PCB Protection
Conformal Coating, Potting, & Encapsulation

M P Rajaram

Henkel Adhesive Technologies India Pvt Ltd
Agenda

- Reasons for using PCB Protection
- Conformal Coating
- Low Pressure Molding (Macromelt®)
- Potting
PCB Protection Agenda

Why?
What Environments?
What Method?
What Chemistry?
Purpose

Environmental
  Moisture
  Harmful fluids
  Dirt
  Ultraviolet light

Mechanical
  Shock and Vibration

Radio Frequency
  Faraday cage

Electrical Insulation

Proprietary Design
Possible Environments

Automotive
  Underhood
  In Cabin
  External
Telecom
  Proprietary Programming
Utilities
  UV protection
  Moisture protection
Military
Marine Environments
Considerations

- Type of protection needed
- Size of board/part
- Weight requirements
- Rework required?
- Protection from aftermarket modification/repair
- Design status
Options – Types of Protection

Conformal Coating
  Thin layer of material to cover all or part of circuit board
Module sealing
  Bonding or sealing two part external case
Low Pressure Molding (Macromelt®)
  Thermoplastic overmolding of entire product except for connector
Potting
  Completely covering circuit board inside external case except for connectors
Microencapsulation
  EPOY overmolding of specific areas or components
Conformal Coating

Various chemistries

Acrylics  One component, highly abrasion resistant, easily repairable.  Temps to 110°C.
Urethanes  Softer systems, thermal shock resistant, somewhat repairable.  Temps to 110 or 125°C
Epoxies  Superb chemical and abrasion resistance.  When reworkability is not needed.  Temps to 125°C.
Silicones  Highest temperature environments, reworkable, zero VOC s, otherwise protected from abrasion.
Why?

“Hey Frank…better have engineering include a conformal coating on that next batch.”

Www.plasmasystems.com/guide.html
Conformal Coating Applications

Traditionally, conformal coatings were only used in high reliability applications

- military
- aerospace
Conformal Coating Applications

- Many Fine Pitch SMT designs will not operate or perform adequately in humid environments without the use of a Conformal Coating.
Conformal Coating Chemistry

- Acrylics (AR)
- Urethanes (UR)
- Epoxies (ER)
- Silicones (SI)
- Paraxylenes

<table>
<thead>
<tr>
<th></th>
<th>&quot;Green&quot;</th>
<th>Protective</th>
<th>Temp °C</th>
<th>Rework</th>
<th>$</th>
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</thead>
<tbody>
<tr>
<td>AR</td>
<td>-</td>
<td>+</td>
<td>150</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>UR</td>
<td>-</td>
<td>0</td>
<td>125</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>ER</td>
<td>-</td>
<td>+</td>
<td>150</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>SI</td>
<td>+</td>
<td>0</td>
<td>200</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>
Conformal Coating
Chemistry - Acrylic (AR)

Thermoplastic Lacquer that Cures by Solvent Evaporation

Advantages
- Easy to apply
- Desirable physical and electrical properties
- Easy to repair

Disadvantages
- Contain solvents
- High modulus
- Solvent resistance
Conformal Coating  
Chemistry - Polyurethane (UR)

A thermoplastic polymer (which can be made thermosetting) produced by the condensation reaction of a polyisocyanate and a hydroxyl-containing material

Advantages
- Solvent resistance
- Electrical properties

Disadvantages
- Contain isocyanates
- Hard to repair
- High modulus
- Two-part pot life
Conformal Coating Chemistry - Epoxy (ER)

**Thermosetting Resins Based on the Reactivity of the Epoxide Group**

**Advantages**
- Desirable physical and Electrical properties
- Solvent resistance
- Solvent free

**Disadvantages**
- High modulus
- Hard to repair
- Two-part short pot life
- Shrink during cure
Conformal Coating
Chemistry - Silicone (SR)

Based on Polydimethylsiloxane

Advantages
- Low modulus
- Electrical properties
- Wide temperature range
- Easy repair

Disadvantages
- High CTE
- Low modulus
- Cost
Conformal Coating Process

(Clean) → (Mask) → (Cure) →

Coat → Cure → (Demask) →
Conformal Coating Process Cleaning

Water Soluble (water washable) Fluxes
  Thorough cleaning required
No Clean Fluxes
  All flux must be activated in reflow
  No Washing
Mold releases and marking inks
  May cause dewetting
Applying the Coating

Dip
Spray (Dispense)
Brush
Conformal Coating - Coating Thickness

Coating thickness recommendations - IPC2221 and J-STD-001
See also IPC - HDBK - 830

<table>
<thead>
<tr>
<th>Type</th>
<th>Material</th>
<th>Thickness Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type AR</td>
<td>Acrylic</td>
<td>1.18 - 5.12 mil</td>
</tr>
<tr>
<td>Type ER</td>
<td>Epoxy</td>
<td>1.18 - 5.12 mil</td>
</tr>
<tr>
<td>Type UR</td>
<td>Urethane</td>
<td>1.18 - 5.12 mil</td>
</tr>
<tr>
<td>Type Si</td>
<td>Silicone</td>
<td>1.97 - 8.27 mil</td>
</tr>
<tr>
<td>Type XY</td>
<td>Paraxylylene</td>
<td>0.394 - 1.97 mil</td>
</tr>
</tbody>
</table>

Every design should be tested
Conformal Coating Process Curing

- Solvent Evaporation
- Heat
- RT
- UV Light Combinations
  - UV/Heat
  - UV/Moisture
  - UV/Two-Part

