Clean Room

Introduction

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The Rubber Lab
IFM, LiU

http://www.ifm.liu.se/cleanroom/

Contents

- General
- Application of clean room
- Ventilation and air flow
- Filters
- Contaminations/Particles
- Clean room classification
- Clean room rules
General

- Why? - mandatory! Special lab, rules, manner of handling...
- Fore-knowledge for new users and courses going to use labs
- Introduction- no theory, straight forward information

Goal
- understand clean room basics
- explain why and how
- apply in practice

Knowledge/experiences from lab, diploma work at IFM, FOI, Silex, ..., professional life

Cleanliness - Home contra clean room

- What is the cleanliness? How to define that?
- To clean home (look clean, no visible dirt )

- Clean room
  Dealing with invisible contamination
Hygiene consideration

- A personal hygiene
daily shower, clean clothes,
wash hand...

- Clean room operator/user

Aims of clean room technology

- Prevent contamination from damaging products, process and operators

- Contamination: the substances which exist in the wrong place and / or wrong occasions

  - Detectable with naked eye: > 40 µm
    (a human hair Ø : 70-100 µm)
  - Invisible contamination
Particle concentration in percent by weight and by number

Rule of thumb: 99.9% of all floating particles ≤ 1µm air borne particles. ISO Standard: 0.1-5 µm

Who uses clean room technology and clean room

<table>
<thead>
<tr>
<th>Industry branch</th>
<th>Product examples</th>
<th>Industry branch</th>
<th>Product examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro-electronic</td>
<td>Mobile telephone, computer processor, hard disk</td>
<td>Pharmaceutical industry</td>
<td>Tablets, ointments, injection solutions, vaccines</td>
</tr>
<tr>
<td>Micro-mechanic</td>
<td>Gyroscope, miniature ball bearing, CD-player</td>
<td>Bio-technique</td>
<td>Incubation, antibiotics, genetic, manipulation</td>
</tr>
<tr>
<td>Optical industry</td>
<td>Lenses, laser equipment, LCD-displayer</td>
<td>Medical device</td>
<td>Prostheses, disposable materials for health care</td>
</tr>
<tr>
<td>Electronic</td>
<td>Computer, TV- (computer-) screens</td>
<td>Hospital</td>
<td>Operation room, isolation of patient, immune therapy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Food industry</td>
<td>Food and drink</td>
</tr>
</tbody>
</table>

Products where particles can be harmful

Micro-electronic – driving force

Products where microorganisms can be harmful

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Moore's law

Moore's Law – The number of transistors on integrated circuit chips (1971-2018)

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are linked to Moore's law.
History

- The first clean room was built in hospital— not spread microorganisms

- To eliminate bacteria and to hinder infections
  - Hygiene technique
  - Clean room
  - Antiseptic, sterilize instruments and clothing

- Ventilation
  - Supply the filtered air flow, revolutionary clean area

Hospital operation room

http://electricdiagram.today/operati
ng-room-laminar-flow-diagram.html
From conventional to laminar airflow

- Conventional airflow
  - Air moves in a turbulent way

- Laminar air (uni-directed air flow)
  - Air moves equally in a plane
  - (Often from filters in the ceiling to perforated and raised floor)
  - Capture airborne particles and transport them away

“Laminar: (of a flow) taking place along constant streamlines, without turbulence.”

Laminar airflow – LAF room
Turbulent or laminar

<table>
<thead>
<tr>
<th>Class</th>
<th>Air change</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 8 (100 000)</td>
<td>10 ... 25</td>
<td>Turbulent</td>
</tr>
<tr>
<td>ISO 7 (10 000)</td>
<td>15 ... 40</td>
<td>Turbulent</td>
</tr>
<tr>
<td>ISO 6 (1 000)</td>
<td>20 ... 100</td>
<td>Turbulent</td>
</tr>
<tr>
<td>ISO 5 (100)</td>
<td>25 ... 400</td>
<td>Turbulent or laminar</td>
</tr>
<tr>
<td>ISO 4 (10)</td>
<td>200 ... 600</td>
<td>Laminar</td>
</tr>
<tr>
<td>ISO 3 (1)</td>
<td>600 ...</td>
<td>laminar</td>
</tr>
</tbody>
</table>

