. Lett. 104, 255702 (2010).]

Epitaxial graphene on 6H-SiC; Li intercalation.
C. Virojanadara, S. Watcharinyanon, A. A. Zakharov, R. Yakimova and L. I. Johansson

Li atoms penetrate graphene as well as the carbon buffer layer and intercalate at the SiC(0001)/buffer layer interface. The process starts immediately after deposition. Li bond to Si in the uppermost Si-C bilayer and creates a dipole layer at the interface that induces a ~2 eV shift of the SiC core levels. Li at the same time transform the C buffer layer into a second graphene layer. [Phys. Rev. B. 82, 205402 (2010)]

(a) LEEM image of a monolayer graphene grown on SiC (0001); the field of view (FOV) is 50 μm and the electron energy is E = ~0.5 eV. (b) LEEM image after Li deposition. (c) LEEM image after annealing the sample to 320°C.

The n band around the K point recorded from (a) monolayer graphene, (b) after Li deposition and (c) after annealing at 250°C. (d) Schematic drawing of the 2D Brillouin zone of graphene and the direction of scan.

Chemical bonding anisotropy and band-gap modeling in w-GaN
Using bulk sensitive and element selective X-ray emission and absorption spectroscopy in fluorescence yield, the differences between the electronic structure and chemical bonding in wurtzite GaN in- and out-of-plane in comparison to pure Ga was used to characterize the hybridization regions and the position of the valence band edge influencing the magnitude of the large band gap of 1.4 eV in GaN. The DFT description of the large band gap, the spectral peak positions, and the hybridization regions can be improved by including a specific on-site Coulomb interaction on the 3d semicore states. [M.Magnuson, M. Mattesini, C. Högland, J. Birch, L. Hultman Phys. Rev. B81 (2010) 085125]
The first identification of an interfacial defect in semiconductor/semiconductor heterostructures

Heterojunctions between two dissimilar solids and associated interfaces are of high scientific interest and technological importance. Here, we reported on the first identification of a point defect residing at an interface between two semiconductors, i.e. an interfacial defect at a GaP/GaNP heterostructure grown by molecular beam epitaxy. The interface nature of the defect was clearly manifested by the observation of its spin-resonance signature originating from only two out of four equivalent \( <111> \) orientations. Based on its resolved hyperfine interaction between an unpaired electronic spin \( S=1/2 \) and a nuclear spin \( I=1/2 \), the defect was concluded to involve a \( 31P \) atom at its core. Defect formation was shown to be facilitated by nitrogen ion bombardment under non-equilibrium growth conditions and the defect was thermally stable upon post-growth thermal annealing. [Phys. Rev. B 81, 115334 (2010)]

Models for the interfacial defect complex located at the GaP/GaNP heterointerface.
The complex shown here involves (a) a PGa antisite or (b) a Pi interstitial, bonded to an unknown defect (or defects) in the nearest neighbor shell (red color) along a \( <111> \) direction on the GaNP side of the interface.

---

Biosensors and Bioelectronics Centre

The Linköping Biosensors and Bioelectronics Centre (LBB) was set up in November 2010, with the aim of bringing together the many competences, activities and resources at LiU that are already working on, or can bring valuable contributions to the development of biosensors and bioelectronic devices. The Centre also aims to be a gateway for international contacts and collaborations within this broad and rapidly expanding field.

Director: Prof Anthony Turner
Professors: Anthony Turner and Fredrik Winquist
Emeritus Professor: Ingemar Lundström
Consultant: Dr Claes Nylander
Managing Editor: Dr Alice Tang
Administrative Staff: Anette Andersson

General information

LBB has set up to capitalise on the experience and potential of Linköping University (LiU) in the fields of Biosensors, Biosensing and Bioelectronics. LiU houses a world-leading group of biosensor scientists, who have arguably had the most significant impact on this rapidly expanding field to date. Our work on Surface Plasmon Resonance (SPR) for real-time bioaffinity monitoring and on mediated amperometric biosensors helped establish the true commercial potential for the field and kick started the current multi-billion dollar industry. Work continues today at LiU across the full range of core technologies including:

- Bioimaging
- Bio-inspired and bio-specific ligands
- Biointerfaces
- Biomolecular electronics
- Biosensors
- Chemical transducers
- Clinical trials
- Fabrication and mass production
- Nanomaterials and nanostructures
- User interfaces and electronic design

LBB’s mission is to mobilise the fundamental research activities and innovation at LiU to facilitate the creation of the next generation of bioelectronic devices and to support the
national and worldwide development of the field. It will build on the legacy of S-SENCE, a Swedish Centre of Excellence for sensor research, which was established at LiU in the mid-90s. LBB will work closely with the Center for Biomimetic Sensor Science (CBSS) in Singapore headed by Professor Bo Liedberg, which was recently set up by LiU, together with Austrian Institute of Technology (AIT) and Nanyang Technological University (NTU).

**BIOSENSORS AND BIOELECTRONICS (ELSEVIER)**

LBB is now home to the principal journal in the field, *Bio-sensors and Bioelectronics*, published by Elsevier. Prof Turner is the Editor-In-Chief, Dr Tang is the Managing Editor and Prof Lundström is an Editor. The journal has the highest Impact Factor (5.43) for a research publication in the broad field of Analytical Chemistry as defined by ISI (69 journals) and is also the highest ranking journal in both Electrochemistry and in Sensors. The team handled 1,866 submissions in 2010. [www.elsevier.com/locate/bios](http://www.elsevier.com/locate/bios)

**THE WORLD CONGRESS ON BIOSENSORS**

LBB is the co-organiser, together with Elsevier, of the 22nd Anniversary World Congress on Biosensors – Biosensors 2012, to be held in Cancun, Mexico 15–18 May 2012. The World Congress is the largest and most prestigious event in the field and is expected to host well over a thousand delegates. LiU will present a number of scientific papers at the conference and will also mount an exhibition stand to promote the activities of LiU. [www.biosensors-congress.elsevier.com](http://www.biosensors-congress.elsevier.com)

**EU COST ACTION TD1003: BIO-INSPIRED NANOTECHNOLOGIES: FROM CONCEPTS TO APPLICATIONS**

This new four-year COST action commenced in November 2010, with Prof Turner as the UK representative. However, it is expected that Professors Turner and Lundström will shortly become the Swedish representatives, following a formal request to the Swedish Government to recognise the Action.

