Resins in power magnetic design

Potting and Encapsulation

Matching chemistry to performance

Power Magnetics @ High Frequency Workshop

PSMA Magnetics Committee - 18 March 2023, Orlando FL USA

PSMA

pels IEEE POWER ELECTRONICS SOCIETY Powering a Sustainable Future

Darryl Lallande

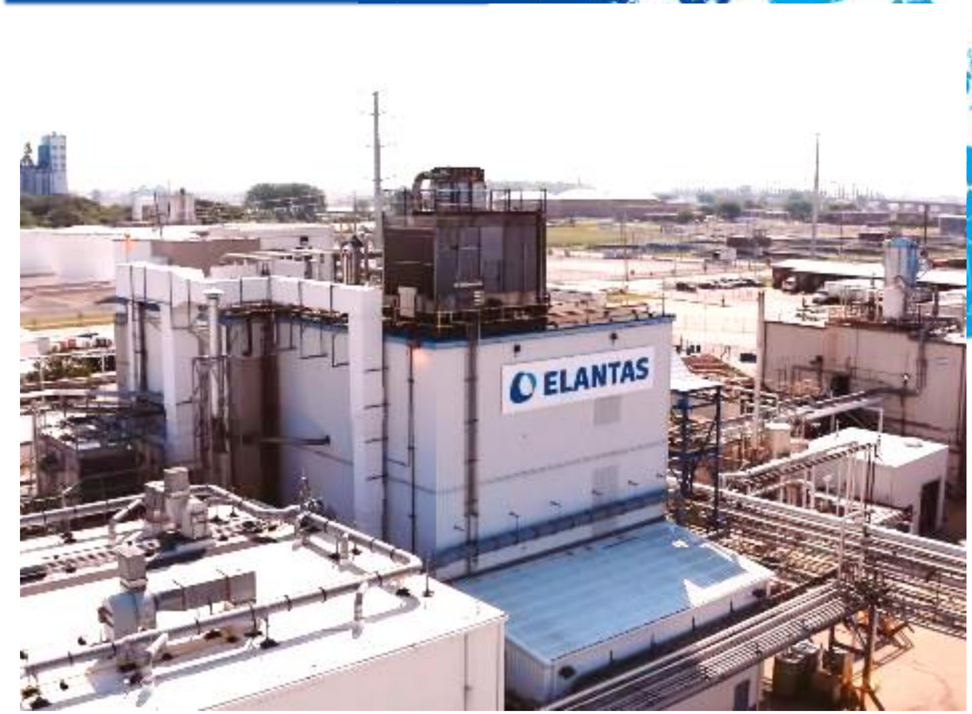
Business Development

ELANTAS PDG

The Epoxylite Corporation
Essex Brownell
Von Roll
From New Orleans, LA
Born on the bayou

ELANTAS PDG
Specialty chemicals for protection of power electrical and electronic components
North American Locations