- **Air change**: how many times the total air in a room is changed with clean air per hour (fan, air flow: 0.54 m/s, over pressure 10-15 Pa)
  - To get a laminar air, it needs at least 60 air changes (typically employed across 80% of a cleanroom ceiling to maintain constant air processing) (office and school: 2-4 times/hour)


Differential Pressure

- **Positive differential pressure**
  - A positive pressure, between adjacent clean rooms or between a clean room and an airlock means that there is a higher pressure in the cleanest clean room compared to adjacent clean rooms with a lower purity rating.
  - Is almost exclusively used to protect the product being handled.

- **Negative differential pressure**
  - Negative pressure is generally used only in cases where it is not desired to spread any contaminants, for example when handling radioactive material, toxic products or even handling dangerous microorganisms.
  - Minimize the risk of these potentially dangerous substances or organisms leaving the clean room and entering the uncontrolled external environment.

Filters

- One uses HEPA filter
  - High Efficiency Particulate Air filter (HEPA)
  - Filter materials consists of glass fiber medium that is folded and glued in a plywood or metal cassette
  - Due to the folding, a big surface results big amount of air passes
  - HEPA retain 99.97% of incident particle of 0.3 micron and larger
  - HEPA: Class 100 or higher

- Fore-filters needed - change often
  Two stages: DPL

- ULPA, Ultra low particulate air filter, class 10 and low

HEPA filtration mechanism

- Interception
- Impaction
- Diffusion
Contaminations/particles
- sources, spreading and concentration

Range of particle sizes: 0.1-100 µm
Contributed by nature, human being, air, surface and products

- Source from nature: sand, clay, dust, ash, pollen, ...
- Friction products: tires, textiles...
- Inorganic by-products: exhaust released from cars, ...
- Living organism: bacteria’s (most: 0.5-5µm), virus (30~300nm), ...
- Human being: skin, mouth, nose, hand, ...
- Processing: polishing, sawing, ...
- Other form of unwanted impurities

Airborne particles

- Concentration varies
  - Where one measures
  - Which time during a year one measures
  - Which time during a day one measures

- With the cold weather it releases more particles due to the heating through burning up materials

<table>
<thead>
<tr>
<th>Places</th>
<th>Number of particles (≥ 0.5 micrometer) per cubic foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial zone</td>
<td>10 000 000</td>
</tr>
<tr>
<td>City environment</td>
<td>1 000 000</td>
</tr>
<tr>
<td>Mountain tract</td>
<td>100 000</td>
</tr>
<tr>
<td>Moon</td>
<td>100</td>
</tr>
</tbody>
</table>
Fact

Enclosure:

If contamination entering from outside of clean room is blocked, so the main dirt comes from people or products.

Contaminations/particles
- sources, spreading and concentration

- Human being is the biggest dust source

- Human being: skin flakes
  - Cells renew constantly and replacing with newly grown skin
  - The old skin is knocked away
  - 100 000 particles per minute (standing still person)
  - Light particles float around (not influenced by gravity)

- Human being: mouth and nose
  - Speaking, coughing, and sneezing generate micro organisms
  - Transport long way in the direction of speaking/coughing and sneezing

- Human being: hands
  - Touching and leave particles, fat on surface,

- Protection to limit contamination from us: special clothes, boot, mouth mask, gloves, ...

Picture: http://www.pharmamicroresources.com/2012_01_01_archive.html

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Classification

<table>
<thead>
<tr>
<th>Classes</th>
<th>≥ 0.5 µm</th>
<th>≥ 0.2 µm</th>
<th>≥ 0.1 µm</th>
<th>≥ 0.05 µm</th>
<th>≥ 0.03 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70</td>
<td>7.5</td>
<td>3</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>350</td>
<td>30</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>100</td>
<td>-</td>
<td>750</td>
<td>300</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>1,000</td>
<td>-</td>
<td>7,600</td>
<td>3,000</td>
<td>1,000</td>
<td>7</td>
</tr>
<tr>
<td>10,000</td>
<td>-</td>
<td>75,000</td>
<td>30,000</td>
<td>14,000</td>
<td>70</td>
</tr>
<tr>
<td>100,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>100,000</td>
<td>700</td>
</tr>
</tbody>
</table>

