ePTFE UND eFRM MEMBRAN HEPA & ULPA FILTER
FÜR ANWENDUNGEN IN MIKROELEKTRONIK
UND PHARMAZIE

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Who We Are

• World’s Leading Air Conditioning and Air Filtration Company
• 2016 sales approximately $20B
• sales in over 150 countries
• 67,036 employees
• AAF Founded 1921

• 245 Subsidiaries
• 218 International
• 27 in Japan

HVAC Systems  Air Filtration  Chemicals

Goodman  AAF  Flanders

NIPPO MUKI CO.
PTFE - Polytetrafluoroethylene

Discovery

- Dr. Roy Plunkett (1910-1994) accidentally discovered PTFE on April 6, 1938 at DuPont.
- He had been looking for better coolant agent.
- Leaving a batch of TFE gas in a pressure container overnight, he found the next day a layer of a white translucent waxy solid, polymerized TFE: PTFE!
- Polytetrafluoroethylene was abbreviated to Teflon as registered as trademark in 1945.

Structure

- Fluorine saturated carbon chain (C₂F₄)n.
- Long chains with high molecular weight.
- Strong fluoro-carbon bonding.
- Fluorine atoms surround central ethylene carbon chain completely protecting it.
- Hydrophobic.
ePTFE – expanded PTFE

- **1958 Jan**: W.L. „Bill“ Gore (1912-1986) left his job at DuPont to pursue his belief in the untapped potential of PTFE and launched together with his wife W. L. Gore & Assoc. in the basement of their home in Newark, DE.

- **1969 Oct**: Their son Bob Gore accidently discovered expanded PTFE (ePTFE):
  - Frustrated with rods breaking when being stretched too slowly, he quickly draws a hot PTFE rod.
  - Bob finds that he can stretch PTFE 1000-times its original length.

- **1970**: 1st ePTFE commercial product – Teflon Pipe Tape Sealant.

- **1973**: Industrial filter bag business begins, expanded PTFE is used for filtration, pioneering membrane surface filtration to capture contaminants and other particles.

- **1976**: ePTFE Gore-Tex in apparel was introduced.

- **1994**: ePTFE membrane HEPA filter for deep filtration revolutionized filtration for microelectronic cleanrooms due to ultralow low emission of volatiles.
Glass Fiber Media

- First developed in the 1940's
- Slurry of glass fibers in water with binder
- Poured on a moving screen conveyor
- Water vacuumed from below
- Baked dry in an oven
- Pleated into packs
- Potted in urethane in filter frames

Media is delicate and vulnerable at every stage of manufacturing, filter installation to testing

Media is extremely fragile

Glass Fiber in use 75+ Years

Industry ‘standard’ for high efficiency filtration
1988 Daikin discovered ultrafine fiber structure

- Starts with ‘fine powder’
- Mixing & pre-forming paste
- Paste extrusion
- Stretching/drying/calandering
- Stretching-Scoring
- Laminating/Pleating

**Whole process controlled in a cleanroom environment**

- **Media is VERY robust.**
- e-PTFE approx. 30 years
- Semicon application adoption late 1990’s
e-PTFE Membrane Media

- Single layer of expanded PTFE supported by a layer of spun bonded synthetic media on the upstream and downstream side.
- Available in H13 – U17
- Standard for Microelectronic and Tool Market
- Compatible with Discrete Particle Counters (DPC) testing
HEPA filter media

**ePTFE membrane**
- ave. pore size 0.5 – 1 µm, effective pore size much smaller
- 100 million pores per cm²
- about 1.000 - 2.000 pores across the tip of a ball point pen
HEPA filters are tested in the factory by filter manufacturer using DPC (Discrete Particle Counter) and are supplied together with test certificate.

HEPA filters are leak tested in situ to:
- **test for leakage** of filter medium and sealant to frame due to transport, installation mishaps and/or misuse of the filter element and
- **test for bypass** in the frame, housing, gasket seal and grid system.

It’s a leakage test no performance test re-approving filter class!