ELANTAS PDG
Saint Louis, MO, USA
1919: founded / 1996: part of ALTANA



ELANTAS PDG, NY
Olean, NY, USA
1958: founded / 2017: part of ALTANA

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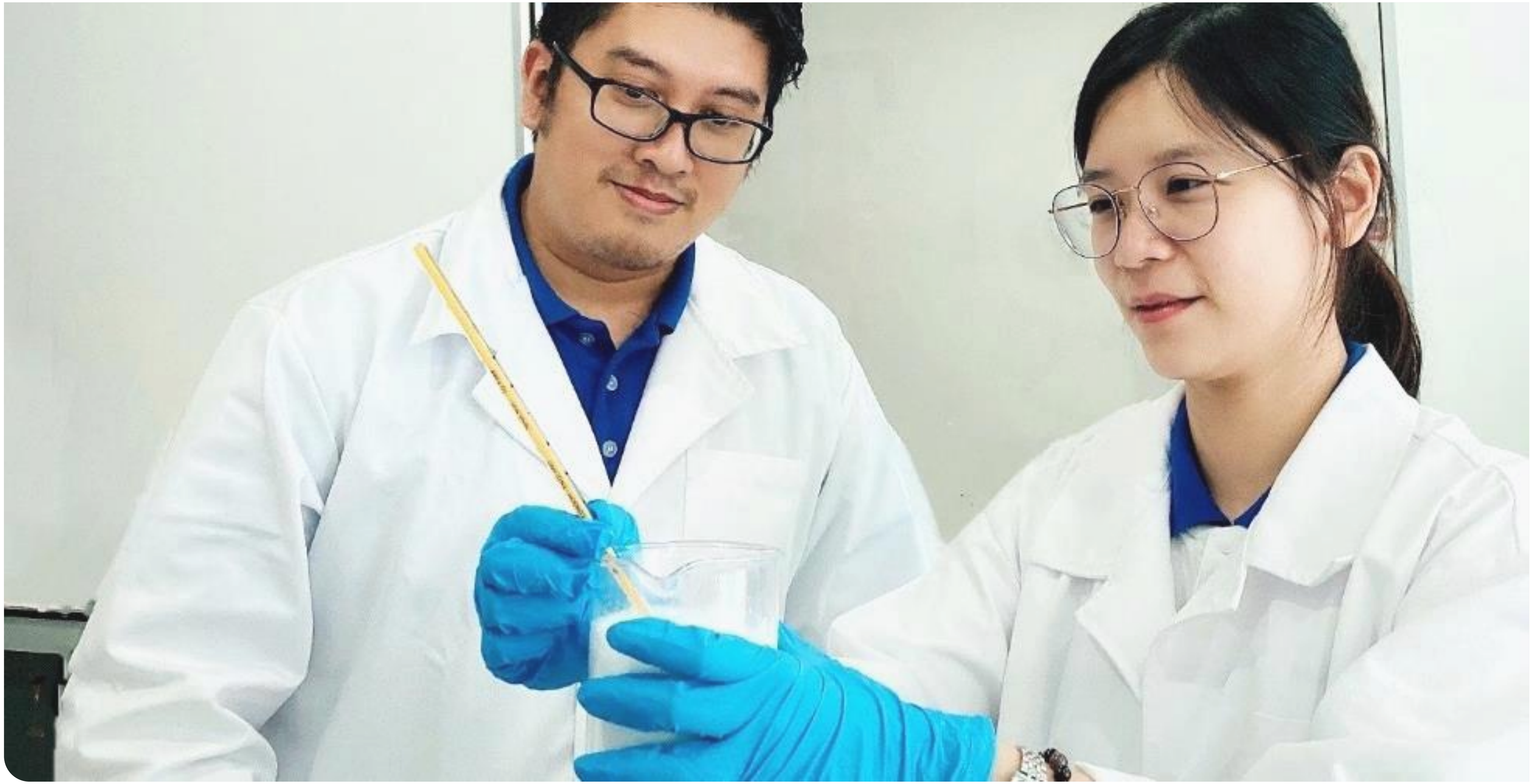
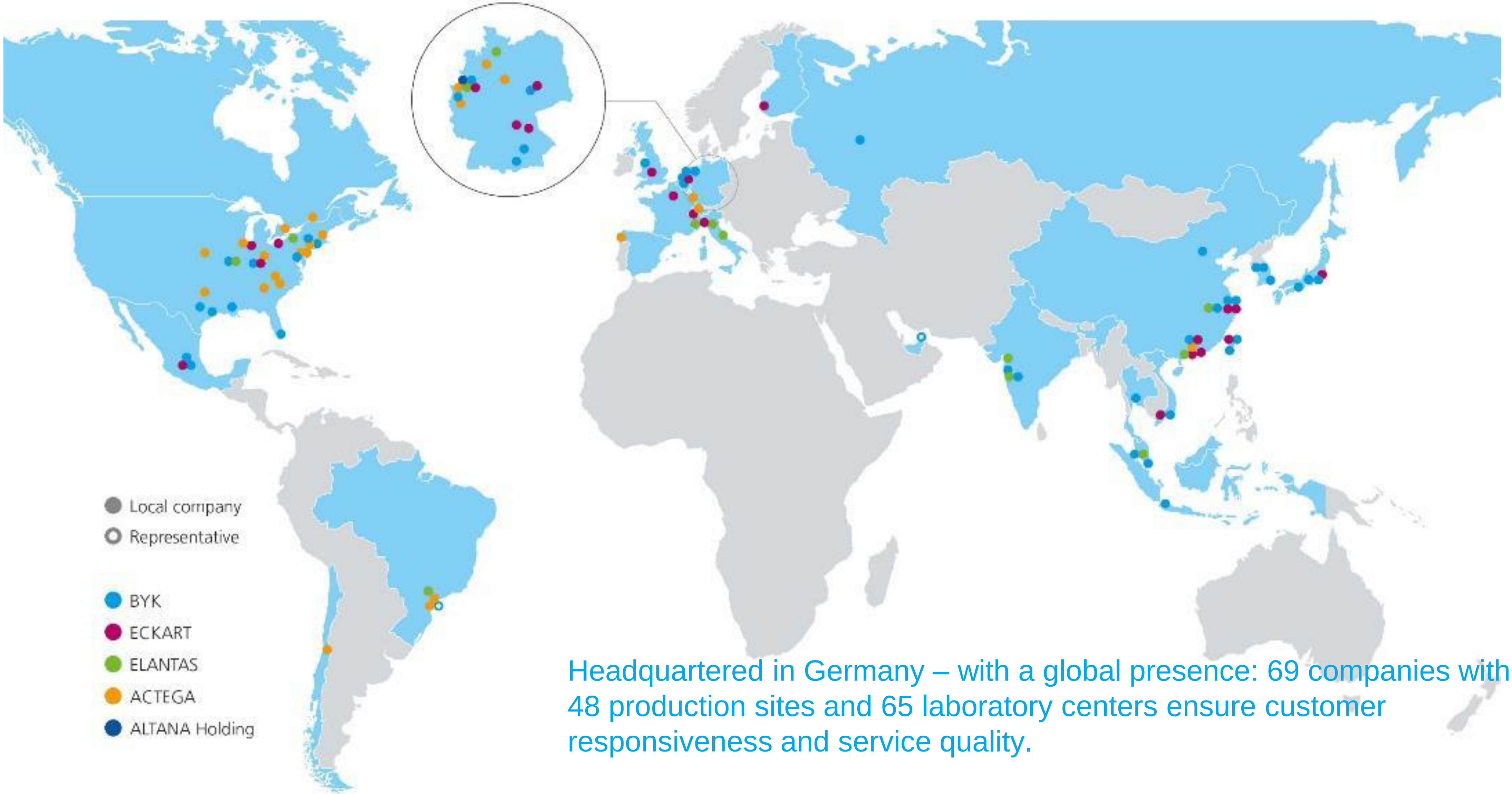
Mission: We create **value for customers** by developing, manufacturing, delivering and supporting **innovative solutions** for dedicated industries where our **technology** and **application expertise** makes the difference.



ALTANA Is Present All Over the World

Global network – local presence



Headquartered in Germany – with a global presence: 69 companies with 48 production sites and 65 laboratory centers ensure customer responsiveness and service quality.

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Why?
Protecting your vital components from:
Moisture – Dirt/Dust – Chemicals – Vibration – UV