Over recent decades, biology has made significant advances in providing a rational understanding of the molecular mechanisms governing life’s processes. New materials have emerged from living systems, which physicists and chemists have then promptly fabricated, manipulated and addressed at the molecular scale. The flagship example is DNA technology, which facilitates the elaboration of programmable synthetic chemical s routes to build complex architectures and functions with molecular precision and sheds light on a new generation of robust tools. Concurrently, the development of the semiconductor industry has lead to impressive performance in miniaturisation. The current challenge, is to develop lithographic technology for feature sizes below 20 nm and explore new classes of electronic devices based on carbon nanostructures and polymeric materials. This cross-disciplinary research consortium is constructing multi-scale structures in order to organise functional materials in nanodevices. The marriage of top-down and bottom-up fabrication methods paves the way to arrange complex molecular nano units, to electronically address them and integrate them into functional devices.

Several national and international networks and foundations will participate in the COST action including C’Nano GSO, NanoSpain, Portugal Nano, Phantoms Foundation, SUDOE Interbio, nanoICT (bioICT Working Group). These networks have the technical facilities and power to provide technical support to the summer schools, give international workshops and hold meetings with businesses and governmental organisations.

**COLLABORATIVE PROGRAMMES WITHIN LIU**

Although it was only set up in November 2010, LBB is already establishing itself as a central contact point for biosensor and bioelectronics research. It is clear that combining the efforts of a number of research groups at LiU would be highly beneficial and greatly accelerate the development of novel devices. The aim of the Centre is to bring these groups closer together and link further to national and international research establishments within the field. While each group is focussing on its own particular speciality, the objective of LBB is to catalyse an efficient conduit from fundamental biomolecular sensing principles through to fabrication of actual devices and to ensure the practical utilisation of these. There are a number of ongoing projects at IFM that naturally mesh within the scope of LBB. Examples include the development of microelectrodes used with pulsed voltammetry to further refine “electronic tongue” technology and a new biosensor project based on the correlation between salivary amylase activity and various stress related deceases. Other exciting examples are work which seeks to harness the natural phenomenon of optical polarisation in scarab beetle cuticles and the use of mobile phones for remote biosensing.
**MS²E**

SSF Strategic Research Centre on Materials Science for Nanoscale Surface Engineering

**Board**
Dr. Ingrid Reineck, Sandvik Tooling Sverige AB, *Chair*
Prof. Kajsa Udval, Deputy Head IFM, LiU
Prof. Jan-Ake Schweitz, Dean Eng. Sci., UU
Prof. Peter Isberg, ABB AB
Dr. Lars Bräthe, Volvo Technology AB
Prof. Sven Lidin, Stockholm University
Docent Johanna Rosén, LiU, *Secretary*

**Director**
Prof. Lars Hultman, IFM, LiU

**Deputy Director**
Prof. Karin Larsson, *Materials Chemistry, UU*

**Senior Researchers**
Lars Hultman, LiU  Karin Larsson, UU
Igor Abrikosov, LiU  Ulf Jansson, UU
Joakim Andersson, UU  Åsa Kassman, UU
Jens Birch, LiU  Ilia Katardjiev, UU
Hans-Olof Blom, UU  Tomas Kubart, UU
Valeriu Chirita, LiU  Martin Magnuson, LiU
Vanya Daracheva, LiU  A. Mikhailushkin, LiU
Fredrik Eriksson, LiU  Peter Münger, LiU
Naureen Ghafoor, LiU  Tomas Nyberg, UU
Gueorgui Gueorguiev, LiU  Magnus Odén, LiU
Ulf Helmersson, LiU  Per Persson, LiU
Hans Högborg, LiU  Johanna Rosén, LiU
Eyvaz Isaev, LiU  Sergei I. Simak, LiU
Håkan Engqvist, UU  Ferenc Tasnádi, LiU
Staffan Jacobsson, UU  Urban Wiklund, UU
Ventislav Yanchev, UU  Gunilla Wingqvist, LiU

**PhD Students**
Montri Aiempawanakit, LiU  Nils Nedfors, UU
Benny André, UU  Lina Liljeholm, UU

**Visiting Scientists/Post Docs**
Andrzej Furlan, UU  Jussi Koskilinna, UU
Manfred Beckers, LiU  Daniel Söderström, LiU
Johan Bjurström, UU  Stefano Rubini, UU
Gunilla Wingqvist, LiU

**SCOPE**

MS²E is a consortium of research groups from Linköping University and Uppsala University. We focus on solving strategic research issues in functional materials for nanotechnology and advanced surface engineering. Our mission is to:

1. Provide strategic basic research to expand and maintain core research and development capabilities by protecting and enlarging the intellectual property base of companies in key industrial sectors;
2. Create high performance surfaces by exploring new concepts for thin film processing with the design of interfaces and surfaces; and
3. Train future generations of leading scientists and industrialists.

MS²E is funded by SSF 2006–2011.

