Filtration Media

- **Fibers**
  - "depth" filters
  - many randomly oriented intertangled strands laid into a mat
    - Fourdrinier process, usually submicron glass fibers
  - void volume is typically about 85 - 90%
- **Membranes**
  - "surface" filters
  - homogeneous sheet material with holes punched into it
    - 1. cellulose nitrate; void volume is about 70 - 85%
      - holes formed by solvent evaporation, irradiation, or stretching
    - 2. polycarbonate sheets; void volume is about 10 - 20%
    - 3. PTFE sheets; biaxially stretched
    - 4. sintered silver particles

Clean Room Air Filters

- **High Efficiency Particulate Air (HEPA) Filters**
  - most common type of clean room air filter
  - high efficiency, low pressure drop, good loading characteristics
  - uses glass fibers in a paper-like medium
  - are rated by their particle retention:
    - A true HEPA-rated filter will retain 99.97% of incident particles of 0.3 µm or larger. (DEFINITION)

Fundamentals of Micromachining

Clean Rooms

How Big of a Particle is Tolerable?

- Example: 0.5 µm CMOS technology
- **Lateral Features**:
  - pattern size = 0.5 µm
  - pattern tolerance = 0.15 µm
  - level-level registration = 0.15 µm
- **Vertical Features**:
  - gate oxide thickness = 10 nm
  - field oxide thickness = 20 nm
  - film thicknesses = 250-500 nm
  - junction depths = 50-150 nm
HEPA History

- developed during WWII atomic bomb research for containment of radioactive aerosols
- called “superimpingement” or “superinterception” filters; later referred to as “absolute” filters
- first prototype filters used esparto grass as the filter medium
- in 1950s glass fibers were introduced into the paper
- in 1960s specifications were standardized and called HEPA filters
- in 1970s asbestos was removed
- in 1960 the first laminar flow bench was invented at Sandia National Laboratory
- HEPAs have now been developed by the semiconductor industry to far outstrip their original specifications

HEPA Filter Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Application</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>industrial, noncritical</td>
<td>&gt; 99.97% @ 0.3 μm (MIL-STD-282)</td>
</tr>
<tr>
<td>B</td>
<td>nuclear containment</td>
<td>&gt; 99.97% @ 0.3 μm</td>
</tr>
<tr>
<td>C</td>
<td>laminar flow</td>
<td>&gt; 99.97% @ 0.3 μm (MIL-STD-282)</td>
</tr>
<tr>
<td>D</td>
<td>ultra-low penetration air (ULPA)</td>
<td>&gt; 99.995% @ 0.12 μm (MIL-F-51477)</td>
</tr>
<tr>
<td>E</td>
<td>toxic, nuclear, and biohazard containment</td>
<td>MIL-F-51068 (classified performance)</td>
</tr>
</tbody>
</table>

Grade 1 = fire resistant
Grade 2 = semicombustible

HEPA / ULPA Characteristics

- Most submicron fabrication lines use Type-D ULPA filters as an improvement over traditional HEPAs for Class-1 and Class-10 environments.
- Usual size is 3 ft. x 6 ft. x 5.875 in. frame.
- When new, maximum pressure drop is 1 in of HO = 0.036 psi
- Each ft² of opening corresponds to about 50 ft² of paper area.
- Designed for 90 lfm air velocity, or 45.7 cm/sec.
- Designed for entraining 500 - 1000 grams of dust per 1000 cfm
- Are sealed into the ceiling using gel-sealed T-bars
- Typical lifespan is several years if air is properly prefiltered

HEPA Filter Construction

- Metal separator grids
- Pleated layers of fiber lay paper
- Pressboard frame
- Air flow direction
Clean Room Class Ratings