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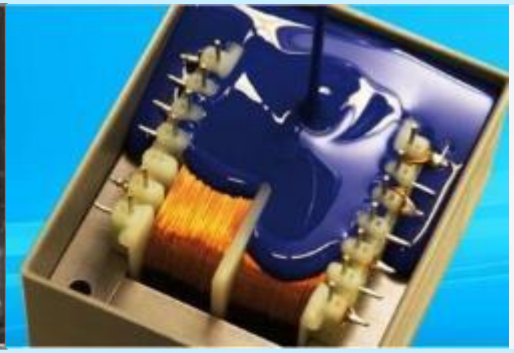
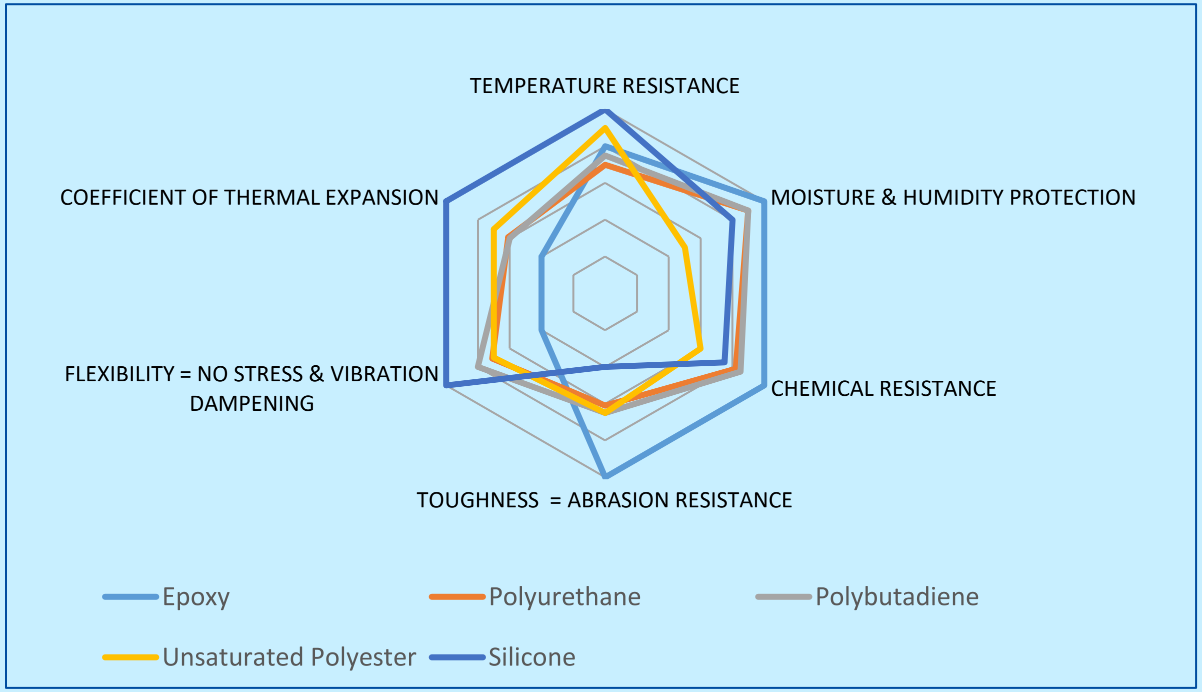
Typical Applications

- **DC/DC converter**
- **Power inverter**
- **On-board chargers**
- **Transformers**
- **Capacitors**
- **CTs and VTs**



- Application based chemistry selection
  - Epoxy
  - Polyurethane
  - Unsaturated Polyester
  - Polybutadiene
  - Silicone



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Design –

Begin with the end in mind – Stephen Covey

- Application
- <u>Environment</u>
- Part or component
- Regulatory requirements
- <u>Process</u> capabilities
- Volume
- Time to start production
- <u>Chemistry</u>

POTTING ELANTAS

APPLICATION QUESTIONNAIRE

New or existing application	
Application Type– Specific Information	
If existing, what is current material?	
Product Environment – Temperature Range?	
Product Environment – Dust, Fluids, Corrosives, Moisture?	
Product Environment – UV Exposure?	
Product Environment – Shock/Vibration?	
Coil or other small patch high voltage components?	
Case or pot material?	
PCB Complexity/Component Mix? (Low, Medium, High)	
Hidden cavities to fill?	
Vacuum Potting necessary?	
Settling time necessary/available?	
Product handling equipment?	
Desired Pot Life?	
Refrigerated storage available?	
Desired Cure Method? (Heat, RTV, UV, 2-part RT)	
Maximum Cure Temperature allowed?	
Desired Cure Cycle Time?	
Opacity Required? What color is preferred?	
Any fragile components on the assembly to be potted?	
UL required?	
Re-entertainability / reworkable required?	
Anti-piracy/no reverse engineer required?	
What is the end product?	
When is the start of production?	
Is there a size / packaging requirement? Cartridge, pail, drum, etc.	

Workshop Focus

Applications

Chemistry

Considerations for voltage and frequency

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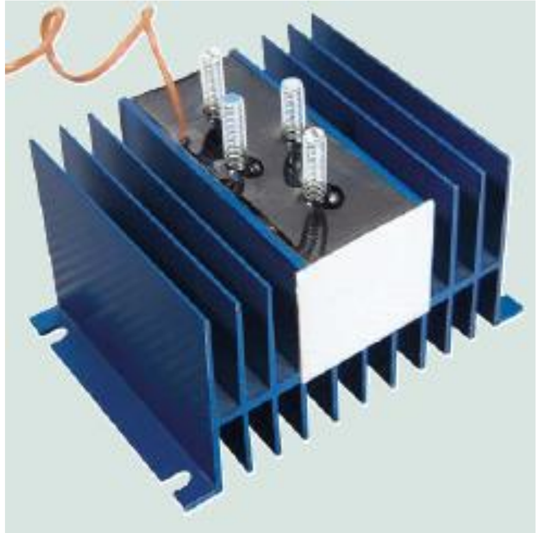
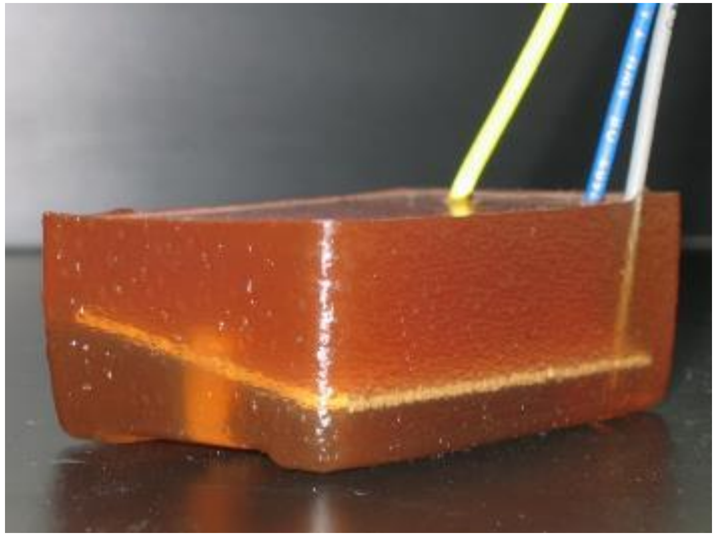
Methods of Application