**RESEARCH PROJECT CLUSTERS AND PROJECT LEADERS**
Wide-Band Gap Nitrides by MSE, *Jens Birch*
Wide-Band Gap Nitrides/Borides; DFT&ALD, *Karim Larsson*
Wide-Band Gap Nitrides by PVD, *Ilia Katardjiev*
Piezo-electric Nitrides – PVD, *Gunilla Wingqvist*
Age Hardening in Thin Films, *Lars Hultman*
Nanocomposite and amorphous carbide films, *Ulf Jansson*
Arc Processing and DFT, *Johanna Rosén*
Self organizing nano surfaces, *Urban Wiklund*
Biotribology, *Håkan Engqvist*
Quasicrystalline Thin Film Materials, *Fredrik Eriksson*
High-Rate HIPIMS, *Ulf Helmersson*
Reactive Sputter Process Development, *Tomas Nyberg*
Plasma Control, *Joakim Andersson*
Hybrid PVD/CVD Processes for borides, *Hans Högborg*
Quantum Surface Chemistry Calc., *Karim Larsson*
Multiscale Materials Simulations, *Igor Abrikosov*
Molecular Dynamics Simulations *Valeriu Chirita*
Synthetic Growth Approach (DFT) *G.K. Gueorguiev*

**PHD THESSES IN 2010**

*Carina Högland:* Growth and Phase Stability of Epitaxial ScAlN and TiAlN Thin Films

*Christian Ask:* Effects of disorder in metallic systems from first-principles calculations

*Björn Alling:* Configurational and magnetic interations in multicomponent systems

*Tobias Marten:* Theoretical Considerations of Local Environment Effects in Alloys

*Daniel Lundin:* The HIPIMS Process
SCIENTIFIC HIGHLIGHTS

Innovation of a new high speed plasma synthesis of core-shell particles.

Homogeneous films of ternary material produced from three elemental arc cathodes used in pulsed mode.

New materials concept for orthopaedic joint replacements – resorbable wear resistant materials.

The origin of the anomalous, 400% increase of the piezoelectric coefficient in Sc₃Al[N alloys is revealed by means of quantum mechanical calculations. The underlying mechanism is the flattening of the energy landscape due to a competition between the parent wurtzite and the so far experimentally unknown hexagonal phases of the alloy. Our observation provides a route for the design of materials with high piezoelectric response [F. Tasnádi, et al., Phys. Rev. Lett. 104, 137601 (2010)].

We prove that by limiting the temperature to 400 °C Sc₃Al[N solid solutions can be grown with pure dielectric properties with only very minor increase in the dielectric losses compared to AlN films. Increased temperature generated films with increased leakage current. The high frequency dielectric response showed good correlation with our theoretical predictions on the solid solution. Our evidence of generating dielectric solid solutions together with our extraction of the dielectric constants enabled predictions of increased electromechanical coupling from 7% to 10% for alloying AlN with up to 20% ScN. [G. Wingqvist, et al., Appl. Phys. Lett., 97 112902 (2010)]

An importance of the effects of magnetic disorder and strong electron correlation on the thermodynamics of CrN has been demonstrated and a technique for their theoretical simulations has been developed [B. Alling, T. Marten, and I. A. Abrikosov, Nature Materials 9, 283 (2010); Phys. Rev. B (accepted)]


We used ab-initio calculations to predict the existence of several supertough transition metal nitrides, one of which (V,W,N) has been recently synthesized in the laboratory at LIU. Currently work in advanced stages for implementing an improved interaction potential which will make possible large scale classical molecular dynamics simulations of nitrides.


The phonon dispersions show that the (111) interface is dynamically stable while distortion of the Si-N bond from ideal in-plane B1 positions almost, but not completely, stabilizes the (001) interface dynamically. The ideal interfaces are shown in the figure.

Experimental work on the transport of charged particles in high power impulse magnetron sputtering (HiPIMS) demonstrated a new type of anomalous fast transport due to instabilities in the plasma [D. Lundin, PhD thesis, Linköping (2010)]. This mechanism affects the trajectories of ionized sputtered material as well as increasing the energy of these ions and thereby changing the overall deposition process conditions compared to, e.g., DC magnetron sputtering [M. Samuelsson et al., Surf. Coat. Technol. 205, 391 (2010)].
Spintronic semiconductor materials and nanostructures: The aim is to understand the fundamental physics underlying spin phenomena such as spin relaxation, spin injection, mechanism for spin loss, etc., so that the full potential as well as the fundamental limits of spintronics can be assessed. Within this year we have concentrated our studies on (i) understanding and optimization of our recently discovered defect-engineered spin filtering effect in Ga(In)NAs quantum and nano structures at room temperature; (ii) studies of spin loss at GaAs/GaNAs interfaces during spin injection at room temperature; (iii) spin dynamics in ZnO-based materials; and (iv) optical spin injection in InAs quantum dots.

Development of spin-sensitive local probe microscopy/spectroscopy: The aim is to develop a variety of advanced spin-sensitive scanning probe microscopies (SPM) and to apply them to studies of nano-magnetism and spin detection and manipulation on the nano- and atomic scale in novel electronic and magnetic materials and nanostructures.

EPR dosimetry: The aim of the research within this project is to improve EPR dosimetry (ionising radiation dose measurements) to be a competitive dosimetric method for applications in radiation therapy. We are working with the optimization of measurement precision and accuracy in dose measurements by the development of new dosimeter read-out protocols and dosimeter calibration protocols. We are also searching for new dosimeter materials with higher sensitivity and better tissue equivalence with respect to attenuation and scattering of ionizing radiation. We are currently clinically evaluating a lithium formate EPR dosimeter system for dosimetry in special measurements situations such as dosimetry in intensity modulated radiation therapy (IMRT) and brachytherapy.

