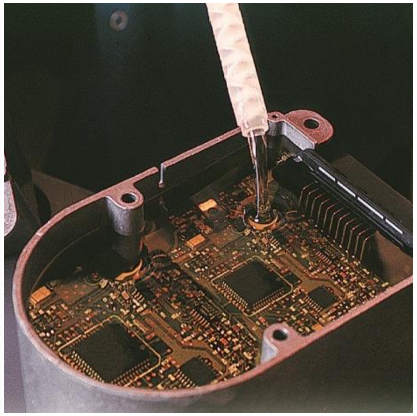
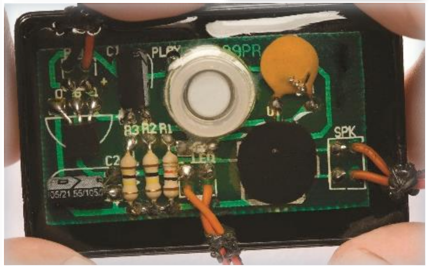
Introduction:
Circuit Board Protection Materials:
Liquid Potting Materials

Hilde Goossens





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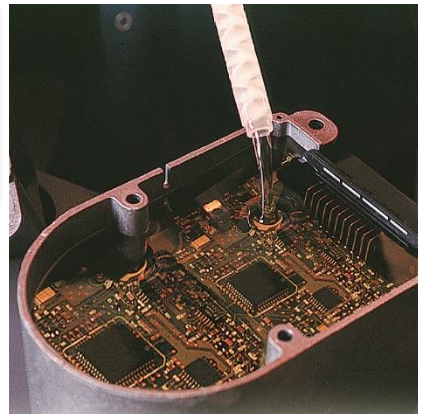
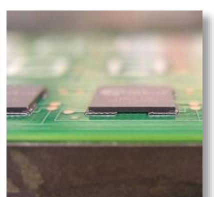
Agenda

1. Embedding process of electronic devices
2. Industry trends
3. Potting Material options
4. Overview potting systems
5. Application Techniques
6. Selecting the right product
7. Henkel Potting Materials Product line

Introduction





Introduction: Embedding processes of electronic devices

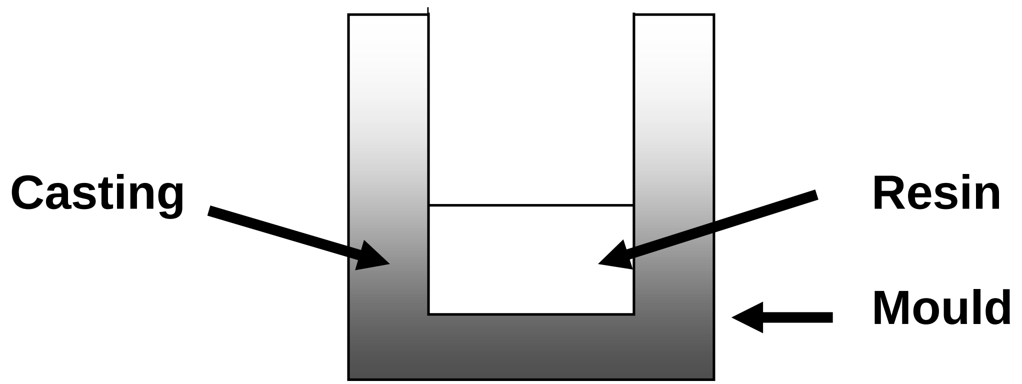
To isolate devices from generally degrading environmental and operational effects such as oxygen, moisture, heat and cold, dust, current leakage, corrosion, mechanical shock and vibration.