Potting



- ◆Process in which a device or assembled components are placed in a container
- ◆Container is then filled with the compound, which covers the device
- ◆The container remains an integral part of the completed unit

Casting



- ◆Process in which a device or assembled components are placed in a mold
- ◆Container that is then filled with the compound, which surrounds the components
- ◆After the compound has cured, the mold is removed

Encapsulating

- ◆Process also describes a method where a device is dipped into a resin system
- ◆A thick coating completely surrounds the unit

Potting

Resin fills a case, housing, or other container

Considerations

- Mass or volume
- Sensitivity of components
- Color
- Operating temperature
- Physical forces: vibration, shock
- Viscosity
- Vacuum processing
- Hardness

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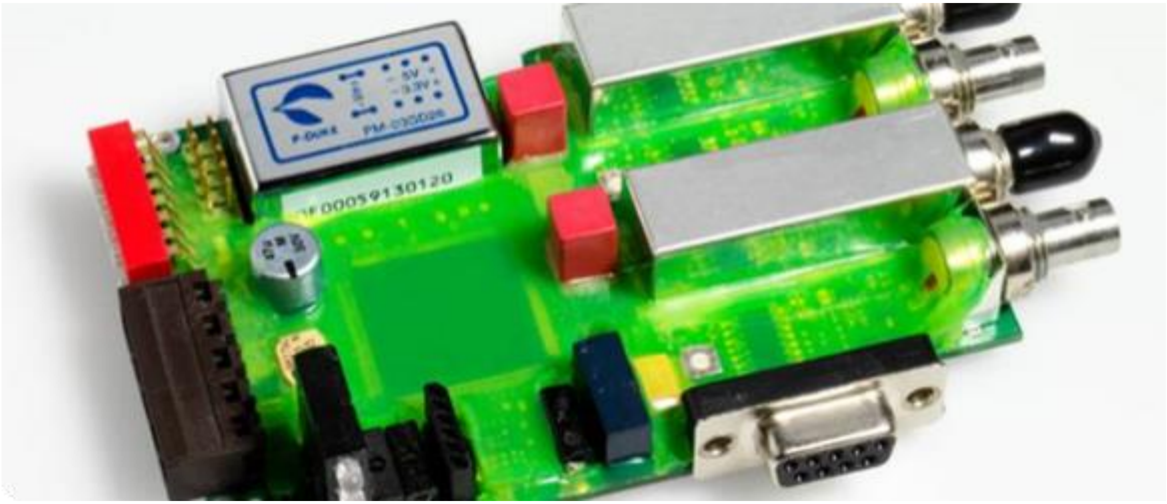
Encapsulation

The resin becomes the outside of the component. No mold is used.

Considerations

- Viscosity
- Cure time
- Color
- Operating temperature
- Physical forces: vibration, shock
- Hardness



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Casting

Part is processed in a mold that is removed.
Resin becomes the outside of the part

Considerations

- Mass or volume
- Sensitivity of components
- Color
- Operating temperature
- Physical forces: vibration, shock
- Viscosity
- Vacuum processing
- Hardness

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Resin Casting & Potting

Transformers, Insulators and Bushings

Cast Resin Application Systems

UVC
Under Vacuum Casting

APG
Automatic Pressure Gelation Technology

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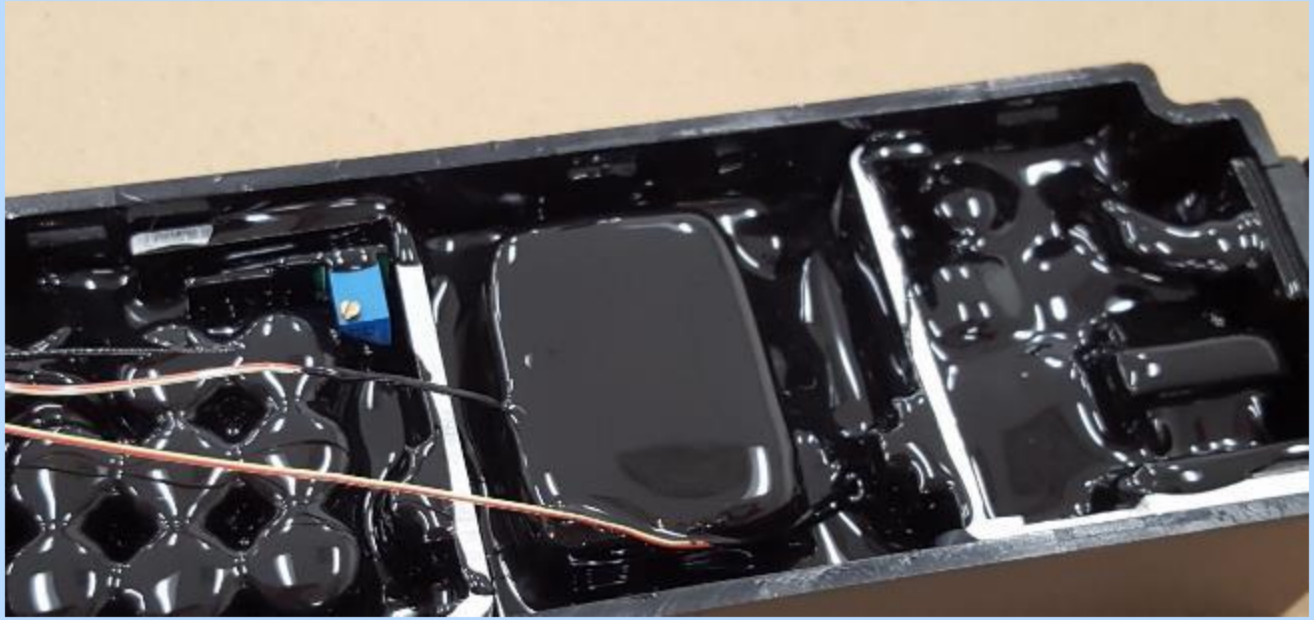
Flood Coat
Polyurethane Selective Coating