Retrospective dosimetry by means of EPR spectroscopy: EPR spectroscopy measurements of chewing gums and sweeteners sorbitol and xylitol have been performed in order to optimize the use of them as retrospective dosimeters. Radical identification, transitions, stability, dose response and light dependence have been investigated. Retrospective dosimetry on tooth enamel has also been performed through participation in an international tooth comparison study.

Medical applications of electron paramagnetic resonance imaging (EPRi): Research aiming to use EPRi for medical applications such as: (i) imaging of radical distributions in atherosclerosis for a better understanding of the role of reactive oxygen species (ROS) in atherosclerosis; (ii) imaging of radical distributions for experimental verifications of calculated dose distributions in radiation therapy of cancer, e.g. narrow beam dose distributions and interface dose distributions.
HIGHLIGHTS

Identification of a complex defect between a carbon antisite-vacancy pair and a third neighbor carbon vacancy in 4H- and 6H-SiC

The EI4 EPR center is commonly detected in some types of high-purity semi-insulating (HPSI) 4H- and 6H-SiC and seems to play an important role in carrier compensation processes and hence the SI properties of the materials. Enhancing the signal by electron irradiation and proper annealing enabled detailed EPR studies of the center in both 4H and 6H polytypes. Combining EPR studies and ab initio supercell calculations led to the identification of the defect as a complex between a carbon antisite-vacancy pair and a third neighbor carbon vacancy. Annealing studies and calculations of the migration energy barriers also suggested a model for the formation of the defect, by the migration of the silicon vacancy at low temperatures, and the transformation of the defect to a divacancy at higher temperatures. [Phys. Rev. B 82, 235203 (2010)].

Response of lithium formate EPR dosimeters at photon energies relevant to the dosimetry of brachytherapy

The energy dependence of the detector response of lithium formate EPR dosimeters for photon energies below 1 MeV relative to that at 60Co energies was experimentally investigated. In addition to any differences in mass-energy absorption properties between water and detector, variations in radiation yield (detector response) with radiation quality, caused by differences in the density of ionization in the energy imparted (LET), may exist. Results: Significant decreases in the relative response ranging from 5% to 6% were seen for x-ray beams at tube voltages ≤180 kV. No significant reduction in the relative response was seen for 137Cs and 250 kV x rays. Conclusions: When calibrated in 60Co or MV photon beams, corrections for the photon energy dependence of detector response are needed to achieve the highest accuracy when using lithium formate EPR dosimeters for measuring absorbed doses around brachytherapy sources emitting photons in the energy range of 20–150 keV such as 169Yb and electronic sources. [Med. Phys. 37, 4946 (2010)].

COLLABORATIONS

About 30 research groups from Europe, USA and Asia are in active collaboration with SIMARC.

OTHERS:

Daniel Dagnelund defended his doctoral thesis “Magneto-optical studies of dilute nitrides and II-VI diluted magnetic semiconductor quantum structures” on May 7, 2010.


gymnasiet. Stockholm: Talentum Media AB; NyTeknik. 2010;


Andersson M, Lloyd Spetz A. Tailoring of SiC based field effect gas sensors for improved selectivity t non-hydrogen containing species. In: IMCS13 2010. p. 369-.


---

**APPLIED OPTICS**


Forsgren G, Winquist F, Öström Å. Analysis of volatile compounds of aqueous thyme solutions by headspace gas chromatography, gas sensor arrays (“electronic nose”) and a sensory odour panel.


In Other Hepaticotransfer Aggregates In Journal of Hepatology, vol 52, issue, pp 540-540.


BIOTECHNOLOGY


SENSOR SCIENCE AND MOLECULAR PHYSICS


Ekblad T. Hydrogel coatings for biomedical and biofouling applications. Dissertations, 1102.


SCIENTIFIC BRANCH OF BIOLOGY
ECOLOGY
Grönlund E, Billgren C, Sundblad-Tonderski K, Rahuru P. Sugar industry effluent treatment in the Lake Victoria basin – a case study of Sugar industry effluent treatment in the Lake Victoria basin: 2a case study of performance, cost and resource use including local ecosystem services. 2010.


MOLECULAR GENETICS


ZOOLOGY


Lindgren I. Cardiovascular beta-adrenergic signaling: Maturation and programming effects of hypoxia in a chicken model. Dissertations, 1330.


Andersson A. Maternal behaviour, infanticide and welfare in enclosed European wild boars (Sus scrofa. Thesis, 1439.


Olsson P, Laska M. Human male superiority in olfactory sensitivity to the sperm-attractant odorant bourgeonal. 2010.


SCIENTIFIC BRANCH OF MATERIALS PHICS

FUNCTIONAL ELECTRONIC MATERIALS


Daganelidou D. Magneto-optical studies of dilute nitrides and II-VI diluted magnetic semiconductor quantum structures. Dissertations, 1316.


Chen W, Buanova I. Efficient room temperature spin filter based on a non-magnetic semiconductor. 2010.


NANOSTRUCTURED MATERIALS


Knutsson A, Johansson M, Karlsson L, Odén M. Thermally enhanced mechanical properties of arc evaporated Ti0.34Al0.66N/TIn mul- tilayer coatings. Journal of Applied Physics. 2010;108(4):044412-.


Ballem M, Córdoba J, Odén M. Mesoporous silica templated zirconia nanoparticles. Journal of nanoparticle research. 2010
PLASMA AND COATING PHYSICS


SEMI CONDUCTOR MATERIALS


Leone S. Advances in SiC growth using chloride-based CVD. Dissertations. 2010.