Table above: USA, FS 209D (1988) one measures number of particles ≥ 0.5 µm per cubic foot (One cubic foot ~28.3 liter in volume)


Table 1: Air cleanliness classification table by particle concentration. (Reproduced from the Journal of the IEST with permission)
Particle counter

Particle counter bought from Ninolab

http://www.machinerylubrication.com

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Device Physics Lab and Rubber Lab

Dear users,

We are glad to inform you that Device Physics Lab maintains its classifications of 100 (also ISO 5) for the photolithography room, and class 1000 for the main area (ISO 6).

We have measured airborne particles in the yellow room, sputter room, corridors, entrance and service areas inside DPL with a new particle counter (borrowed from Ninolab) calibrated according to the latest standard (ISO 21501-4). The average number of particles with sizes of 0.5 micrometer and larger, is well below 100 per cubic foot of air for the photolithography room and even for most processed and service areas, while other areas show a value well below 1000 per cubic foot of air.

Next to DPL, the Rubber Lab is also equipped with HEPA filters but without raised floor for air circulation. It contains an average number of ~3000 particles with sizes of ≥ 0.5 micrometer per cubic foot of air, indicating that the rubber lab remains its class 10 000 level.

To compare with and have general pictures, air in an ordinary corridor outside DPL and in office environment contains an average number of ~20 000 particles per cubic foot for the sizes of ≥ 0.5 micrometer at working hours. There are of cause a lot of more small particles for a size of 0.3 micrometer as well. According to reference, the air in a typical office building contains 500 000 to 1 000 000 particles with sizes of ≥ 0.5 micrometer per cubic foot.

We will use this particle counter periodically to track any changes.

Best regards
Chun-Xia, Jeanette and Mikael
More about contamination

- Cleanliness, hygiene and quality goes hand in hand

- The dead particles
  - Do not reproduce
  - Generate e.g. from printer, papers

- The living particles
  - Related to living microorganisms
  - Reproduce themselves
  - Humid, warm and nourishing rich environments easy to grow

- Controlled temperature, ~20°C
- Controlled humidity in clean room, rh 45%

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Clean room definition

- ISO 14644-1

A room in which the concentration of airborne particles is controlled and which is constructed and used in a manner to minimize the introduction, generation and retention of particles inside the room and in which other relevant parameters, e.g., temperature, humidity and pressure, are controlled as necessary.
A bio clean room

- GMP, Good manufacturing practice _ bio-industry: pharmaceuticals, biotechnology and medical device manufacturing, ...

- Control both particles and microorganisms through separate microbiological analyzes.

- Difference between manufacturing e.g., in microelectronics and in the pharmaceutical industry or other bio industry?
  - Microelectronics: Perform a functional test after the component is manufactured.
  - Drug manufacturing, function tests are not performed after the products have been manufactured.
  - The GMP - a methodical and similar way at all stages during production to always produce exactly the same products.

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Good Manufacturing Practice

- **Grade D** is the least clean clean room and this is generally used for all forms of preparation work... or less critical products

- **Grade C** is also a clean room and this is used in the manufacture of sterile products, i.e. such products that must not be contaminated with living organisms.

- **Grade B** is also used for sterile manufacture. Aseptic manufacturing involves filling a pre-sterilized product in pre-sterilized packages under aseptic forms. "Keep it sterile sterile"

- **Grade A** is not a clean room but a locally located clean zone, which in aseptic manufacturing is placed in a Grade B. clean room. The local clean zone is used to protect the most critical part of aseptic manufacturing.

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Vertical vs. Horizontal laminar airflow workbench (LAFW)

Contamination transfer

- **Human being** - the biggest source
  - Smokers and people with running nose or coughing should not go in clean room
- **Ventilation**
- **Machines and production equipment**
- **Raw materials**
- **Packing materials and papers**
  - One writes on special paper in clean room
- **Chemicals**
  - Floating and gas form contamination
  - Can be harmful for product, process and human being
- **Textiles**
Sneezing

- Full of droplets
- Long distance
- Droplets get transferred to the areas constantly held or touched.