Product Features

- Rheology modified systems to reduce material usage with superior edge coverage
- Reactivity modified systems for rapid throughput
- 30 – 60% weight reduction possible



Applications

- Converters
- Sensors
- Power Supplies
- Power Electronics
- Inverters

Industries

- Contract Manufacturing
- Motors
- Drives
- Power distribution
- Lighting
- Micro Grid

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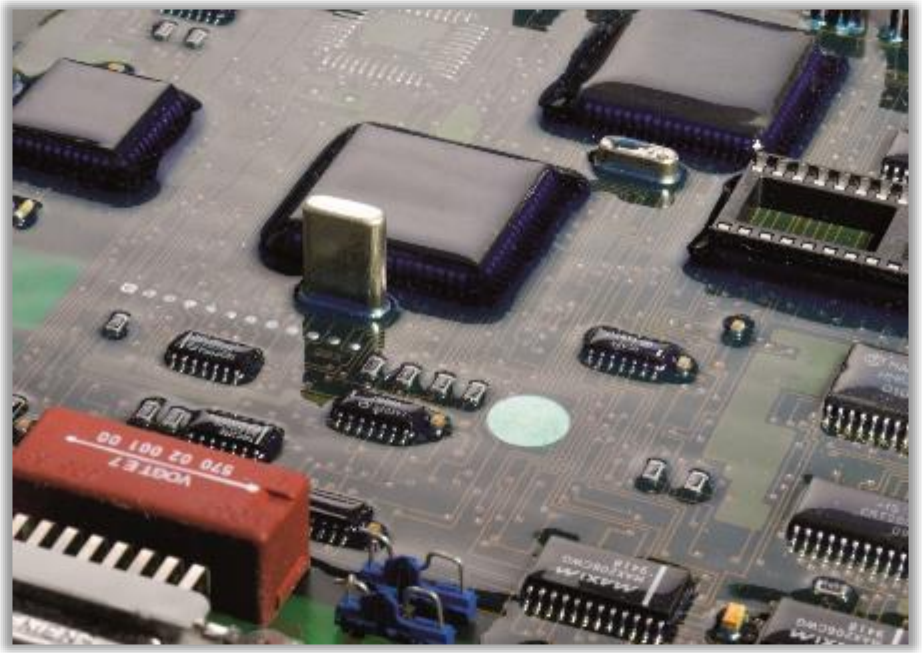
Power Electronics – Protection of PCBs
Conformal Coatings

Conformal Coatings protect PCBs against

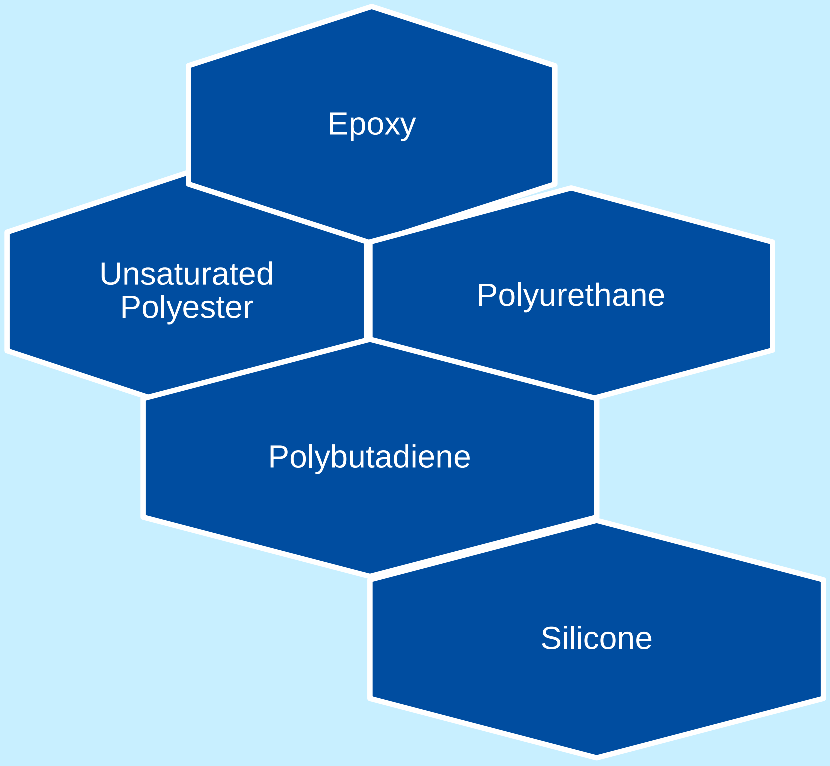
- Dust and particles
- Moisture and humidity



Application	Chemistry	Specific Benefits
Interior, exterior, under the hood	Polyurethane - Alkyd	- Industry established - Fast drying
Interior, exterior, under the hood	Polyurethane	- High Reliability
Interior or transient	Polyurethane - Acrylate	- UV curable - High throughput
High Temperatures and harsh conditions	Epoxy	- UV curable - High throughput - Chemical resistance
High Temperature applications	Silicone	- High temperature areas

Popular Chemistries

How they stack up in power electronics



Moisture Absorption

Chemistry	Moisture Absorption
Polyurethane	+
Polybutadiene	++
Unsaturated Polyester	-
Epoxy	+
Silicone	++

Adhesion

Chemistry	Adhesion
Polyurethane	+
Polybutadiene	+
Unsaturated Polyester	+
Epoxy	++
Silicone	-

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Chemical Resistance

Chemistry	Chemical Resistance
Polyurethane	+
Polybutadiene	+
Unsaturated Polyester	+
Epoxy	++
Silicone	++

