A High-Performance/High-Temperature Resin for Implantable Devices

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A Brief History: NASA HSR Program:

- Develop a **matrix resin** and **high performance adhesive** that provides continuous service for **10,000 hrs at 177°C** – properties defined by Boeing.

- Maximum processing conditions are **350°C, 100 psi**.

- Use as many **COTS monomers** as possible.
LaRC™-SI - synthesized from the following commercially available monomers:

**Dianhydrides**

- ODPA
- BPDA

**Diamine**

- 3,4’-ODA

Molar ratio of ODPA to BPDA is typically 1:1, but can be adjusted up to 1:3 favoring either dianhydride. Glass transition temperatures range from 230°C to 265°C depending on the offset and chemistry used.

**LaRC™-SI Performance** - excellent processability and mechanical properties. LaRC™-SI is solution processable as the polyamic acid and as the final polyimide. The polyimide also lends itself readily to melt processing. Thus, a wide range of processing options are available. Neat resin, adhesive and composite properties are excellent.

**LaRC™-SI Cost** - the cost when compared to conventional high performance polymers (e.g. polyimides) is relatively high. Cost is based on economics of scale.
**NASA’s LaRC™-SI : Room Temp. Properties:**

<table>
<thead>
<tr>
<th>Table</th>
<th>Neat Resin</th>
<th>IM7 Composite*</th>
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</thead>
<tbody>
<tr>
<td>Tg (°C)</td>
<td>248 - 251</td>
<td>SBS Str. (MPa) 95</td>
</tr>
<tr>
<td>Density (g/mL)</td>
<td>1.376</td>
<td>0° Flex Str. (MPa) 1600</td>
</tr>
<tr>
<td>Hardness (HK50)</td>
<td>23-27</td>
<td>Modulus (GPa) 134</td>
</tr>
<tr>
<td>Thermal Cond. (W/m-K)</td>
<td>0.244</td>
<td>DCB Fract. Tough. (kJ m(^{-2})) 1.72</td>
</tr>
<tr>
<td>CTE (ppm °C)</td>
<td>48 - 60</td>
<td>90° Flex Str. (MPa) 144</td>
</tr>
<tr>
<td>Tensile Str. (MPa)</td>
<td>141</td>
<td>0° Tensile Str. (GPa) 2.71</td>
</tr>
<tr>
<td>Tensile Mod (GPa)</td>
<td>4.05</td>
<td>IITRI Comp. Str. (MPa) 1.03</td>
</tr>
<tr>
<td>K(_{1c}) (MN/m(^{3/2}))</td>
<td>4.4</td>
<td>OHC Str. (MPa) 296</td>
</tr>
<tr>
<td>G(_{1c}) (MN/m(^2))</td>
<td>4.6</td>
<td>CAI str. (MPa) 348</td>
</tr>
<tr>
<td>Ti/Ti Lap Shear (MPa)</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Al/Al Cleave Str. (MPa)</td>
<td>17</td>
<td></td>
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</table>

*60/40 (v/v/) Fiber/Resin
LaRC™-SI Thermoplastic / Thermoset Roadmap:

**Reactor**
- PAA Solution
  - Film
  - Varnish
- PI Solution
  - Prepreg

**Base Products**
- PI Powder
- Molded Stock
- Extruded Stock
- Powder Coating

**Applications**
- Adhesives: supported and unsupported
- Thin Dielectric / Protective: Wire, Fiber optic, Spray coat
- Composites: structural foam, FR-dielectric
- Mechanical Parts: filled & Unfilled
- Melt Production: Fiber, Film, Tubes, Parts
- Thick coating: Parts, pipes, structure, porous & solid

**Demonstrated Products**
- Thin Films for Flexible Circuitry & Cables
- Coated Wire
- Optical Fiber Cladding
- Carbon Fiber and E/S-glass Prepreg
- Rigid and Flexible Foam
- Extruded Rods, Fibers, Film, Wire Insulation and Hollow tubing
- Compression Molded Articles (Gears, Rings, etc)
- Advanced Composites
- Hot Melt Adhesive film
- Flame Sprayed Protective Coatings
- Multilayer flexible and Semi-rigid circuits

**TRL**
- TRL 1-4 Lab to Vendor
  - Repeatability & Supply
- TRL 4-7 Vender to OEM
  - Reliability & Verification
- TRL 7-9 OEM to Customer
  - Testing & Economics
**NASA’s LaRC™-SI : (Products):**

LaRC™-SI has been solution processed to produce the following:
- Thin Films for Flexible Circuitry and Cables
- Wire Coating
- Optical Fiber Cladding
- Supported and Unsupported Adhesive Films
- Carbon Fiber and E-glass Prepreg
- Sprayable Ultrathin Coatings
- Rigid and Flexible Foam

LaRC™-SI coated pacemaker lead wires

LaRC™-SI has been melt processed to produce the following:
- Extruded Rods, Fibers, Film, Wire Insulation and Hollow Tubing
- Compression Molded Articles (Gears, Rings, etc)
- Advanced Composites
- Hot Melt Joining of Various Metals
- Flame Sprayed Protective Coatings
- Multilayer flexible and Semi-rigid Circuits

3-Layer SI high speed A/D flex circuit board

LaRC™-SI mechanical parts
NASA’s LaRC™-SI: Medtronic Pacemaker Lead

“Surgeons wanted us to develop small diameter leads that could navigate the intricate curves of the heart’s left side. The common wisdom in the industry was that silicones and polyurethanes were the only available materials with properties acceptable for insulating leads. But, with those materials, it was extremely difficult to design a truly small lead. It seemed that this new polyimide might open the way to smaller leads and provide better therapy for heart failure patients.”

- Ken Brennen, Medtronic

SI Polyimide (SI-PI) is a unique polyimide developed by the NASA Langley Research Center. The material was specifically created by NASA to withstand harsh environments and extreme temperatures. SI Polyimide has all the features of conventional polyimide, plus the added benefits of hydrolytic stability and self-adhesiveness. Medtronic optimized the wire coating process, enabling SI Polyimide to be applied for the first time to an implantable medical device.”

- Medtronic

<table>
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<tr>
<th>Benefit</th>
<th>Specifications</th>
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| Trackability     | • Lead body – 4 Fr  
                  | • Tip electrode – 4.6 Fr  
                  | • Ring electrode – 5.1 Fr  
                  | • Flexible distal end |
| Programmable Repositioning | • Polarity – Bipolar (dual electrode)  
                             | • Electrode surface area – 5.8 mm² (each)  
                             | • Electrode spacing – 21 mm |
| Stability        | • Fixation – Cants                                  |
| Performance      | • Insulation  
                  |   • Inner: SI-Polyimide (SI-PI)*  
                  |   • Outer: Polyurethane 5SD |

*Technology developed by NASA
NASA’s LaRC™-SI: Medtronic Pacemaker Lead

http://www.youtube.com/user/TechnologyGateway#p/u/7/uCw26BFRYVw
Collaboration Opportunities

Seeking potential licensees to serve as commercial partners

Material Characteristics:
- Biologically inert
- FDA-approved
- Moisture resistant
- Radiation resistant
- Resistant to oxidation
For further information, please contact:

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