### HEPA filter validation (leak testing)

<table>
<thead>
<tr>
<th>methods</th>
<th>principle</th>
<th>pharma: leak testing</th>
<th>pharma: monitoring</th>
<th>micro-electronic: general</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPC</td>
<td>counting single particles passing measuring volume</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>photometer</td>
<td>measuring attenuation of light by cloud of particles</td>
<td>/X</td>
<td>X</td>
<td>X</td>
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</tbody>
</table>

### Methods usage in leak testing

<table>
<thead>
<tr>
<th>methods</th>
<th>usage in leak testing</th>
<th>H14</th>
<th>H15</th>
<th>U16</th>
<th>U17</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPC</td>
<td>for all filter classes used in pharma in German speaking countries (DACH)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>photometer</td>
<td>for H14 traditionally used in pharma in non-DACH countries</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Aerosol challenge concentration

- DP C: 
  - $\approx 0.03 - 0.3$ mg/m$^3$

- Photo meter: 
  - $\approx 5 - 40$ mg/m$^3$

$\mu$g/l = mg/m$^3$
e-FRM Membrane Media

- Dual layer of expanded Fluororesin supported by a layer of spun bonded synthetic media on the upstream and downstream side
- Available in H13 – H14
- High DHC on Oil Based aerosols.
- Compatible with photometric test methods
e-PTFE is a 3 layer composite with 2 layers of PE/PET (Polyethylene/Polyethylene Terephthalate) Scrim on both air entering side and air leaving side. The composite media is uni-directional.
e-FRM is a 4 layer composite with 2 layers of PE/PET (Polyethylene/Polyethylene Terephthalate) Scrim one layer each on air entering side and air leaving and 2 layers of the eFRM membranes in the middle as shown in figure 5. The composite media is uni-directional. The eFRM membrane on the air entering side is more open giving the media a gradient density.
Proven Durability—84x the Pleated Strength of Microglass

During:
- filter installation
- filter validation
- cleaning of ceiling
- cleanroom modifications
- working activities in the cleanroom

Risk of filter damage, resulting in:
- cleanroom downtime
- unscheduled replacements
- costly recovery actions
- cross contamination
- uncontrolled release of harmful substances

VERY FRAGILE
Very thin fibers – Less energy consumption

- ePTFE membrane at 10,000x magnification
  - 0.02 - 0.2 µm
  - Much finer (nano) fiber diameters with slip-flow air movement
  - HIGHER efficiency and LOWER pressure drop (up to 50%)

- Glass fibers at 10,000x magnification
  - 0.5 - 1.0 µm

ePTFE membrane filtration technology provides the highest efficiency at the lowest operating resistance
Comparision glass media vs. ePTFE HEPA

MEGAcel I (ePTFE membrane) vs AstroCel I (glass media)
610x610x292mm, H14

*this MEGAcel I to be tested by DPC
Oil loading behaviour traditional ePTFE membrane

- **Traditional ePTFE membrane**
- **Glass fiber media type K**
- **Glass fiber media type J**

Data taken from:
Devine, S., O'Reilly, S., Stillo, A., Thornburg, D.,
“A science based approach to selecting air filters”,
Pharmaceutical Engineering,
Vol. 33, No. 1, Jan/Feb 2013
Oil loading behaviour advanced ePTFE membrane

Thanks to:
Milholland & Associates,
Holly Springs (NC), USA,
for conducting these tests.

592x592x69mm MEGAcel II
50mm mini pleat filter pack
535 m3/h
0,45m/s
E>99,9999% @ 0,3µm

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**Pressure drop vs loading time @ 15µg/l exposure**

- Blue line: glass media
- Red line: ePTFE membrane

- Life time (1h exposure/6month):
  - 6 years
  - 9 years
  - 12 years
  - 15 years
  - 18 years

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Benefits of ePTFE membrane HEPA filter

Increased safety of critical processes
- Unmatched mechanical stability and chemical resistance are nearly completely eliminating risk of uncontrolled particle release

Potential savings in initial cleanroom investment
- Smaller fan motor power requirements, also requiring less cooling, because of low operating resistance
- Reduced construction depths because of smaller media pack depths

Cost savings during HEPA filter lifetime
- Lower energy costs because of low operating resistance
- Reduced noise in the cleanroom
- Fewer premature filter replacements because of superior mechanical strength and water and chemical resistance
- Reduced downtime costs, recovery expenditures and re-qualification and other costs from filter media failure
Why AAF Membrane Technology?

- **High Collection Efficiency**
  - H13 – H14 eFRM
  - H13-U17 ePTFE

- **Low Pressure Drop**
  - Up to 50% lower
  - Reduces energy cost
  - Reduces construction depths

- **Low Off Gassing**
  - Extreme low impurities
  - No Boron
  - Low Dopant Content
  - Improved yield
  - Reduced probability of contamination from filter

- **High Durability**
  - Reduces transport and installation damage risk
  - No Boron
  - Hydrophobic media
  - Media tensile strength is 84X that of standard micro-fiberglass media
  - Improved yield
  - Reduced probability of contamination from filter

- **High Chemical Resistance**
  - Hydrofluoric acid resistance
  - No media degradation from H₂O₂, alkaline, acid, and organic substances
  - Longer life expectancy
“The electric light did not come from the continuous improvement of candles.”

Prof. Oren Harari
Global and Strategic Management
University of San Francisco
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