Methods Of Embedding

- **Casting**
- **Potting**
- **Encapsulation**
- **Sealing**
- **Impregnation**

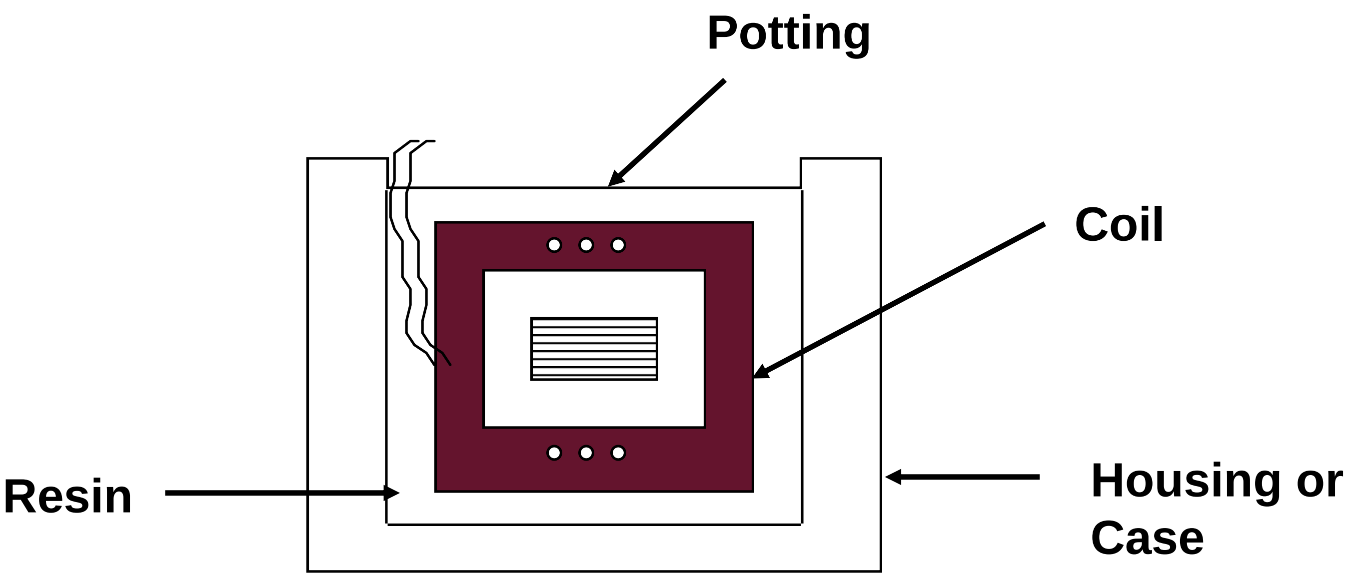
Definition : Casting

“Method which consists of pouring a catalysed or hardenable liquid into a mould. The hardened cast part takes the shape of the mould, and the mould is removed for re-use.”



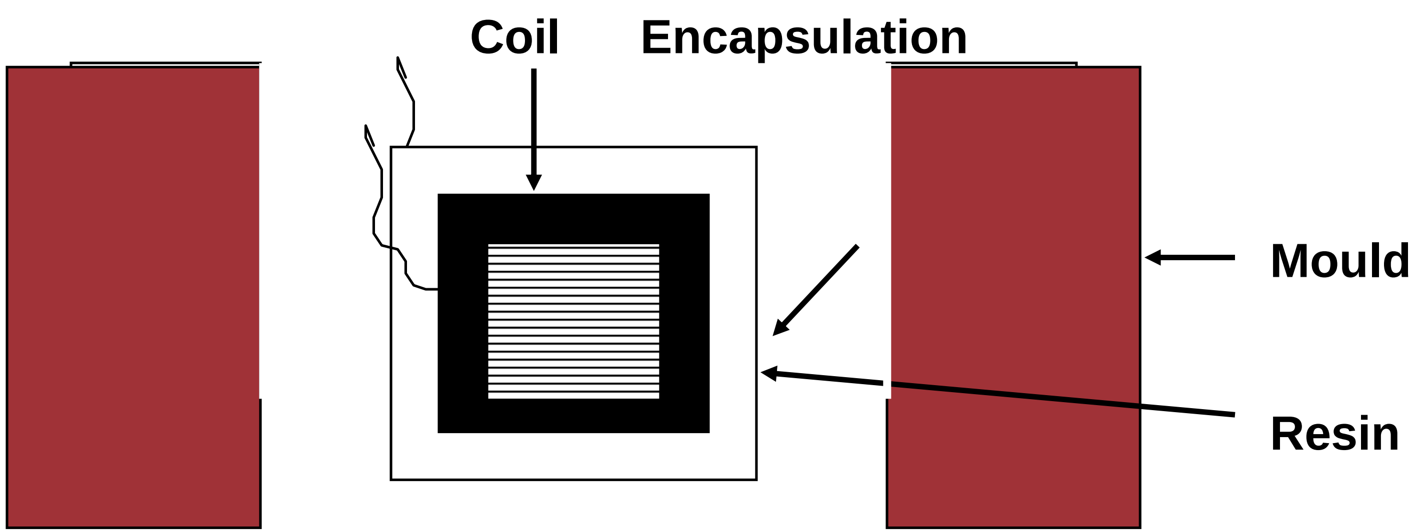
Definition : Potting

"Method which consists of pouring a catalysed or hardenable liquid into a shell or housing which remains as an integral part of the unit."



Definition : Encapsulation

"Method of providing a protective coating or a thin shell around a component or assembly. A mould is used rather than a permanent container. When the mould is removed, the cured resin is the outside surface of part."



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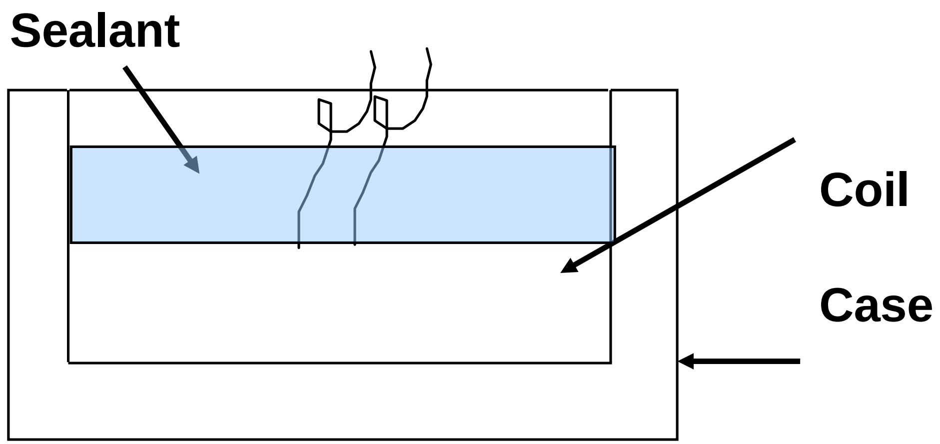
Definition : Sealing

"Sealing describes a method of providing a barrier on a surface or around the joint of the container which houses some devices."

Sealant may also be used to fill cracks, voids, vents holes in casts or potted parts. Sealant does not surround the device, the sealant may form the entire upper surface of the embedment, or it may be used to gasket a lid or caulk a joint.