Clean room dresses

- Simple design
- No pocket
- Comfortable size but not too big
- Tightly fit in throat and ankle
- Blue plastic over own shoes, head cover, coverall, clean room boots, gloves
Dressing code

- Prior to entering
- Blue overshoes over your own shoes
- Head cover: make sure all hair is inside, tighten if possible
- Coverall: hold in sleeves and waist, step in as high as possible, tighten if possible
- Cleanroom boots: tighten under knees and over shoes
- Gloves: do not touch outside of fingertips with bare hands

Taking off: the opposite order

OBS: Human being and office materials give the most contaminations!!!!!!

Particles generate from various type of dresses per minute vs. different physic activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Daily clothes</th>
<th>Lab coat with head cover</th>
<th>Clean room dress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sit still</td>
<td>448 000</td>
<td>142 000</td>
<td>14 920</td>
</tr>
<tr>
<td>Sit but arm moves</td>
<td>4 450 000</td>
<td>462 000</td>
<td>46 600</td>
</tr>
<tr>
<td>Standing, turning</td>
<td>2 240 000</td>
<td>390 000</td>
<td>31 700</td>
</tr>
<tr>
<td>Walking, running</td>
<td>5 380 000</td>
<td>1 285 000</td>
<td>157 000</td>
</tr>
</tbody>
</table>
Measures need to take

- Preventing from contamination when man enters clean room
  - Dressing and controlling pressure
- Air filtering
- Open building structure
  - No hinder for airflow
- No process generating damn
  - Example, polishing, sawing
- Cleaning in right way
  - Following up the instructions how one cleans

Cleaning

- Preventive and active care
  - Preventive: Prevent from contamination
  - Active: cleaning and decontaminating
- Cleaning
  - Vacuum cleaner: only effect for big particles (≥ 100 µm)
  - Wet and humid wiping
  - Stick mat
  - ......
- Using exact amount cleaning agent
- Cleaning agent should be supplied to the wipers, not pour or spray on the surface need to be cleaned
- Wiping in long straight line, not circulating or scrubbing
- Start from clean area to the dirty area
- Wipers should be folded so always use the clean side after working with the dirty side
- Work with the air flow direction
- Do not touch HEPA-filters
- ......
TO DO and NOT TO DO in the cleanroom

Not to do:
- Do not touch skin with gloves
- Do not touch equipment not working with
- Do not use perfume or cosmetic
- Do not use ordinary paper and pencil that leave dust or lint

To do
- Keep the hair under head cover
- Shave regularly, otherwise beard cover
- Change gloves whenever dirty or torn out
- Use fresh pair of gloves whenever handle wafers
- Change the dirty or damaged clothes
- Use clean room paper and particle-free overhead or boll-point pens
- Clean spillage immediately
- Remove used items
- Rinse the used glassware or other processing tools before put into dish washer
- Work calmly – no over-driven movement
- Clean afterwards

Safety considerations

In place, informing

Safety measures
Material, chemical, and gas safety data sheet in Klara
Risk assessments
Waste handling
Evacuating route
Some final words

- To work in the clean room requires knowledge, motivation and understanding
- Contamination is harmful, invisible
- One can not identify if the surface clean or not, how contamination is generated neither spread in a room
- Knowledge - avoid generating contamination/particles
- Follow detailed instructions and routines to carry out activities

Literature and references

- Renhetsteknik och rena rum: Matts Ramstorp
- Högteknologins osynliga fiende: Leif Månsson
- 41st R³ – Nordic symposium, Cleanroom technology, contamination control and cleaning
- Course note from ‘Grundkurs i renhetsteknik’
- Working experiences
Questions?

☐ Should we use vacuum cleaner in clean room? What type?

☐ Should we shake hand inside clean room when we greet each other?

Before the lab...

☐ Photolithography basics

☐ SU-8 2000 Permanent Epoxy Negative Photoresist

☐ Meet at entrance of the Device Physics Lab at 13:00 On Thursday, 12/9