Veranstaltungsreihe / researchXchange: Parylene-based encapsulation technology for wearable or implantable electronic devices
09. Dezember 2022
THE COMPANY

LEADER IN THIN FILM ENCAPSULATION

Solution provider

- Founded in 2016
- Headquarters @ Microcity La Chaux-de-Fonds, Switzerland
- Financed by two private investors, one strategic investor and 4 founders
- 15 (Switzerland) engineers and technicians
- 2 sales representatives for USA and Northern Europe
- COAT-X Japan has been founded in 2021
- Headquarters in Shinshiro
- 3 engineers and 2 sales persons
AN INTERNATIONAL FOOTPRINT

Coat-X sales representatives

Coat-X and affiliates
THE PROBLEM...

Packaging challenge for electronic or medical devices:

- Limitation in miniaturization
- Complex welding process
- Rigid and non-flexible
- Cost intensive
Conformal multilayer packaging:
• Allows significant miniaturization
• Controlled deposition at room temperature
• Transparent / flexible
• Reduced costs
• 2’000 times more waterproof than Parylene!

Ceramic layers which high tightness are integrated into conventional Parylene layers.
Parylene coatings by CVD are defect-free and conformal. But, they are not absolutely tight at molecular level.

Ceramic coating by CVD have pinholes and cracks due to high internal stress. But, they are tight at molecular level.
OUR COATING PORTFOLIO

Tightness level

Super-Hydrophilic / Hydrophobic

Parylene

Ceramic

Multilayer

Heat Resistant

Application-specific barrier coatings
COAT-X SERVICES AND PRODUCTS

1. Coating Services (PE-CVD, CVD, ALD)
   - Parylene-C, Parylene-F, Parylene-N
   - Ceramic coatings (SiO$_2$, SiC, SiO$_x$N$_y$, Al$_2$O$_3$, TiO$_2$)
   - Multilayered combinations
   - Masking/demasking
   - ISO 13485, ROHS, REACH compliance

2. Solution Development Verification
   - Hermeticity measurements
   - Adhesion tests
   - Corrosion tests
   - Accelerated aging tests
   - Network of experts for test outsourcing*

3. Technology Transfer
   - Tailored reactor design
   - Tech licensing
   - Reactor renting & servicing
   - Co-development and research partnership

(* MEB, XPS, WVTR, aging, ...)

COAT-X
## Parylene Grades

![Structural formulas for N, C, VT-4, and AF-4 grades]

<table>
<thead>
<tr>
<th>Property</th>
<th>Parylene XPC</th>
<th>Parylene XPN</th>
<th>Parylene XPD</th>
<th>Parylene XPF1</th>
<th>Parylene XPF2</th>
<th>SiO2 XCR (°C)</th>
<th>Multilayer ML3</th>
<th>Method ASTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/cm³)</td>
<td>1.29</td>
<td>1.10-1.12</td>
<td>1.42</td>
<td>1.3-1.5</td>
<td>1.65</td>
<td>2.17-2.65</td>
<td>-</td>
<td>D1505</td>
</tr>
<tr>
<td>Index of refraction (n₀)</td>
<td>1.64</td>
<td>1.66</td>
<td>1.67</td>
<td>1.56</td>
<td>1.57</td>
<td>1.40-1.50</td>
<td>-</td>
<td>Abbe Refractometry</td>
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<tr>
<td>Transmission visible range (%)</td>
<td>&gt;90</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>&gt;85</td>
<td>&gt;85</td>
<td>UV-Vis Spectrophotoscopy</td>
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<tr>
<td>Friction Coefficient Static</td>
<td>0.29</td>
<td>0.25</td>
<td>0.35</td>
<td>0.15</td>
<td>0.39</td>
<td>-</td>
<td>-</td>
<td>D1894</td>
</tr>
<tr>
<td>Friction Coefficient Dynamic</td>
<td>0.29</td>
<td>0.25</td>
<td>0.31</td>
<td>0.13</td>
<td>0.35</td>
<td>-</td>
<td>-</td>
<td>D1894</td>
</tr>
<tr>
<td>Temporary peak temp. (°C)</td>
<td>80-100</td>
<td>60-80</td>
<td>100-120</td>
<td>550</td>
<td>140-200</td>
<td>1050</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Durable heat Resistance (°C)</td>
<td>115</td>
<td>95</td>
<td>130-135</td>
<td>450</td>
<td>250-350</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Melting point (°C)</td>
<td>290</td>
<td>420</td>
<td>380</td>
<td>&gt;500</td>
<td>435</td>
<td>-</td>
<td>-</td>
<td>DSC</td>
</tr>
<tr>
<td>Dielectric Constant (1 MHz)</td>
<td>2.95</td>
<td>2.66</td>
<td>2.8</td>
<td>2.17</td>
<td>2.35</td>
<td>-</td>
<td>-</td>
<td>D1500</td>
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<td>Breakdown voltage DC (V)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1µm</td>
<td>1100</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10µm</td>
<td>3500</td>
<td>4000</td>
<td>-</td>
<td>-</td>
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<tr>
<td>25µm</td>
<td>5800</td>
<td>7000</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Hardness Rockwell (HR)</td>
<td>80</td>
<td>85</td>
<td>80</td>
<td>122</td>
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<td>-</td>
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<tr>
<td>WVTR (g.mm)/(m2.day)</td>
<td>0.1</td>
<td>0.75</td>
<td>0.12</td>
<td>0.28</td>
<td>0.32</td>
<td>-</td>
<td>6.00E-04</td>
<td>F1249-06</td>
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</tbody>
</table>
TRANSPARENT CERAMIC COATING

