

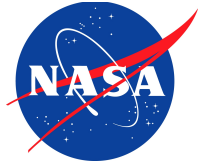
A High-Performance/High-Temperature Resin for Implantable Devices

Robert G. Bryant, PhD

Branch Head, Advanced Materials & Processing Branch

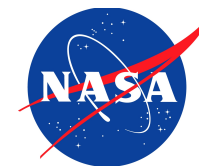
NASA Langley Research Center

A Brief History : NASA HSR Program:



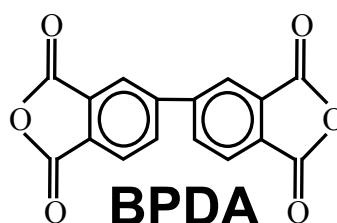
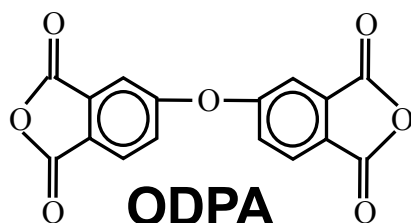
- Develop a **matrix resin** and **high performance adhesive** that provides continuous service for **10,000 hrs at 177°C** – properties defined by Boeing.
- Maximum processing conditions are **350°C, 100 psi**.
- Use as many **COTS monomers** as possible.

NASA's LaRC™-SI : Chemistry:

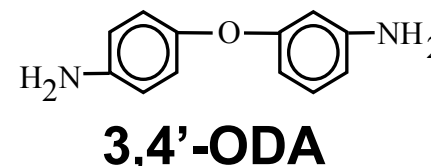


LaRC™-SI - synthesized from the following commercially available monomers:

Dianhydrides



Diamine

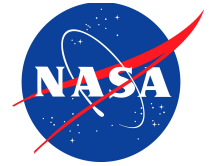


Molar ratio of ODPA to BPDA is typically 1:1, but can be adjusted up to 1:3 favoring either dianhydride. Glass transition temperatures range from 230°C to 265°C depending on the offset and chemistry used.

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.

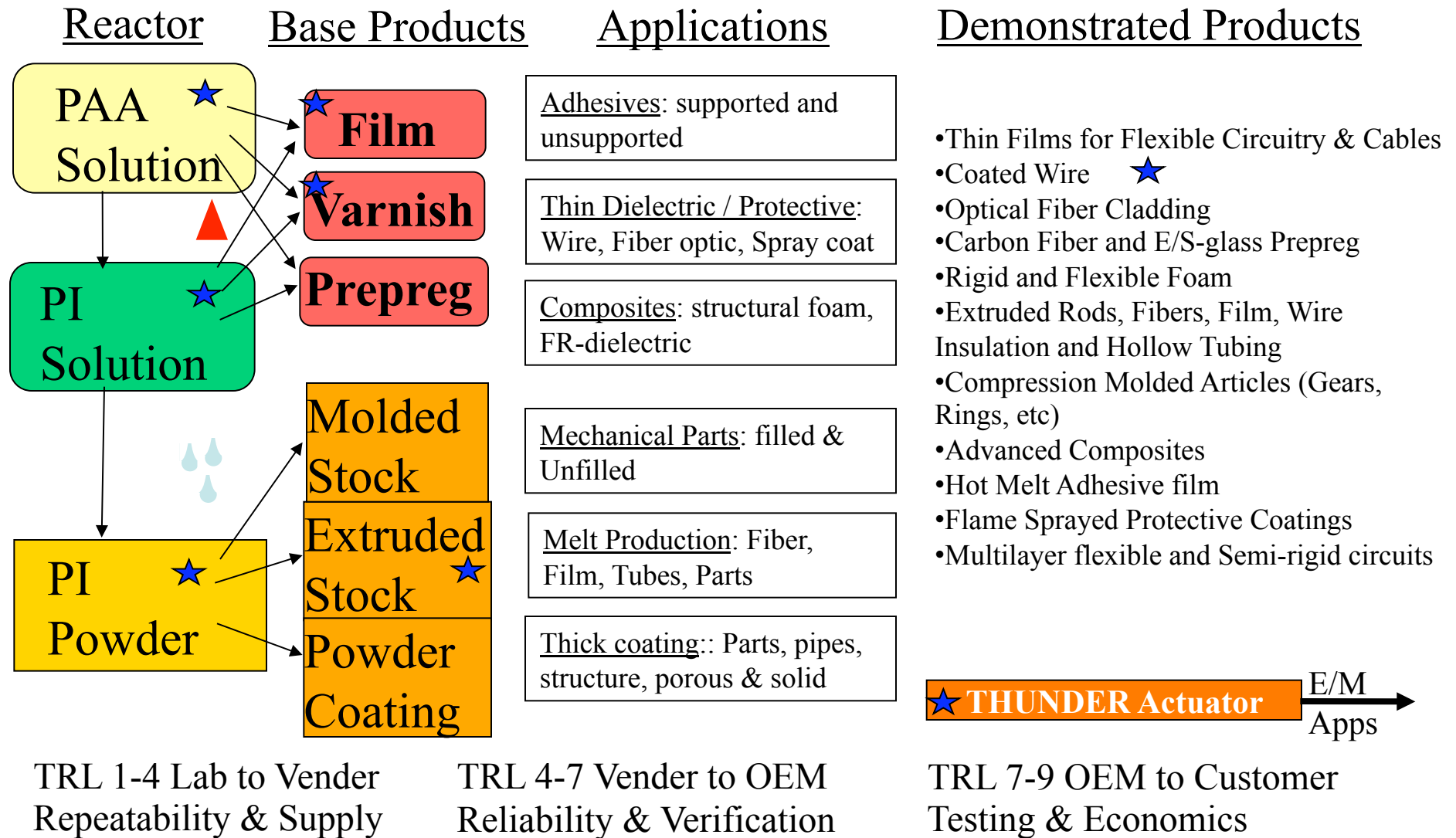
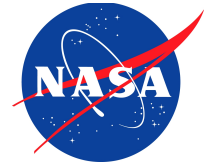
NASA's LaRC™-SI : Room Temp. Properties:

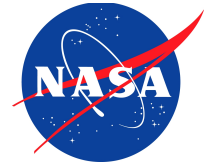


Neat Resin		IM7 Composite*	
Tg (°C)	248 - 251	SBS Str. (MPa)	95
Density (g/mL)	1.376	0° Flex Str. (MPa)	1600
Hardness (HK50)	23-27	Modulus (GPa)	134
Thermal Cond. (W/m-K)	0.244	DCB Fract. Tough. (kJ m ⁻²)	1.72
CTE (ppm °C)	48 - 60	90° Flex Str. (MPa)	144
Tensile Str. (MPa)	141	0° Tensile Str. (GPa)	2.71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

*60/40 (v/v) Fiber/ Resin

LaRC™-SI Thermoplastic / Thermoset Roadmap:



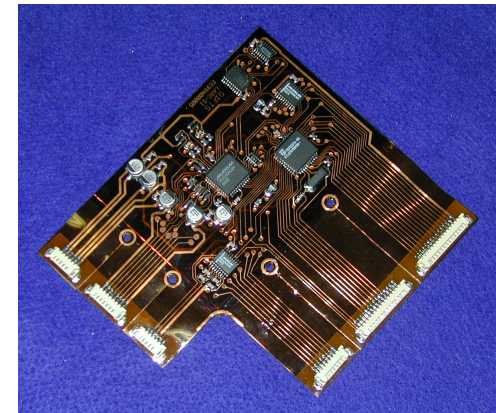


NASA's LaRC™-SI : (Products):

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



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

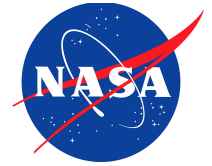
LaRC™-SI has been melt processed to produce the following:

- . 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



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.”

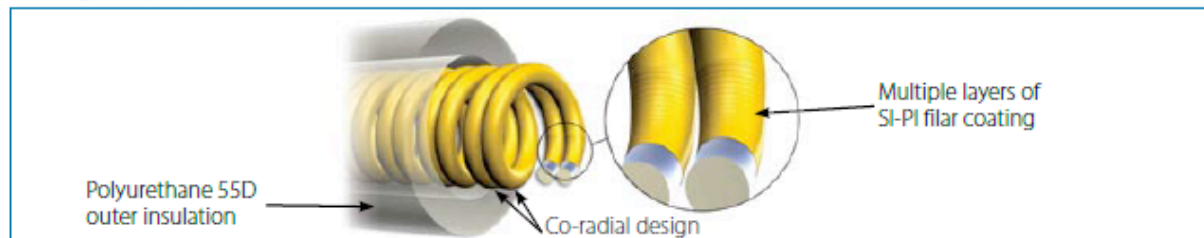
- Ken Brennen, Medtronic

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.”