Mechanical

Chemistry	Mechanical
Polyurethane	Soft to hard
Polybutadiene	Soft
Unsaturated Polyester	Medium to hard
Epoxy	Hard
Silicone	Soft

Generally Accepted Thermal Classes

Chemistry	Thermal Class, typical
Polyurethane	**120-130**
Polybutadiene	**120-130**
Unsaturated Polyester	**180-200**
Epoxy	**155-180**
Silicone	**200**

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Thermal Conductivity

Material	Thermal Conductivity (W/m·K)
Air	0.03
Neat resin	0.2
Filled resin	1.0
Thermal Interface Materials	2.5+

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Thermal Conductivity Measurement Methods

MEASUREMENT

Methods		Temp Range [K]	W/mK	Accuracy [%]	Materials	Standards (examples)
Steady-state Methods	Guarded hot plate methods	80-800	< 0.8	2	Glass, polymer, insulation materials	ASTM C177 ISO8302 EN12667 ASTM E1225
	Axial flow Methods	90-1300	0.2-200	2	Polymers, ceramics, metals	ASTM E 1225
	Heat Flow meter method	253-523	<10	3	Glass, polymers, insulation materials, ceramics	ASTM C518 ASTM E1530 ISO8301 EN12667
	Pipe Method	293-2770	0.02-200	2	Metals, high conductivity inorganics, polmyer composites	ISO8497
Transient Methods	Laser flash method	373-3273	>0.01	3-5	Glasses, polymers, ceramics, metals	ASTM E161 ISO 22007-4 ISO 18755
	Transient hot wire method	293-2273	<25	1-10	Glasses, polymers, cermics, most of liquid, gas, powders	ASTM-C 1113 ISO 8894-1 ISO 8894-2
	Transient plane source method	20-1273	0.005-1800	5	Insulation materials, powders, polymers, ceramics, metals, liquids	ISO 22007-2

From: Thermal Conductivity of polymer based composites, Hongyu Chen, Progress in Polymer Science, 59 (2016), 41-85

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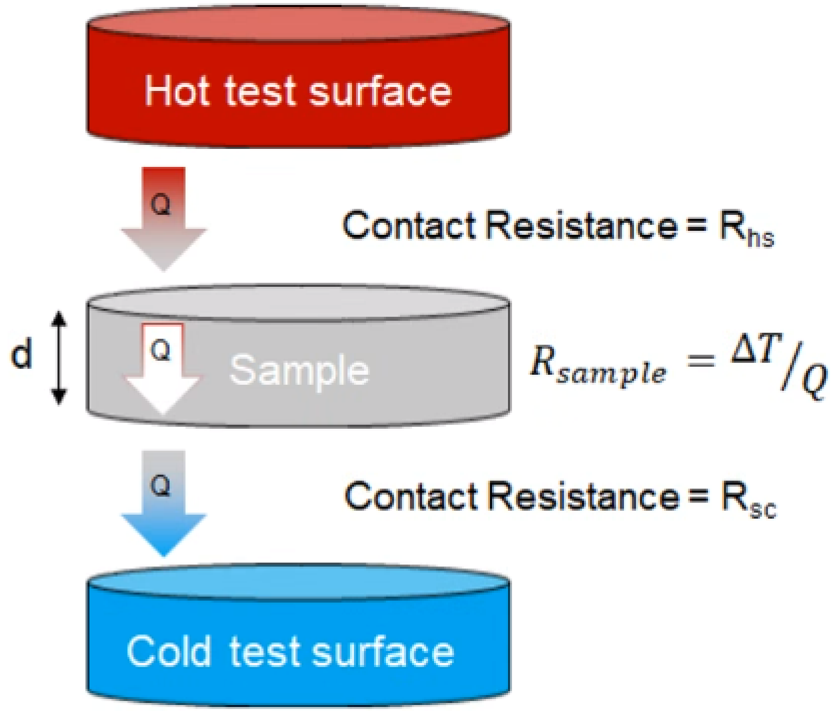
Apparent Thermal Conductivity

MEASUREMENT

Measurement Setup



$$\lambda_{total} = \frac{Q_{total} \cdot d}{A \cdot \Delta T} \quad \curvearrowright \quad \frac{\Delta T}{Q_{total}} = \frac{d}{\lambda_{total} \cdot A} = R_{total}$$

with $R_{total} = R_{sample} + R_{hs} + R_{sc}$

and $R_{sample} = \dfrac{d}{\lambda_{apparent} \cdot A}$

Insert and multiply by A(rea)

$$R_{total} \cdot A = \frac{1}{\lambda_{apparent}} \cdot d + (R_{hs} + R_{sc}) \cdot A$$