Thin and transparent ceramic coating by PE-CVD to protect noble metals, stainless steel and alloys.
## Multilayer vs. Single layer

**Water permeation measurements (WVTR) according ASTM F 1249**

<table>
<thead>
<tr>
<th>Materials</th>
<th>WVTR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[g um m⁻² day⁻¹]</td>
</tr>
<tr>
<td>Silicone</td>
<td>25000</td>
</tr>
<tr>
<td>Acrylic</td>
<td>14000</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>1500</td>
</tr>
<tr>
<td>Epoxy</td>
<td>950</td>
</tr>
<tr>
<td>Parylene N</td>
<td>590</td>
</tr>
<tr>
<td>PET</td>
<td>500</td>
</tr>
<tr>
<td>Parylene C</td>
<td>80</td>
</tr>
<tr>
<td>SiO₂ (PE-CVD)</td>
<td>15</td>
</tr>
<tr>
<td>Al₂O₃/TiO₂ (ALD)</td>
<td>8</td>
</tr>
<tr>
<td>Multilayer (PE-CVD)</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Multilayer (ALD)</strong></td>
<td><strong>0.003</strong></td>
</tr>
</tbody>
</table>

→ A 2 µm Multilayer has the same protection performance than an epoxy layer of 10 cm and a silicone layer of 300 cm.
Multilayer vs. Single layer

Water permeation measurements according ASTM F 1249

The Calcium mirror test shows a WVTR of $4 \times 10^{-3}$ g/m²/day for a 5 µm multilayer at 38°C and 90% RH (ASTM F 1249).


→ 2000 times better than conventional Parylene-C
Multilayer vs. Single layer

Multilayers of Parylene and ceramic provide much tighter encapsulation than single Parylene layer or allow thickness reduction and faster deposition to ensure similar tightness.
CORROSION PREVENTION WITH MULTILAYER COATING

- Corrosion-sensitive permanent magnets are protected with the thin-film encapsulation technology of Coat-X
- Electrochemical dissolution of the metallic alloy is prevented
- Applied to surgical electro-motors, this allows resistance to hundreds of sterilization cycles
MEDICAL APPLICATION

Protection of rare earth metals (for magnets)

The eyeWatch system

Central magnet coated with Coat-X Multilayers

Silicone tubing

Ruby spheres

metallic ring
CORROSION PROTECTION WITH MULTILAYER

- Superior performance barrier coating (liquid & gas)
- 3D conformal protection of complex microstructures
- Single reactor, room temperature, batch process
- Transparent, flexible and biocompatible
Protection of implantable electronic with multilayer parylene coating

- RF tags including sensing capabilities have been encapsulated with a 10-micron multilayer coating from COAT-X. It combines alternating Parylene and ceramics layers. No other packaging material nor casing was used.

- The multilayer coating was prepared using COAT-X proprietary PE-CVD technology.

- An accelerated aging test protocol was developed to demonstrate the long-term performance of the technology in the human body. The devices have been immersed at 87°C in Phosphate Buffered Solution (PBS) for several months to simulate years of implantation.

- Contactless interrogation of the RF tag was performed on a regular basis to verify proper function of the device.

After more than 14 years of simulated implantation all tags are still fully functional. The test is extended to reach 20 years of implantation.
Thermal cycling of various PCB’s with multilayer parylene coating

- Various types of PCB have been encapsulated with COAT-X multilayer parylene coating and submitted to thermal cycling.
- Up to 1000 cycles have been performed and the surfaces inspected.
- The coating is very robust on all PCBs, including on solder masks.
- It demonstrate the high tolerance of the technology towards large temperature cycles, without delamination or cracks.

Electronics still functional up 1000 cycles
No damages to the protecting multilayer film and could be observed
Surface functionalization

SUPER HYDROPHOBIC COATING

- Hydrophobic very thin ceramic films make any surface water repellent.
- Fluorene free
- Biocompatible
- OEKO-TEX validated
- Compatible with organic materials
Aerosol Filtration Testing of Fabrics for Development of Reusable Face Masks

Fig. 10. Influence of coating on aerosol particle size-selective filtration performance. (A) Four materials before and after coating, with the increase in contact angle in overlay. (B, C) Average filtration efficiency over 10 coated and non-coated fabrics for particles smaller and larger than 0.5 μm. (D) Percentage of filtration improvement per particle size.

ESTABLISHED CUSTOMER BASE - PROVEN TECHNOLOGY

Minimally invasive surgical instruments

Rheon Medical – implant for glaucoma treatment

Implant for lymphedema treatment

Probe for water analysis

Microelectrodes array for bioassay

Boucheron – high jewelry
COAT-X develops and manufactures CVD and PE-CVD production equipment

- Tailored-made to meet specific customer requirements
- Large chamber for better productivity
- Fully automated an integrated processes (activation, Parylene and ceramics deposition)
- Development and verification of application-specific recipes
Production Line

Installation of lean production line into clean room (ISO 5)

✓ Single chamber process
✓ Ambient temperature
✓ Cleanroom performance
✓ ESD compatible
✓ Certification for Medical Devices ISO 13485:2016
Thank you for your attention