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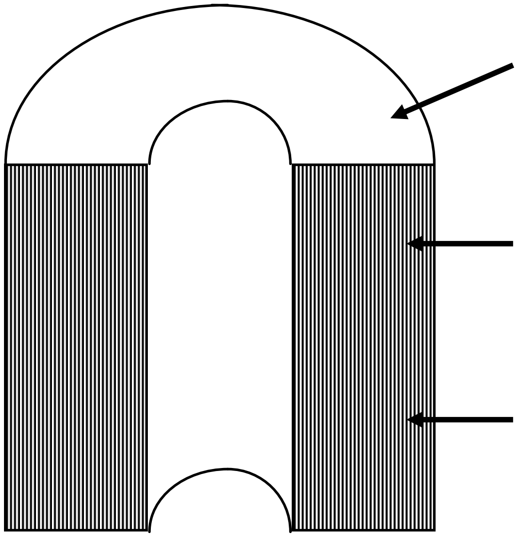
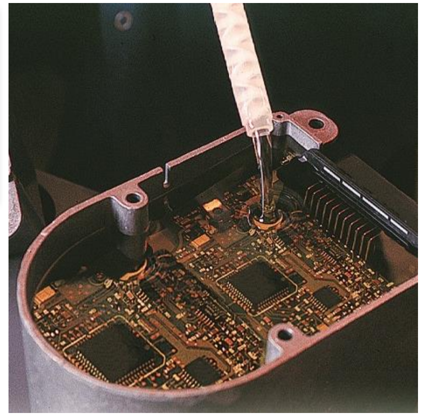
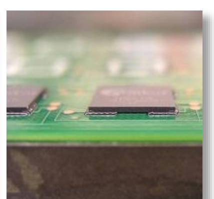
Definition : Impregnation

"Method consisting of completely immersing a part in a liquid so that the interstices are thoroughly soaked and wetted ; usually accomplished by vacuum and/or pressure."



Industry Trends

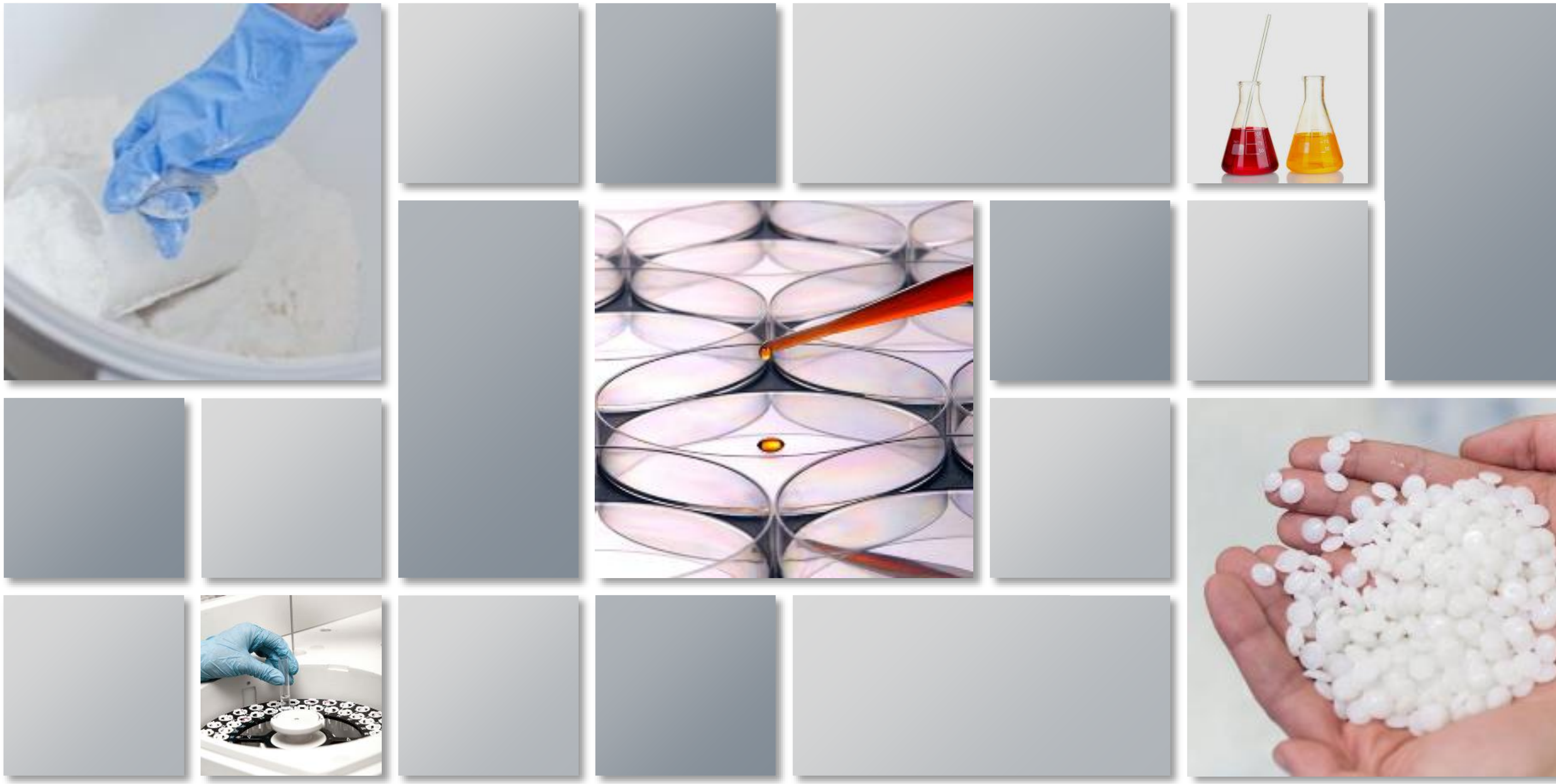




Industry Trends

- Historically potting materials were used for impregnation of coils and consumer electronics
- Automotive electronics has rapidly transferred into this category with life critical applications
    - Air bag sensors
    - ABS modules
    - Oil sensors
    - Clutch sensors
    - Transmission control units
- Request for higher temperature resistant materials (up to 175-200°C)
- Request for higher chemical resistant materials:
    - Automotive fluids (ATF, oils and different fuels)
- Better heat dissipation = improved thermal conductivity