Hsu C, Lundskog A, Karlsson F, Forsberg U, Janzén E, Holtz P. Optical characterization of InGaN quantum dots on GaN pyramids grown by MOCVD.


SURFACE PHYSICS AND CHEMISTRY


THIN FILM PHYSICS


Greczynski G, Hultman L. Time and energy resolved ion mass spectroscopy studies of the ion flux during high power pulsed magnetron sputtering of Cr in Ar and Ar/N2 atmospheres. Vacuum. 2010;84(9):1159-1170.


Frodelius J. Thick and Thin TiAl2Co Coatings. Dissertations, 132A.


Czigan Y, Hultman L. Interpretation of electron diffraction patterns from amorphous and fullerene-like carbon allotropes. Ultramicroscopy. 110(7):835-


Gunnarsson Sarius N. Surface Technology for Optical and Electrical Connectors. Linköping. Dissertations, 1342.


Johansson M, Kopidakis G, Auby S. KAM tori in 1D random discrete nonlinear Schroedinger model?. EDP Sciences.; EPL. 2010;91(5)


**Theses**

**Doctinal Theses**

**ASKER, CHRISTIAN:** Effects of disorder in metallic systems from First-Principles calculations  
*Thesis No 1309*

**EKBLAD, TOBIAS:** Hydrogel Coatings for Biomedical and Biofouling Applications  
*Thesis No 1302*

**ERIKSSON, JOHAN:** “Atomic and Electronic Structures of Clean and Metal Adsorbed Si and Ge Surfaces: An Experimental and Theoretical Study”  
*Thesis No 1313*

**LINDSTRÖM, TOM:** Spatial Spread of Organisms: Modeling ecological and epidemiological processes  
*Thesis No 1311*

**DAGNElund, DANIEL:** Magneto-optical studies of dilute nitrides and II-VI diluted magnetic semiconductor quantum structures  
*Thesis No 1316*

**OLSSON, JOHN:** Characterization of a Voltammetric Electronic Tongue  
*Thesis No 1267*

**WIGENIUS, JENS:** Conjugated polyelectrolytes in interaction with biomolecules for supramolecular assembly and sensing.  
*Thesis No 1308*

**BERG, INA:** Modeling amyloid disease in drosophila melanogaster  
*Thesis No 1320*

**CARLEGRIM, ELIN:** Development of organic-based thin film magnets for spintronics  
*Thesis No 1317*

**LUNDIN, DANIEL:** The HiPIMS Process.  
*Thesis No 1305*

**HÖGLUND, CARINA:** Growth and phase stability studies of epitaxial Sc-Al-N and Ti-Al-N Thin Films  
*Thesis No 1314*

**CARLSSON, PATRICK:** Electron Paramagnetic Resonance Study of Defects in SiC  
*Thesis No 1319*

**ADNANE, BOUCHAIB:** Optical characterization of Silicon-based self-assembled nanostructures  
*Thesis No 1296*

**FRODELIUS, JENNY:** Thick and Thin Ti2AlC Coatings  
*Thesis No 1328*

**ALLING, BJÖRN:** Configurational and Magnetic Interactions in Multicomponent Systems  
*Thesis No 1334*

**LINDGREN, ISA:** “Cardiovascular β-adrenergic signaling Maturation and programming effects of hypoxia in a chicken model”  
*Thesis No 1330*

**CARLSSON, KARIN:** Tissue factor in complex – Studies of interactions between blood coagulation proteins  
*Thesis No 1329*

**LEONE, STEFANO:** Advances in SiC growth using chloride-based CVD  
*Thesis No 1340*

**GUNNARSSON SARIUS, NIKLAS:** “Surface Technology for Optical and Electrical Connectors”  
*Thesis No 1342*

**HEDLUND, JOEL:** Bioinformatic protein family characterisation  
*Thesis No 1343*

**KASHIF, AHSAN-ULLAH:** Optimization of LDMOS Transistor in Power Amplifiers for Communication Systems  
*Thesis No 1346*

**MARTEN, TOBIAS:** Theoretical considerations of local environment effects in alloys  
*Thesis No 1253*

**MACKEN, STEPHEN:** Integrated optical solutions for ubiquitous sensing  
*Thesis No 1355*

**Licentiate Theses**

**SJÖLANDER, DANIEL:** Fluorescence studies of amyloid structures  
*Thesis No 1433*  
*LIU-TEK-LIC-2010:4*

**DAHLQVIST, MARTIN:** Stability of MAZ phases from First-Principles calculations  
*Thesis No 1435*  
*LIU-TEK-LIC-2010:6*

**KNUTSSON, AXEL:** Mechanical properties and thermal stability of reactive arc evaporated TiAlN/TiN Multilayer coatings  
*Thesis No 1437*  
*LIU-TEK-LIC-2010:8*

**ANDERSSON ANNELIE:** Maternal behaviour, infanticide and welfare in enclosed European wild boars (Sus scrofa)  
*Thesis No 1439*  
*LIU-TEK-LIC-2010:10*

**ZHU, JIANQIANG:** Microstructure evolution of cathodes used for growth of TiSiN and TiSiCN coating by cathodic arc evaporation  
*Thesis No 1440*  
*LIU-TEK-LIC-2010:11*

**JOHNSON, LARS J.S.:** Nanostructuring and Age Hardening in TiSiCN, ZrAlN, and TiAlN Thin Films  
*Thesis No 1442*  
*LIU-TEK-LIC-2010:13*

**JOHANSSON M. EMMA:** Controlling the pore size and morphology of mesoporous silica.  
*Thesis No 1451*  
*LIU-TEK-LIC-2010:22*

