The Use of PVDF in Additive Manufacturing

Howard Fisher, Ph.D.
### Nile Polymers

- Manufacture parts from PVDF using injection molding
  - Cable Ties
  - Mixers
  - Snap Lock Fittings

<table>
<thead>
<tr>
<th>Advantages</th>
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</thead>
<tbody>
<tr>
<td>High quality surface</td>
</tr>
<tr>
<td>Large quantities</td>
</tr>
<tr>
<td>Tight tolerances</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages</th>
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</thead>
<tbody>
<tr>
<td>Mold cost</td>
</tr>
<tr>
<td>Manufacturing time</td>
</tr>
<tr>
<td>What if only 20 parts are needed?</td>
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</tbody>
</table>
Fusion Deposition Manufacturing (FDM)

- **Advantages**
  - Lower entry cost
  - Prototype
  - Manufacture small quantities

- **Disadvantages**
  - Consumer grade materials
What is FDM?
What is PVDF?

Polyvinylidene Fluoride

Zero flame propagation - LOI > 40%

Resistant to UV and ionizing radiation

Excellent chemical resistance
  - Acids, caustics, solvents

Several varieties including Kynar®
  - PVDF manufactured by Arkema
    - ppb extraction level
    - USP Class VI
Variety of homopolymer and copolymers available
Wide melt processing window
Non-corrosive melt
Melt compatibility with acryics
3D Printing Process

- **Kynar® 710 homopolymer reactor bead**
- **Filament extrusion using desktop extruder**
- **Printing on Lulzbot Mini machine**
Kynar® 710
Homopolymer

- Melting Temperature: 165 - 172°C
- Elongation at Break: 20 - 100%
- Tensile Strength: 45 - 55 Mpa
- Excellent Creep Resistance
- Well known history in the CPI industry
Lab Extrusion

- **Vertical extrusion format**
- 0.5mm to 3.0 mm filament
- ~0.5 - 1.0 kg per hour
- Four separate heating zones in the barrel
- Extrusion of materials up to 450 C
- Filament diameter controlled by laser measurement feedback to the pulling wheel
- Quick material change out
Lulzbot Mini

- Control Material Parameters
  - Extrusion Temperature
  - Heated Bed
- Simple to clear hot end
- Tolerant of filament diameter variations
- Auto leveling and self-cleaning features
- Wide installation base
Printing Guidelines with PVDF

- Use every adhesion technique available:
  - Heated bed slows cooling rate and helps reduce part warpage (100°C)
  - Glue stick on the heated bed as an adhesive
  - PEI print surface
  - 10 mm raft

- Nuclear Option: Use of PMMA (Plexiglass®) as the print surface

- Print temperature: 240°C

- Print rate: 30 mm/sec
## 50 cm Test Cube Results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Material</th>
<th>Raft</th>
<th>Infill</th>
<th>Print Speed</th>
<th>Layer Height</th>
<th>Print Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Kynar® 710</td>
<td>10 mm</td>
<td>50%</td>
<td>50 mm/sec</td>
<td>0.38 mm</td>
<td>~4 hours</td>
</tr>
<tr>
<td>Center</td>
<td>Kynar® 710</td>
<td>10 mm</td>
<td>50%</td>
<td>40 mm/sec</td>
<td>0.25 mm</td>
<td>~6 hours</td>
</tr>
<tr>
<td>Right</td>
<td>Kynar® 710</td>
<td>10 mm</td>
<td>50%</td>
<td>30 mm/sec</td>
<td>0.14 mm</td>
<td>~8.5 hours</td>
</tr>
</tbody>
</table>
Examples of Kynar® PVDF Prints
Market Status of PVDF Filament

- Filament is not easy to source
- Filament is very expensive
- Nile Polymers Fluoronar™ PVDF Filament with Kynar® 710
  - Available in 1.75mm and 2.85 mm sizes
- 3D Printer in every lab and facility
Thank You!
Booth 808