Potting Material Options



Liquid Potting Materials :

<u>**4 major constituents**</u> **:**

- **Resin: different chemistries like epoxy, polyurethane, silicone**
- **Hardener (catalyst) : Amine, Amide, Dicy, Imidazole, Anhydride, …**
- **Fillers**
- **Diluent / solvents**

Resin

“A resin is a natural or synthetic compound that begins in a highly viscous state and hardens with treatment. Typically, it is soluble in alcohol, but not in water. The compound is classified in a number of different ways, depending on its exact chemical composition and potential uses.”

Hardener

“A hardener (catalyst) is a substance or mixture of substances that undergoes a reaction with a resin and is consumed in that reaction, becoming a part of the polymer backbone.”

Epoxies

- >50 Epoxy Formulations
- Mix ratios: 1:1 to 20:1
- Mixed viscosity: 200 cP to >1M cP
- Hardness: 23 (A) to 95 (D)
- Gel time: 2 minutes to months
- Dk from: 3 to 7
- Df from: 0.01 to 0.09
- Dielectric Strength: up to 2000 volts/mil (20mil thickness)

Epoxy resins

RESINS	
Diglycidyl Ether of Bisphenol A	• Most common • Long chain • Low cost
Diglycidyl Ether of Bisphenol F	• More expensive
Cycloaliphatic	• More expensive • High performance • Low viscosity

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Epoxy Hardeners/Catalysts

	Amines Aliphatic	Amines Aromatic	Polyamides	Anhydrides
Advantage	RT cure Good overall properties	Excellent chemical resistance High Tg	Good mixing ratio Good adhesion	Excellent high temperature performance Low exothermal Good chemical properties Long pot life
Disadvantage	High exothermal Poor mix ratio	Elevated temperature cure High exothermal	Poor chemical resistance Poor thermal resistance	Long cure schedule Dianhydrides are solid
Typical Max. Operating Temperatures,°C	105°C – 150°C (221 °F)	155 – 180°C (302-356 °F)	105°C (221 °F)	To 200°C (392 °F)
Typical Pot life, hrs.	0.5 – 0.75	8	2 – 3	20 hrs +
General Uses	Modules, small castings, adhesives	Solvent resistant apps, thermal cycling	Thermal cycling, low stress adhesive	Excellent electrical, module potting, coil potting

Urethanes

- >40 Urethane Formulations
- Mix ratios from: 1:1 to 1:7.7
- Mix viscosity from: 400 cP to 25,000 cP
- Hardness from: 60 (OOO) to 85 (D)
- Gel time from: 2 to 360 minutes @ 25°C
- Dk from: 3 to 7
- Df from: 0.01 to 0.2
- Dielectric Strength: up to 1200 volts/mil (20mil thickness)

Urethane resins

POLYOL	
Polyether's Polyoxypropylene glycol (PPG) Polytetramethylene ether glycol (PTMEG)	 Most common type of polyol High cross-linking , thermoset urethanes Used when high strenght is required
Polybutadiene (PolyBD)	Very low moisture absorption Excellent tow temperatue flexibility Restricted for export
Polyesters Adipates Polycaprolactones Castor Oil	 Excellent abrasion resistance and outdoor weatherability Used for shoe soles, under hood automotive applications and coatings Low viscosity, good retention with age

Polyurethane Hardeners

	TDI	MDI	HDI
Appearance	toxic	Pure MDI : Solid (flake, fused solid) MDI Adduct: Liquid at RT, crystallizes below 60°F Polymeric MDI : Dark Brown color, non-crystallizing	Very expensive
Typical Max. Operating Temperatures,°C	125	125 - 150	150
Typical Pot life, hrs.	<1	<1	<1
General Uses	Foams	General purpose electronics casting	Optically clear (non-yellowing)

TDI = toluene diisocyante
MDI = methylenebis(phenyl isocyanate)
HDI =hexamethylene diisocyanate

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Silicones

- Approximately 30 products
- Predominantly 1K but some 2K available
- Hardness 30 (OO) to 80 (A)
- Gel time from 1hour to months
- Dk from 2 to 5
- Df from 0.002 to 0.2
- Dielectric strength up to 700volts/mil

Silicones

- **Cure mechanism either condensation cure or catalyst (addition cure)**

- **Some condensation cures systems are also known as RTVs (room temperature vulcanisation)**

Silicones – comparison by cure

Cure Mechanism	By-product	Advantages	Disadvantages
Acetoxy	Acetic acid	High adhesion High temperature Fast cure	Corrosive Strong smell
Acetone	Acetone	Non-corrosive High adhesion High temperature Fast cure	Damaging to some plastics
Alkoxy/ Methoxy	Ethanol or Methanol	Non-corrosive High adhesion	Lower temperature Longer cure
Oxime	Methylethylketoxime	Non-corrosive High adhesion	Some H&S concerns
Addition	None	Non-corrosive High adhesion Fast cure	Catalyst can be poisoned