**ERIKSSON, ANDERS:** Cathodic arc synthesis of Ti-Si-C-N thin films from ternary cathodes  
*Thesis No 1456*  
*LIU-TEK-LIC-2010:27*
BERGMAN CAROLINE: Enantioselectiv HPLC-analys med kiral stationärfaser bestående av makro-cyliska glykopeptider och polysaccharider Ex-2245

BERGNER SANDRA: Screening of volatile compounds in washing water and cloths from the sponge cloth process Ex-2246

BERGOVIST JONAS: Microstructure and temperature stability of APFO-2:PCBM organic photovoltaic blends Ex-2201

BJÖRK ANNAK: Metodik för bestämning av vitamin D3 i blodgrov på filterpapper med hjälp av vätske-kromatografi och elektrokemisk detektion Ex-2247

BJÖRN PATRIK: Human platelet aggregation induced via protease-activated receptor 1 (PAR1) signalling is reversed by nitric oxide (NO) through inhibition of a Thaskin/ROCK-mediated pathway Ex-2265

BOMAN LINDA: Metodutveckling för analys av organiska temnöten med GC/MS Ex-2248

BROBERG MIKAEL: Protein i kort - En torkstudi utförd med etablerade analysmetoder på tre kornsorter Ex-2249

CHEDID FADIA: Determination of absolute molecular mass distribution and other structural properties of kraft lignin samples - Investigation using SEC in combination with MALDI-TOF-MS and Py-GC/MS Ex-2271

CHENG AN-SHENG: Study of 3C and 6H SiC polytype stability in sublimation epitaxial growth using on-axis substrates Ex-2292

CLAESSON LISA: Ekologisk hållning av mjölkorrar – en jämförelse mellan KRAV och konventionella produktionsmetoder Ex-2345

COLNERUD NILSSON EMMAN: Database for targeted drug screening with liquid chromatography time-of-flight mass spectrometry, LC-TOF-MS Ex-2226

DAHLERUP NINA: Effect of site quality and surrounding landscape on bryophytes and brackets on logs in woodland key habitats Ex-2222

DAVIDSSON VICTORIA: En jämförande studie av KRAV-anslutna respektive konventionella lantbruk. Inom vilka mjölkkorsbesätt-ninang kan djuren enklast utföra sin naturliga beteenden? Ex-2324

EDIN JOEL: Alternativ splicing in människal sjukdom Ex-2345

EDLER-WIRÉN RICKARD: Improving the mechanical properties of paper-based materials by using chemical strength additives Ex-2268

EKSTRÖM ANDREAS: Effects of the NO donors Sodium Nitroprusside and S-nitrosglutathione on oxygen consumption and embryonic organ growth in the domestic broiler chicken, Gallus gallus domesticus Ex-2256

ELVIN JOHANNE: Using TAF affinity purification as a tool too purify the intact TAF-TBP complex in one step Ex-2269

ENELAND ANNA: Metoder för att undersöka effekterna av natuvardshänsynen i skogsbruket efter den nya skogsvårdslagen Ex-2327

ENGSTRÖM IDA: Olfactory sensitivitiy of spider monkeys (Ateles geoffroyi) for L- and D amino acids Ex-2302

ERICSSON MARIA: Social behaviour responses in red junglefowl (Gallus gallus) selected for tameness Ex-2303

ERICSSON PÅR: Utveckling av analysmetod för vitamin A och vitamin E med vätskekromatografi Ex-2250

ESFAHANI ALI NASR: Validation of a transgenic mouse line with knock down of mGluR5 selectively in dopamine D1 receptor expressing neurons Ex-2377

FEDERWITZ FRAUKE: Protecting dogs against attacks by wolves (Canis lupus), with comparison to African wild dogs (Lycaon pictus) and dholes (Cuon alpinus) Ex-2304

FLYKTY LINDA: Reningesultat, drifterfarenheter och konstnadsaktivitet i svensk vätmåtten för spälvetten Ex-2377

GASPARINI ISABELLA: Alternativ splicing hos djur och hur den förhåller sig till bätters alternativa splicing Ex-2328

GILLÉN PETER: ECP-modell för Pt i BWR-miljö Ex-2357

GONZALEZ-BENGTSSON AMANDA: Inducing β-hairpin structure in designed peptides

GUNNAR ERIKA: Characterization of the genetic bases in two cases of abetalipoproteinemia reveals two novel mutations Ex-2287

GUSTAFSSON JOHAN: Optical studies and micro-structure modelling of the circular-polarizing scarab beetles Cetonia aurata, Potomaria cuprea, Liocara marmorata Ex-2368

GUSTAVSSON JAKOB: Identifiering av lakbara potentiellt farliga ämnena i gummiasfalt Ex-2251

GUSTAFSSON GABRIEL: Finding and characterisation of genes in the hyperthermophile desert ant Cataglyphis fortis Ex-2467

HAGELIN ALEXANDER: ZnO nanoparticles. synthesis of Ga-doped ZnO, oxygen gas sensing and quantum chemical investigation Ex-2192
HAQVIST PETTER: Analyser av ljudspektroskopiska signaler med artificiella neurala eller bayersiska nätverk Ex-2282

HALDIN ELIN: Metodutveckling av fastfasextraktion för fosfatdialytanol från blod Ex-2279

HJELM JOHAS: Tonic immobility and effects of early stress on chickens (Gallus gallus) Ex-2446

HÖGBERG SOFIA: Zero-order manipulation task to obtain a food reward in Colombian black spider monkeys (Atelus fusciceps ruifiwnris) kept in a zoo Ex-2393

HÖGBERG ANNA: Analyser av dricksvattenrenning med metoderna Mikrobiologisk riskanalys, MRA och God desinfektionspraksis. GDP Ex-2372