or

Thermal Impedance = $f(d) = \dfrac{1}{\lambda_{apparent}} \cdot d + const.$

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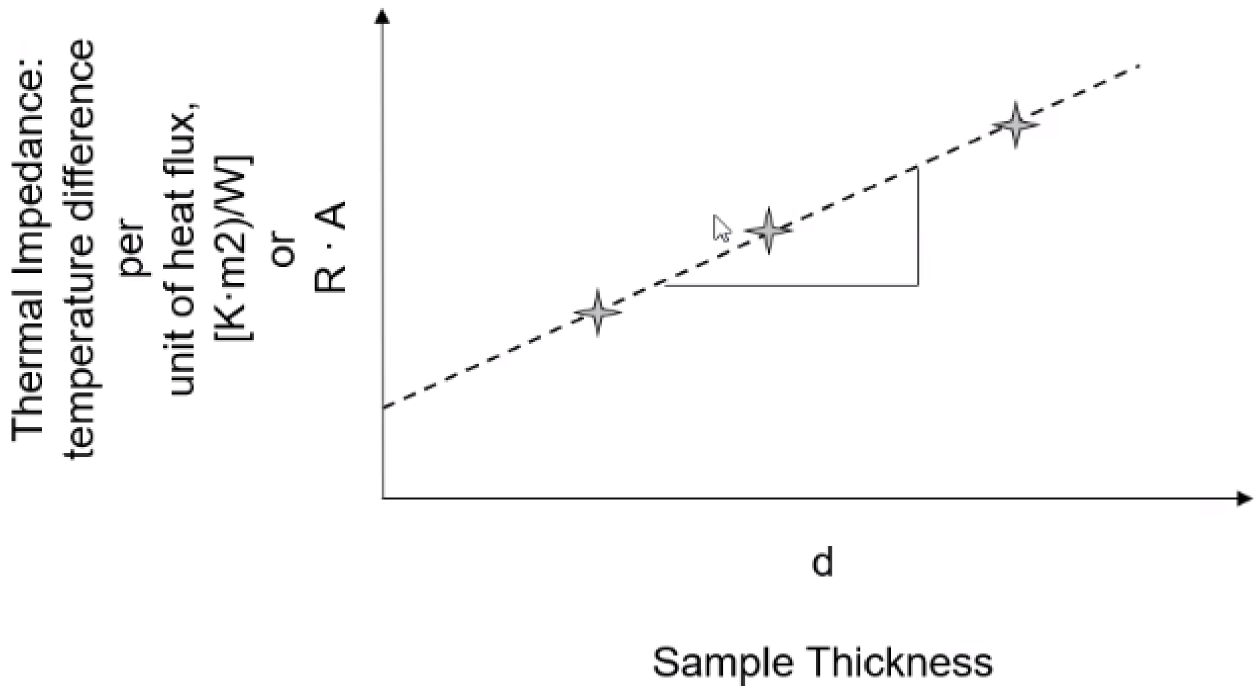
Possible Concept of Conductivity Measurement - Thermal Impedance ASTM D5470

MEASUREMENT



$$R_{total} \cdot A = \frac{1}{\lambda_{apparent}} \cdot d + (R_{hs} + R_{sc}) \cdot A$$

$$Slope = \frac{1}{\lambda_{app}}$$

$$Intercept = (R_{hs} + R_{sc}) \cdot A$$

Thermal Conductivity of TIM sample only equals apparent thermal conductivity if contact resistance values are zero