<table>
<thead>
<tr>
<th>Class</th>
<th># 0.5 µm particles per ft³</th>
<th># 5.0 µm particles per ft³</th>
<th>changes per hour</th>
<th>ceiling filter coverage (%)</th>
<th>air velocity (fpm)</th>
<th>max. temp. tolerance (°F)</th>
<th>RH tolerance</th>
<th>approx. capital cost per ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>office</td>
<td>12-18</td>
<td>65</td>
<td>30</td>
<td>10</td>
<td>7 cm/s</td>
<td>±3.0°F</td>
<td>±5%</td>
<td>$10</td>
</tr>
<tr>
<td>10,000</td>
<td>10,000</td>
<td>65</td>
<td>30</td>
<td>10</td>
<td>3.5 cm/s</td>
<td>±2.0°F</td>
<td>±5%</td>
<td>$200-250</td>
</tr>
<tr>
<td>5,000</td>
<td>5,000</td>
<td>65</td>
<td>30</td>
<td>10</td>
<td>1.25 cm/s</td>
<td>±1.0°F</td>
<td>±5%</td>
<td>$3,500-400</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>0.65</td>
<td>80-100</td>
<td>50</td>
<td>7.5-90</td>
<td>±0.5°F</td>
<td>±5%</td>
<td>$5,500</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.0065</td>
<td>500</td>
<td>50</td>
<td>250</td>
<td>±0.3°F</td>
<td>±2%</td>
<td>$5,500+</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.0033</td>
<td>540-600</td>
<td>100</td>
<td>100-110</td>
<td>±0.1°F</td>
<td>±1%</td>
<td>$25,000+</td>
</tr>
</tbody>
</table>

Types of Cleanrooms - 1

Clean Room Class Ratings

- Particles around the 0.1 µm size range are most difficult to filter.
- Reducing air velocity decreases the fractional penetration.
- New trend is to use electrostatic methods in series with HEPAs and ULPAs
  - Obtain a factor of 10 improvement from corona precharging
  - Obtain another factor of 10 improvement from corona precharging followed by collector electrification

Fractional Penetration of 0.1 µm Particles

- HEPA @ 7 cm/s: $10^{-3}$
- HEPA @ 3.5 cm/s: $10^{-4}$
- ULPA @ 7 cm/s: $10^{-4}$
- ULPA @ 3.5 cm/s: $10^{-5}$
- ULPA @ 1.25 cm/s: $10^{-5}$

Clean Room Class Ratings from ULSI Technology by Chang and Sze
Characteristics of Clean Rooms

- Air is recirculated through HEPA filters with about 20% make up.
  - Vapors are entrained, so contamination potential is very high
  - Extensive gas detection and alarm systems are installed
- Temperature is controlled to 68 - 72 °F.
- Humidity is controlled to 40 - 46% RH.
- Room is held at positive pressure
  - Typically 0.1 in of H₂O for Class 100, Class 1000, and Class 10,000
  - Typically 0.3 - 0.4 in of H₂O for Class 1 and Class 10
  - Positive pressure constantly blows dust OUT
  - (Biologic rooms operate at negative pressure to keep bugs IN)
- Doors open inward, so room pressure closes them shut
  - 0.1 in H₂O = 3.6 x 10⁻³ psi = 0.52 lb/ft²
  - This produces 9.1 lbs. force on a 7' x 30” door
Gowning - Class 10,000

- Putting On
  - Shoe Covers
  - Laboratory Coat
  - Hair Net
  - Safety Glasses
  - Clean Room Gloves

- Taking Off

Clean Room Dos and Don’ts

- Don’t:
  - touch your face or skin with gloves
  - touch building hardware, oily machinery, or wafer loading areas
  - lean on equipment
  - wear cosmetics, powders, or colognes
  - wear anything on fingers--remove all rings and bracelets
  - use paper, pencils or markers that leave dust or lint

- Do:
  - change gloves whenever they get dirty or torn
  - use a fresh pair of gloves whenever handling wafers
  - wipe down wafer handling areas with isopropanol
  - use clean room paper and dust-free ball point pens

Laminar Flow Benches

- A HEPA filter used to provide local clean air conditions
  - Can usually drop the class rating by 2 decades within a local area
  - Example: Class 100 local environment within a Class 10,000 room
- Designed to minimize turbulence which creates dust and dirt collection pockets
- Vertical style used above free standing equipment and load zones
- Horizontal style used behind microscope and inspection benches
- Benches usually have built-in air diffusers, lights, and occasionally shutters to close off the workspace from the outside

Vertical and Horizontal Laminar Benches

- Blower
- HEPA
- Air Intakes
- C-frame stand
- Work Stands
- Inspection Microscope
Bringing Items In and Out

- Everything should be double bagged
  - Use zip-lock bags or aluminum foil or plastic wrap
- Once cleaned and sealed inside a clean room, items should not be opened unit inside another clean room
- Standard clean and degrease is required for all new items entering the clean room