HOLMQVIST JENNY: NMR and binding studies of S. pompe St13 in the mRNA decapping complex Ex-2472

HSU YU-TE: Comparative study of APFO-1 solar cells using mono- and bisadduct fullerences as acceptor Ex-2370

IBBE MATHIAS: History matters: impact of historical landscape-use on butterfly diversity in clear-cuts in a boreal landscape Ex-2318

IREMARK KERSTIN: Exploring Aβ assemblies and the involvement of coagulation factor X in Alzheimer’s disease pathogenesis Ex-22719

JAHLIC ALMA: Behovsbedömning av detaljplaner i Östergötlands kommuner Ex-2329

JAKOBSEN CAROLIN: Relation of silver release and antimicrobial effect in-vitro of silver containing wound dressings Ex-24731

JAYACHANDRA PANDIYAN MUNESWARAN: A bioinformatics approach to investigate the function of non specific lipid transfer proteins in Arabidopsis thaliana Ex-2375

JOHANSSON LENA: Personligheter hos mjölkkor Ex-2320

JOHANSSON KRISTINA: Identification and characterization of soluble subdomains of TRRAP, a cancer regulator protein Ex-2359

JOHANSSON ROBERT: Elastic properties of Fe-Ni-Mg at high pressure from first-principles study Ex-2375

JOHANSSON ANNICA: Biophysical characterization of Thiopturbine S-methyltransferase Ex-2266

JOHANSSON MARTIN: DNA methylation analysis of promoters in chicken brain by means of high resolution melting Ex-2291

JOHANSSON ANNA: Sökande efter biomarker för lungcancer genom analys av metabolitdata Ex-2363

KARLSSON JENNY: Vilka förhållanden är gynnsamma för mjölkors naturliga beteen- den – förekommer skillnader i djurhållningen vid konventionella respektive KRAV-certifierade lantbruk? Ex-2297

KARLSSON JONNY: Proton exchange in protein gels studied by magnetic relaxation dispersion Ex-2275

KEDSONGPANYA SIT: Nanolaminated thin films for thermoelectrics Ex-2296

KJELLGREN MARIE: En studie i latkostintolerans, inkluderande latkassenzymet, utbredningen, diagnostisering och behandling Ex-2253

KLARSTRÖM ENGSTRÖM KRISTIN: Toll like receptor 2 mediated platelet adhesion, role of P2X1 and P2Y1 receptors Ex-2289

KU NAI-YUAN: Thermal stability investigations of Zr-Si-N nanocomposite hardcoatings by structural and mechanical characterization Ex-2299

LARSSON LINDA: Olfactory sensitivity in CD-1 mice for the sperm-attractant odorant bougonial and some of its structural analogues Ex-2252

LARSSON TOMMY: Partially labelled amino acids for protein NMR spectroscopy using cell-free protein synthesis and novel minimal media approach Ex-2380

LEE MING-TAO: Plasmonic enhanced fluorescence using gold nanorods Ex-2298

LEIJON SARA: Molecular characterization of cholinergic vesibular and olivocochlear efferent neurons in the rodent brainstem Ex-2379

LIND LIZA: Identification and characterization of soluble subdomains of TRRAP, a cancer regulator protein Ex-2259

LIND CAMILLA: Behovsbedömning av detaljplaner i Östergötlands kommuner Ex-2348

LUNDHOLM IDA: Binding studies of the ubiqui- tin ligase Smurf2 and its substrates RhoA and RapiB using NMR spectroscopy Ex-2276

LUNDIN ERIKA: Identification of genes controlling the generation and specification of Apterous neurons through a forward genetic screen in Drosophila melanogaster Ex-2288

LY BECKY: Jämställning av metoder för peroxidedemningar i bränslen Ex-2255

LYSTREN THERES: Predation as selektiv faktor bakom differentiering av populacioner av sötvat- tensgrusugga, Asellus aquaticus Ex-2294

MAGUIRE EMMA: Monitoring of lubricant degradation with RULER and MPC Ex-2358

MIDBJER JOHAN: A Nox sensor based on SiC for high-temperature applications Ex-2286

MOLLÉN ALBERT: Investigation of ageing effects and image stability in hybrid photon pixel detectors at the LHCB experiment CERN Ex-2277

NAUMAN LAILA: Operant conditioning in a self controlling test with a reinforcement delay in Pygmy Hippo (Hippopotomon libreriensis) Ex-2378

NEVIN PHILIP: Dynamics of DNA polymerase exchange mediated by DinB Ex-2277

NILSSON SANDRA: Screening of volatile compounds in washing water and clothes from the sponge cloth process Ex-2246

NORÉN LINA: Forensic low template DNA analysis – A comparison of different extraction methods Ex-2220

NORMAN SOFIA: Extraction of heavy metals from fly ash using electrochemical methods Ex-2381

NYGÅRDS SOFIA: Sedimentation of lera och fosfor i en anlagd våtmark Ex-2331

NYGREN KRISTIAN: Solar cells based on synthesized nanocrystalline ZnO thin films sensitized by chlorophyll a and photopigments isolated from spinach Ex-2322

NYLANDER FILIP: Synthesis of building blocks corresponding to Oligo α((1-4), and α((1-6)- Mannans Ex-2270

OLOFSSON DANIEL: Effects of artificial vegetation density on prey size selection by perch (Perca flaviflavis L.) feeding on the isopod Asellus aquaticus L. Ex-2334

PALMQVIST EMMA: Mutagenesis of the sugar doner site of the Arabidopsis thaliana glycosyltransferase UGT72B1 Ex-2278

PARDONNET SYLVIA: Effect of Tree-fall Gaps on Fruit-Feeding Nymphalide Assemblages in a Peruvian Rainforest Ex-2309