Resin Chemistry : Comparison

Characteristics	Epoxy	Polyurethane	Silicone	Remarks
Service temperature (°C)	High (*) (up to 160-180°C)	Moderate (up to 135°C)	Very high (up to 230-260°C)	(*) depending on the selection of hardener
Thermal conductivity (W/mK)	0.2 (*)	0.2 (*)	0.2 (*)	(*) depending on the addition of filler
Tg (°C)	High	Medium / Low	Very low	
Hardness (shore)	High shore D	Shore A to shore D	Low shore A	
Flexibility	Brittle	Flexible (also low temp)	Very flexible (-50 / 200°C)	
Stress	High	Low	Very low	
Chemical resistance	Excellent	Good	Poor	
Adhesion	Very good	Good	Poor	
Cost	Medium	Low	High	

Fillers

A filler is a substance often inert , added to a plastic material to improve properties and/or decrease cost.

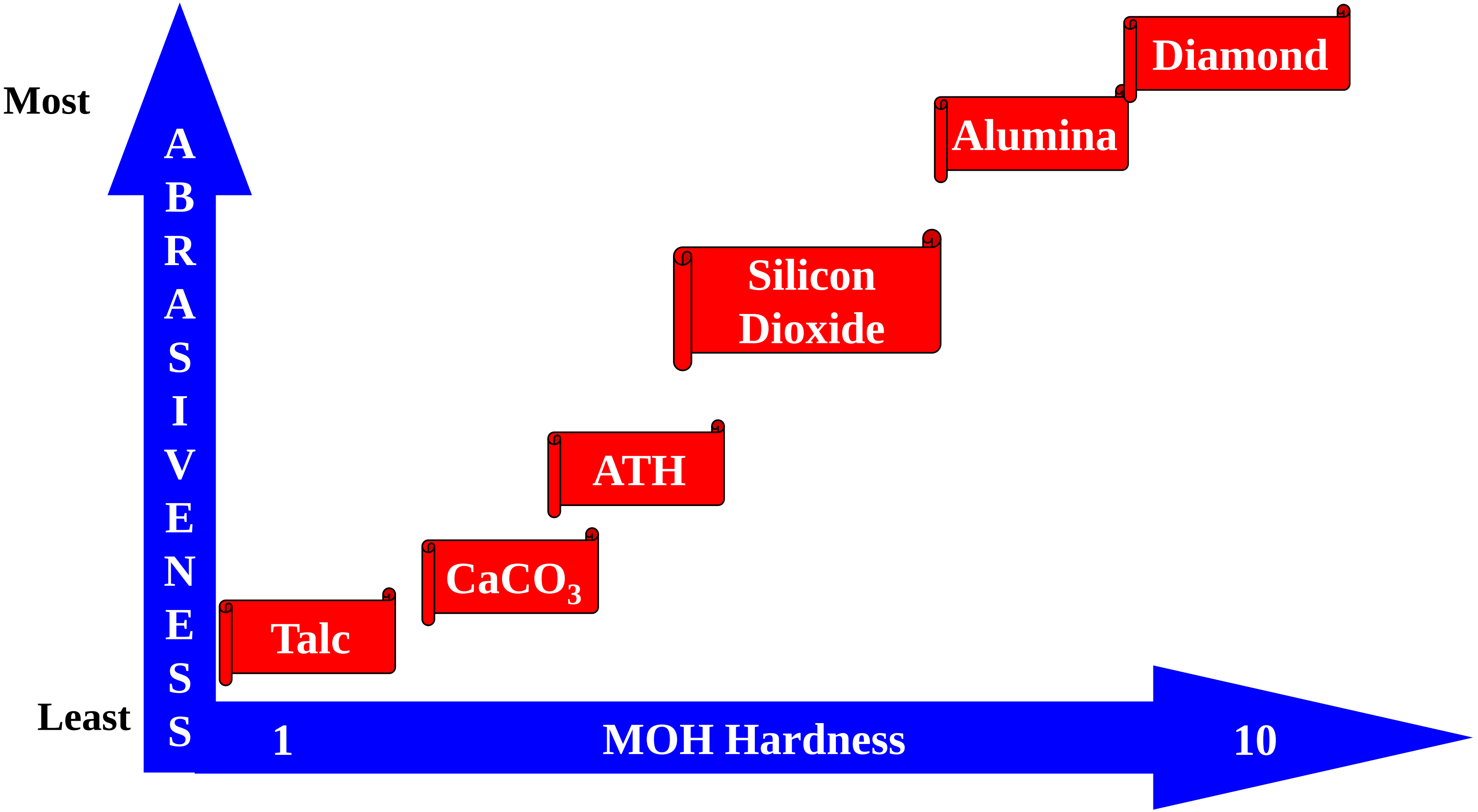
<u>Filler effects :</u>

- **Reduce cost**
- **Reduce exotherm**
- **Reduce thermal expansion coefficient**
- **Improve mechanical shock resistance**
- **Improve thermal or electrical conductivity**
- **Improve fire resistance**

Fillers

Property	Improved Machining	Improved Thermal Conductivity	Improved Abrasion Resistance	Improved Impact Strength	Improved Electrical Conductivity	Improved Thixotropy	Flame retardant
Filler options	Calcium carbonate	Alumina	Glass	Mica	Noble Metals	Silica (colloidal)	Antimony trioxide
	Calcium silicate	Flint powder	Alumina	Silica	Aluminium	Clays	Borates
	Powdered aluminium	Carborundum		Glass	Carbon		Brominated organics
	Powdered copper	Silica					
	Micro balloons (microspheres)	Boron Nitride					