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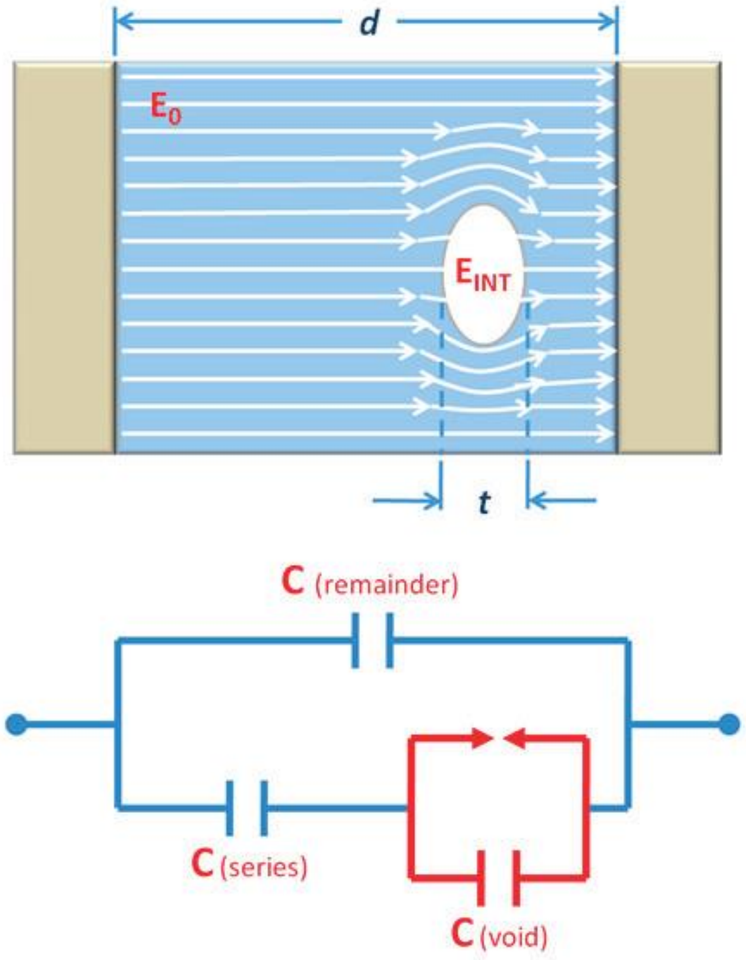
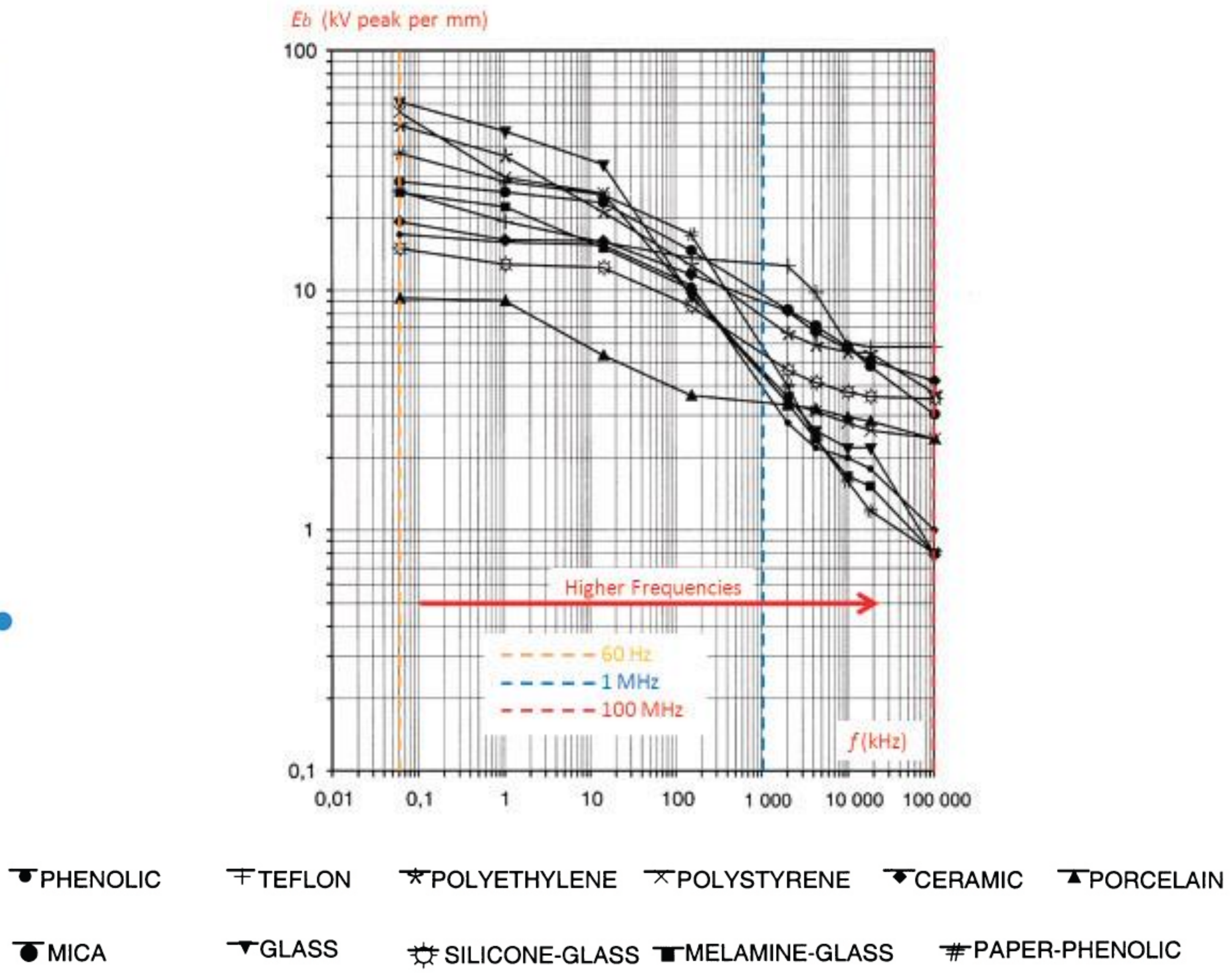
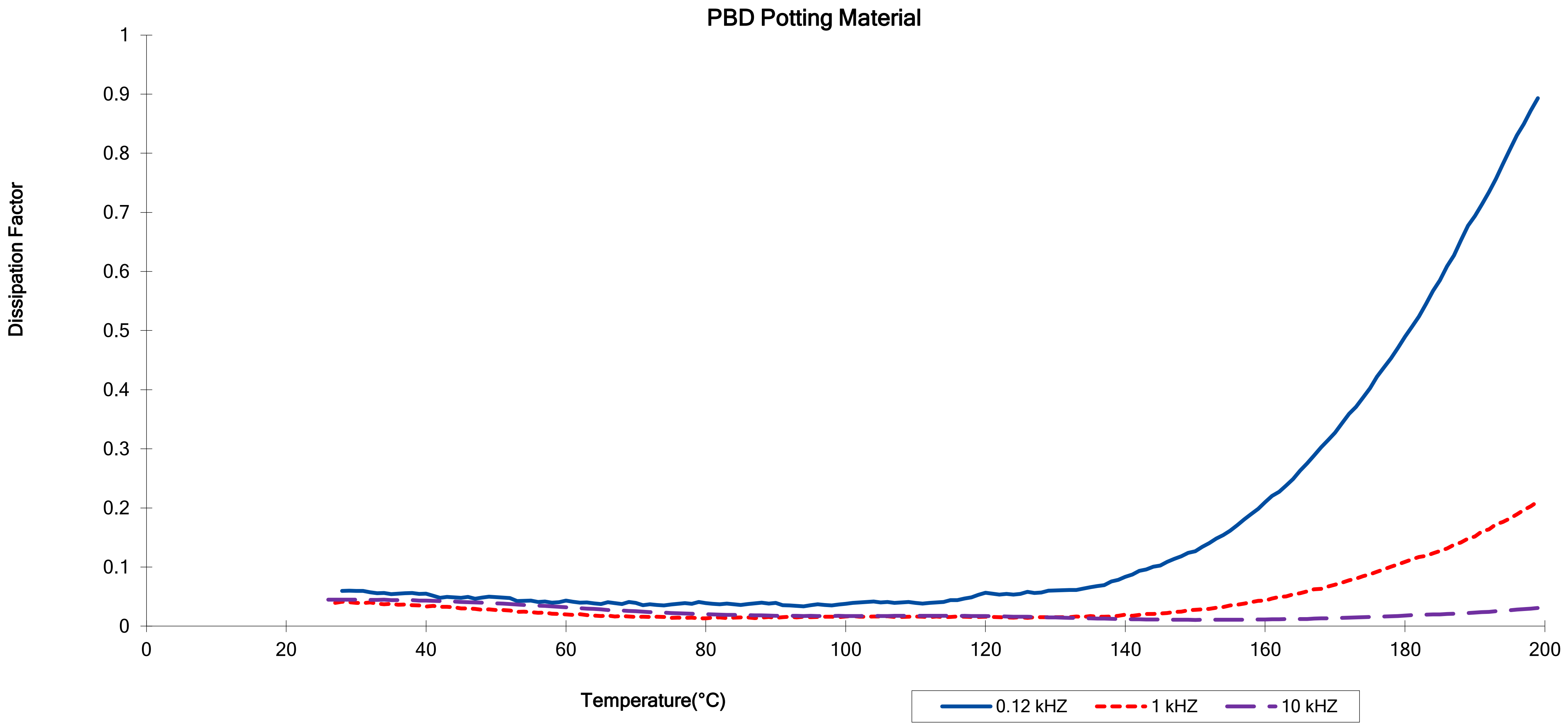
Impact of frequency on PDIV and Breakdown voltage





Source: Effects of High Frequency Voltage Stress on Air Insulation and Solid Insulation – UL IEC 60664-1

Dissipation Factor and frequency



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