PERSSON ALEXANDRA: Metoder för att undersöka effekterna av naturvårdsämnen på skogsbruk; efter den senaste skogsbränsleden Ex-2335

PERSSON MIA: Effects of postnatal stress on tonic immobility in White Leghorn chicks (Gallus gallus domesticus) Ex-2336

PERSSON MIKael: Utveckling av HPLC-metoder för kvantifiering av polyglykoler och fosfates- ter av polyglykoler i en villkorad emulsion Ex-2256

PETERS JESSICA: Sedimentation of lera och fosfor i en anlagd våtmark Ex-2237

PETTERSSON KARIN: Lubricating properties of alternative diesel engine fuels – biodiesel and ethanol, tested with the HHFR method Ex-2257
PETTERSSON KARIN: The HFRR (High-Frequency Reciprocating Rig) – a method evaluation Ex-2258

REIMERS PETRA: Studies of light emission from N-B doped Hf-SiC Ex-2264

REJMSTAD PETER: Developing methods for distributing particles in electrosprun materials Ex-2228

REYER HENRIK: Klorering av organiskt material i jord under olika miljöförhållanden Ex-2259

RHÖNNSTAD SOFIE: Biotinylation and high affinity avidin capture as a strategy for LC-MS based metabolomics Ex-2260

RYBKA MARCIN: Optical properties of MAX-phase materials Ex-2370

RYDMELL SARA: The honesty of the female sexual ornament in Gallus gallus Ex-2305

SÄNDEL EMMA: Optimization of the in vitro pyrogen test (IPT) regarding detection of pyrogens in air samples Ex-2212

SAVAS ISABELLA: Alternativ spicing: en process som medför att flera olika mRNA-transkript bildas från individuella gener Ex-2358

SELLMAN STEFAN: Ecologically viable population sizes: Determining factors Ex-2354

SHAMON DOREEN-MARIE: Utveckling och validering av en LC-MS/MS metod för kvantifiering av clopidogrel och dess metabolit i plasma Ex-2261

SILVERÅ EJNEBY MALIN: TRP channels and regulation of blood flow in the brood patch of Zebra finches (Taeniopygia guttata) Ex-2339

SIMONSSON JACQUELINE: Isothermal titration calorimetry som verktyg i utveckling av inhibitorer mot leukotriene A4 hydrolase Ex-2279

SKOOG LISA: Matematisk modell av genuttrycket i Escherichia coli under kolhydratsvält Ex-2340

SÖDERGREN ANNA: Vasodilatory effects of exogenous nitric oxide on the brood patch of the zebra finch (Taeniopygia guttata) Ex-2342

SUNDLING SIMON: Characterizing the structure of the lipid carrying protein Arabidopsis thaliana sterol carrier protein-2 (ASC2p) by NMR spectroscopy Ex-2283

SVENNAR ERIKA: Metoder för att undersöka effekterna av natuvärdshänsynen i skogsbruket efter den nya skogsärvårdslagen Ex-2347

SVENNAR ERIKA: Metodbeskrivning för identifikation av råvaror med TLC Ex-2333

SVENSSON PETER: Emissioner av smörjolja till luft från gas- och ängturbiner Ex-2281

TAJUELO RODRIGUEZ ELENA: Growth at cryogenic temperatures and structural characterization of Ce/Sc multilayer X-ray mirrors Ex-2300

TAHSHAN NABIL: The effects of prenatal hypoxia on the levels of the α-subunits of G proteins in the heart of the Broiler chicken (Gallus gallus) Ex-2318

THINPRAKONG CHORPURE: Excitation transfer between conjugated polyelectrolytes and triplet emitter confined in protein nanowires Ex-2271

THRIKEDISWARENADEN SINDUJA: Separation, isolation, and size determination of insulin granules from β-cells with asymmetrical flow field-flow fractionation Ex-2361

TRUPINA SNEZANA: Synthesis of metalloporhyrin oligothiophenes as probes for amyloid diseases Ex-2240

TÖRNVALL ERICA: Determination of testosterone esters in serum by liquid chromatography - tandem mass spectrometry (LC-MS-MS) Ex-2263

UR-REHMAN ATEEQ: Does arbuscular mycorrhiza symbiosis increase the capacity or the efficiency of the photosynthetic apparatus in the model legume Medicago truncatula? Ex-2312

VEIBÄCK AXEL: Development of an expression system for a dehydrogenase Ex-2235

VESTELUND JACOB: Prediction of hardwood to softwood ratio in pulp mixtures from online NIR measurements Ex-2264

WALETT EMMA: Foraging and exploratory behaviour in Red Junglefowl (Gallus gallus) selected for fear or humans Ex-2306

WALLÉN HELENA: Olfactory sensitivity in CD-1 mice for six L- and D-amino acids Ex-2357

WENDEL CAROLINE: In Vitro study of recruitment ability of Macrophages and Trophoblasts in early human pregnancy Ex-2313

WINzell ANN: Surface modification of CdSe(ZnS) quantum dots for biomedical applications Ex-2265

WITTE SARA: The effect of redoamodulation on osteoclasisgenesis Ex-2263

YAO XUEFEI: High forest or wood pasture: A model of large herbivores’ impact on European lowland vegetation Ex-2233

ÖSTERMAN HANNA: Olfactory performance and neuropathology in the Tg6799 strain of Alzheimer’s disease model mice Ex-2314
About this publication

- **Editor:** Ingegärd Andersson, IFM Linköping University
- **Print:** DanagårdsLITHO, Ödeshög
- **Production:** Condesign Info Productions AB, Linköping

IFM Activity Reports are also available at www.ifm.liu.se/ar/