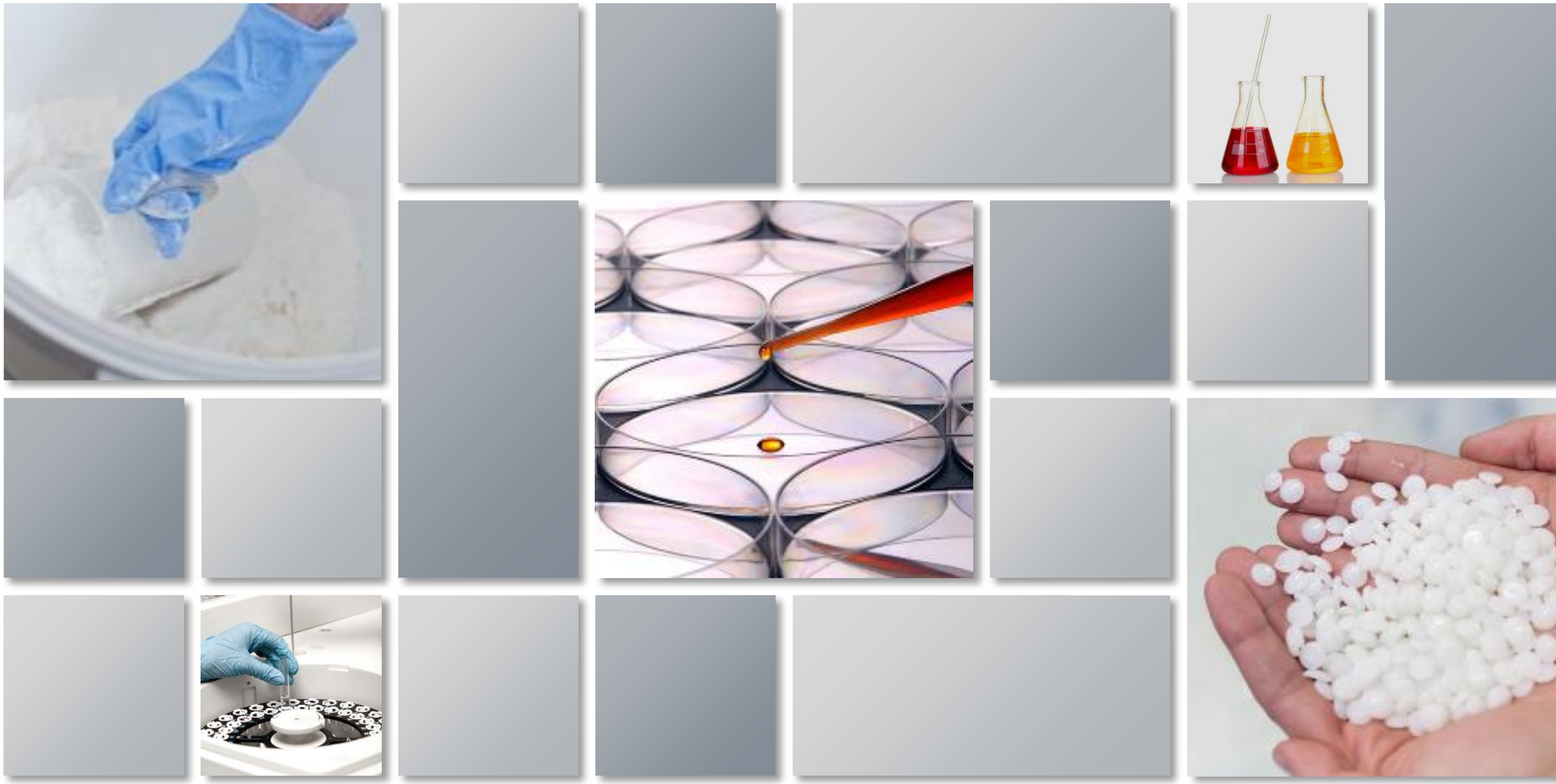
Trade-off: Abrasiveness / Hardness of Fillers



One/Two component systems

One Components	Two Components
• Ready for use	• Needs weighing and mixing
• Limited shelf life	• Long shelf life
• Often requires cool storage	• Room temperature storage
• Activation energy required to start reaction	• Room temperature cure or heat cure

Overview Potting systems



Overview encapsulant systems: Unfilled systems

Strengths	Weaknesses
• Low viscosity • Clear transparent	• High shrinkage/brittle • High CTE • Higher exotherm than filled systems • More expensive

Overview encapsulant systems: Mica filled systems

Strengths	Weaknesses
• Improved thermal shock resistance • Less shrinkage • Good crack resistance • Good chemical resistance • Good mechanical/electrical properties	• Higher viscosity • Slightly abrasive

Overview encapsulant systems: Calcium carbonate filled systems

Strengths	Weaknesses
• Easy dispensable	• Lower crack resistance
• Highly machine-able	• Lower thermal shock resistance
• Low shrinkage	• Poor acid resistance
• Non-abrasive	
• Low cost	

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Overview encapsulant systems: Silica filled systems

Strengths	Weaknesses
• Excellent chemical resistance	• Abrasive
• Good mechanical/electrical properties	• Poor machine-ability
• Low exotherm	• High viscosity
• Low shrinkage/CTE	