Benefit	Specifications
Trackability	<ul style="list-style-type: none"> • Lead body – 4 Fr • Tip electrode – 4.6 Fr • Ring electrode – 5.1 Fr • Flexible distal end
Programmable Repositioning	<ul style="list-style-type: none"> • Polarity – Bipolar (dual electrode) • Electrode surface area – 5.8 mm² (each) • Electrode spacing – 21 mm
Stability	<ul style="list-style-type: none"> • Fixation – Cants
Performance	<ul style="list-style-type: none"> • Insulation <ul style="list-style-type: none"> – Inner: SI-Polyimide (SI-PI)* – Outer: Polyurethane 55D

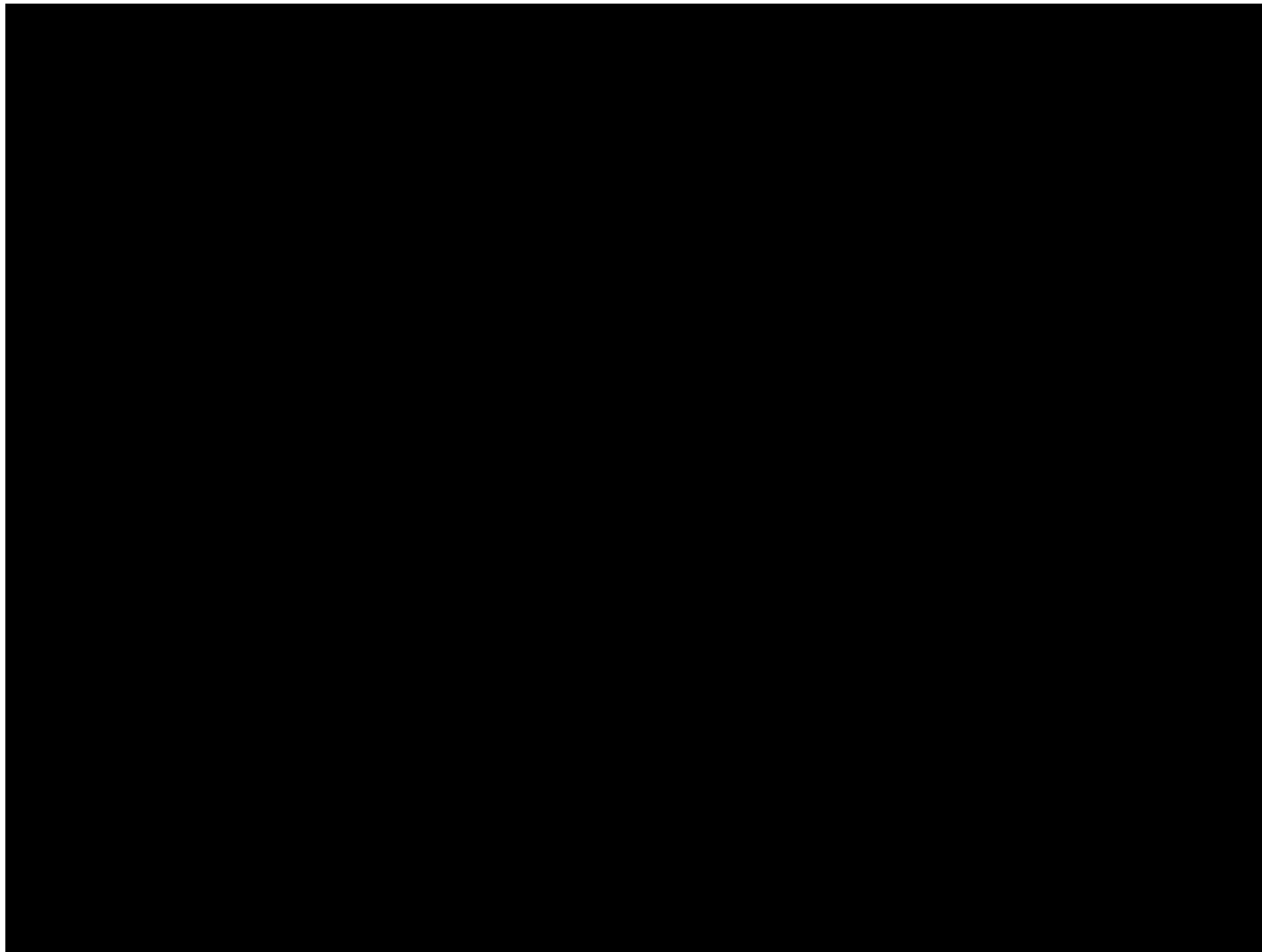
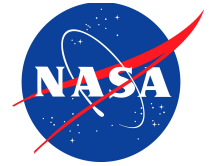


*Technology developed by NASA

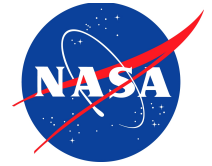


- Medtronic

NASA's LaRC™-SI: Medtronic Pacemaker Lead



<http://www.youtube.com/user/TechnologyGateway#p/u/7/uCw26BFRYVw>



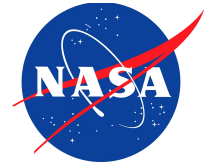
Collaboration Opportunities

Seeking **potential licensees** to serve as commercial partners



Material Characteristics:

- ⊕ Biologically inert
- ⊕ FDA-approved
- ⊕ Moisture resistant
- ⊕ Radiation resistant
- ⊕ Resistant to oxidation



Contact Information

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