Overview encapsulant systems: Aluminium oxide filled systems

Strengths	Weaknesses
Highest heat dissipation	Highly abrasive
High voltage applications	Poor machine-ability
Excellent chemical resistance	High viscosity
Low exotherm	Severe filler settlement
Good thermal cycle/shock	
Low shrinkage/CTE	

Overview encapsulant systems: Aluminium Hydroxide filled systems

Strengths	Weaknesses
• Low exotherm • Good thermal shock/cycle • Flame retardant • Medium heat dissipation • Low shrinkage	• Low temperature resistance • Poor acid resistance

Overview encapsulant systems: Lightweight systems

Strengths	Weaknesses
Low density	High viscosity
Low dielectric constant	Filler “floating”
Low shrinkage	Fragile filler
Good thermal cycle resistance	
High compressive strength	
Good mechanical properties	

Potting Application techniques

Processing

Mix ratio:
The amount of hardener that is needed to stoichiometric cure 100 parts of resin

Cure time/temperature:
Time and temperature that a polymer system need to reach the solid state and its required end-properties

Principal Application Methods

- Manual
- Twin pack systems
- Mixing and dosing equipment

Manual potting

- Small quantities
- Low investment
- Time depending on amount of material
- Pot life is crucial
- Exotherm
- De-gassing required

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MixPacs

- Easy to use
- Simple volumetric mix ratios
- Designed for both small and large users
- Sales tools and help available

Mixing and Dosing Equipment

- Capital investment
- Mixing head: static or dynamic
- High throughput
- Material saving
- Maintenance required
- Abrasive fillers are critical

Selecting the right product

Selecting the Right Product

- Some pointers to help select the correct material for the application
  - Maximum and minimum operating temperature
  - Chemical resistance
  - Physical properties
  - Electrical properties
  - Flame resistant
  - Processing requirements

Selecting the Right Product

- Maximum and minimum operating conditions
  - Not only do you need to know the temperature extremes it is also important to ask:
  - How long will the part be exposed to the extreme conditions?
    - Continuous
    - Intermittent
  - Thermal shock (speed of change from one temperature to another)?
  - What are the CTEs of other materials in the assembly?

Selecting the Right Product

- Chemical resistance
  - What materials will the potting compound be exposed to during operating life?
    - Solvents
    - Inorganic acids/bases
    - Automotive fluids (gasoline, brake fluid, salt water, ATF,etc.)
    - Water
  - Will the fluids be under pressure?
  - Temperature and Duration

Selecting the Right Product

- Physical properties
  - Does the material need to provide inherent strength to the final assembly?
  - Does the material need to be impact resistant?
  - Does the material need to be re-workable?
  - Is colour important?

Selecting the Right Product

- Electrical properties
  - Is dielectric constant and dissipation factor important (and at what frequencies)?
  - Is dielectric strength important (and at what thickness)?
  - Is UL relative thermal index (RTI) important?

Selecting the Right Product

- Flame resistance
  - Is the final assembly UL approved or does the potting material need to be UL approved or both?
  - What level of flame retardancy is required?
  - UL capable or actually listed?

Selecting the Right Product

- Processing requirements
  - How many parts per hour are going to be produced?
  - How is the material going to be dispensed?
  - How fast does the cure process need to be?
  - What is the maximum allowable cure temperature?
  - Does the material need to flow through small gaps?
  - Does the material need to have controlled flow/thixotropy?
  - What is the volume of material per part (potential exotherm issues)?

Selecting the Right Product

- Summary
  - Finding a material that exactly meets all of the previous requirements is going to be very difficult if not impossible
  - It is therefore important to understand which parameters are critical to the success of the application and which are “would be nice” parameters – agree their priorities
  - For example:
    - Does the customer want an optically clear material because they are using LEDs or optical sensors
    - Or
    - Does the customer just want to know the potting application is giving good results
      - If the latter is the case it may be beneficial to work on proving the consistency of the potting application rather than pick something transparent

Henkel Potting Materials Product Line

Selection guide by operating temperature

Service temperature
-40°C / +105°C

Polyurethane

General
- LOCTITE STYCAST U2500
- LOCTITE STYCAST U2535
- LOCTITE STYCAST US2651
- LOCTITE STYCAST US2050

Flame retardant
- LOCTITE STYCAST U2500FR
- LOCTITE STYCAST US1150
- LOCTITE STYCAST US2650
- LOCTITE STYCAST US5532

Epoxy

General
- LOCTITE STYCAST 2651W1/cat 23LV
- LOCTITE STYCAST 2651-40W1/cat 23LV
- LOCTITE STYCAST 2651MM/cat 23LV
- LOCTITE STYCAST ES1000
- LOCTITE STYCAST ES1900
- LOCTITE STYCAST ES2204
- LOCTITE STYCAST A316 series

Thermal conductive
- LOCTITE STYCAST 2850FT/cat 23LV
- LOCTITE STYCAST 2850MT/cat 23LV

Flame retardant
- LOCTITE STYCAST E2534FR/cat 9
- LOCTITE STYCAST G508-1
- LOCTITE STYCAST ES1002
- LOCTITE STYCAST ES2505

Light weight
- LOCTITE STYCAST 1090/cat 23LV
- LOCTITE STYCAST 1090SI/cat 23LV

Service temperature -40°C / +125°C

Polyurethane

General
- LOCTITE STYCAST U2500
- LOCTITE STYCAST U2535
- LOCTITE STYCAST US2651
- LOCTITE STYCAST US2050

Flame retardant
- LOCTITE STYCAST U2500FR
- LOCTITE STYCAST US1150
- LOCTITE STYCAST US2650
- LOCTITE STYCAST US5532
- LOCTITE STYCAST US5544

Epoxy

General
- LOCTITE STYCAST 2651W1/cat 9
- LOCTITE STYCAST 2651-40W1/cat 9
- LOCTITE STYCAST 2651MM/cat 9
- LOCTITE STYCAST ES1900
- LOCTITE STYCAST ES2204
- LOCTITE STYCAST A316 series

Thermal conductive
- LOCTITE STYCAST 2850FT/cat 9
- LOCTITE STYCAST 2850MT/cat 9

Flame retardant
- LOCTITE STYCAST E2534FR/cat 9
- LOCTITE STYCAST G508-1
- LOCTITE STYCAST ES2505

Light weight
- LOCTITE STYCAST 1090/cat 9
- LOCTITE STYCAST 1090SI/cat 9

Service temperature -40°C / +150°C

Polyurethane

General
- LOCTITE STYCAST U2500 HTR

Epoxy

General
- LOCTITE STYCAST 2651W1*
- LOCTITE STYCAST 2651-40W1*
- LOCTITE STYCAST 2651MM*
- LOCTITE STYCAST EO1058
- LOCTITE STYCAST EO7038
- LOCTITE STYCAST A316-48
- XE70202

Thermal conductive
- LOCTITE STYCAST 2850FT*
- LOCTITE STYCAST 2850MT*
- LOCTITE STYCAST 2850KT*

Flame retardant
- LOCTITE STYCAST E 2534FR/cat 9
- LOCTITE STYCAST G 508-1
- LOCTITE STYCAST ES1004
- LOCTITE STYCAST ES2505

Light weight
- LOCTITE STYCAST 1090*
- LOCTITE STYCAST 1090SI*

* Cat 9 or cat 27-1

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Service temperature -40°C / +175°C

Epoxy

General
- LOCTITE STYCAST 2651W1/cat 27-1
- LOCTITE STYCAST 2651-40W1/cat 27-1
- LOCTITE STYCAST 2651MM/cat 27-1
- LOCTITE STYCAST ES2205
- LOCTITE STYCAST ES4322
- LOCTITE STYCAST EO1058
- LOCTITE STYCAST EO7038
- LOCTITE STYCAST A316-48

Thermal conductive
- LOCTITE STYCAST 2850FT/cat 27-1
- LOCTITE STYCAST 2850MT/cat 27-1
- LOCTITE STYCAST 2851FT

Flame retardant
- LOCTITE STYCAST G 508-1
- LOCTITE STYCAST ES1004

Light weight
- LOCTITE STYCAST 1090/cat 27-1
- LOCTITE STYCAST 1090SI/cat 27-1

Silicone

General
- Loctite 5140
- Loctite 5145
- Loctite 5092/5091
- Loctite 5088

Thermal conductive
- Loctite 5952-1
- Loctite 5954

Service temperature
-40°C / +200°C

Epoxy

General
LOCTITE STYCAST 2662/cat 17
LOCTITE STYCAST E2517
Eccobond 104

Thermal conductive
LOCTITE STYCAST 2762FT/cat 17

Silicone

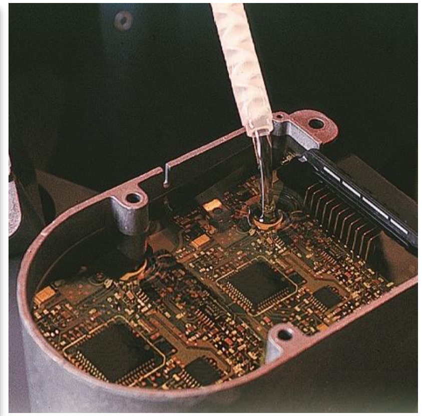
General
Loctite 5140
Loctite 5145
Loctite 5092/5091
Loctite 5088

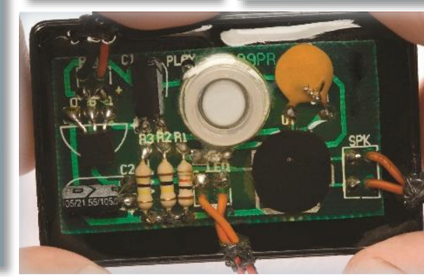
Thermal conductive
Loctite 5952-1
Loctite 5954

Potting							
Application status	New		Existing		Product Design Request		
General information							
Henkel sales person							
Customer name							
Ship-to Address							
Customer contact name							
Customer contact phone number							
Market segment							
Potential Value							
Potential Volume							
Sample quantity							

Process information		Indicate must criteria with X
Application description (housing and inner parts) small gap filling required flow behaviour of product		
Potting volume in cc		
Product Environment - Operating temperature Range continous intermittent		
Desired Cure Method (Heat, RTV, UV, RT- 2part,)		
Max. cure time		
Max. cure temp.		
1 or Two-component acceptable		
Product properties		
Viscosity (mixed viscosity when 2K)		
Flame retardency, UL class		
Hardness		
Tg		
CTE coefficient of thermal expension		
High voltage requirements		
Product Environment - Fluid Exposure		
Product Environment - Thermal shock		
Available dispensing equipment (brand, type)		
Required electrical properties:		
Dielectric strength		
Dielectric constant		
Dissipation factor		
Volume/surface resistivity		
SIR (Surface Insulation Resistance)		
Other		
Other		
Other		
Current Supplier and product description		

Thank you for your attention.





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