Moisture Two-Part
Coating Performance Qualifications

Qualification Standards:
- MIL-I-46058C (not to be used on new procurement)
- IPC-CC-830B
- UL 746C includes flammability
- Telcordia formerly Bellcore TR-NWT-000078
- Individual company standards
Module Sealing

Silicones
  Flexible for high temp thermal cycling
  Adhesion to numerous substrates
  Substrates are usually not functional electronics
  Most protection provided by external hardware (case)

Three types
  Cure in place   Apply, Cure, Assemble
  Form in place   Apply, Assemble, Cure
  Post assembly   Assemble, Apply, Cure

May use material to complete faraday cage too
Potting
Potting Materials

Chemistries
   Epoxy: one and two component compounds
   Urethanes: two component compounds
   Silicones: one component systems

Applications
   Adhesives
   Biomedical
   Filters (Air, Oil, and Water)
   General potting and encapsulation
   Telecommunications Encapsulants
   LED Lighting
   Doming

Packages
   Range from less than one ounce per part to over 300lbs per part
Epoxy Systems

Room Temperature Cure
  Aliphatic Amine/ Polyamide/ Amidoamines Cures
  Good for wide variety of general use systems
Heat Cure
  Cycloaliphatic Amine/ Anhydride
  Used in applications where higher heat resistance is required
One Component
  Dicyandiamide, BCl$_3$/Anhydride, Mod. Aliphatic Amine
  Used in applications where quick cure is preferred or no mixing is required
UV Precure/Cure
Epoxies

**RESINS**

- Diglycidyl Ether of Bisphenol A
  - Most common
  - Low cost

- Diglycidyl Ether of Bisphenol F
  - More expensive

- Cycloaliphatic
  - More expensive
  - High performance

**HARDENERS**

- Amines
  - Aromatic-elevated temp cure
  - Aliphatic-room temp cure

- Polyamides

- Anhydrides-high temp cure

- Dicyandiamide-typically used in 1 components
# Hardener Type vs. Properties

<table>
<thead>
<tr>
<th></th>
<th>Amines Aliphatic</th>
<th>Amines Aromatic</th>
<th>Polyamides</th>
<th>Anhydrides</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Appearance</strong></td>
<td>Rigid, Brittle</td>
<td>Rigid, Tough</td>
<td>Slightly to very flexible</td>
<td>Rigid to flexible</td>
</tr>
<tr>
<td><strong>Operating Temperature, °C</strong></td>
<td>105°C (221 °F)</td>
<td>155-180°C (302-356 °F)</td>
<td>105°C (221 °F)</td>
<td>To 200°C (392 °F)</td>
</tr>
<tr>
<td><strong>Potlife, hrs.</strong></td>
<td>0.5 0.75</td>
<td>8</td>
<td>2 3</td>
<td>20 hrs +</td>
</tr>
<tr>
<td><strong>General Uses</strong></td>
<td>Modules, small castings, adhesives</td>
<td>Solvent resistant apps, thermal cycling</td>
<td>Thermal cycling, low stress adhesive</td>
<td>Excellent electricals, module potting, coil potting</td>
</tr>
</tbody>
</table>
Urethane Systems

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
Dielectric Constant from: 3 to 7
Dissipation Factor from: 0.01 to 0.2
Dielectric Strength: up to 1200 volts/mil (20mil thickness)
Urethane 2 part Systems

Urethanes are produced through reaction of isocyanates (R-NCO) with polyol (HO-R-OH) or a prepolymer (pre-reacted polyol and excess Isocyanate) with a polyol.
Urethanes

POLYOLS
Polyethers
  Polyoxypolypropylene Glycol (PPG)
  Polytetramethylene Ether Glycol (PTMEG)
Polybutadiene (Poly BD)  * restricted for export*
Polyesters
  Adipates
  Polycaprolactones
  Castor Oil

I SOCYANATES
Aromatic
  Toluene Diisocyanate
  4,4 Diphenylmethane Diisocyanate (Pure MDI)
  Crude (Polymeric) MDI
Aliphatic
  Hexamethylenediisocyanate (HDI)
Cycloaliphatic
  Isophorone Diisocyanate (IPDI)
  Methylene Bis (4-cyclohexylisocyanat4e) (HMDI)
# Urethane vs. Epoxy

<table>
<thead>
<tr>
<th>Property</th>
<th>Epoxy</th>
<th>Urethane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temperature, °C</td>
<td>&lt;200</td>
<td>&lt;125</td>
</tr>
<tr>
<td>Thermal Shock</td>
<td>Good</td>
<td>Better</td>
</tr>
<tr>
<td>Exotherm</td>
<td>Varies, can be high</td>
<td>Low (&lt;50°C)</td>
</tr>
<tr>
<td>Moisture Sensitivity During Processing and Storage</td>
<td>Less sensitive</td>
<td>Very sensitive</td>
</tr>
<tr>
<td>Electrical Properties</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Strength</td>
<td>Best</td>
<td>Good</td>
</tr>
<tr>
<td>Elongation</td>
<td>&lt;100%</td>
<td>&gt;100%</td>
</tr>
<tr>
<td>Tg, °C</td>
<td>0 to 160+</td>
<td>-65 to 80</td>
</tr>
<tr>
<td>Hardness</td>
<td>Shore D &gt;35</td>
<td>Shore A &lt;90</td>
</tr>
</tbody>
</table>
## Fillers

<table>
<thead>
<tr>
<th>Desired Effects</th>
<th>Improved Machinability</th>
<th>Improved Thermal Conductivity</th>
<th>Improved Abrasion Resistance</th>
<th>Improved Impact Strength</th>
<th>Improved Electrical Conductivity</th>
<th>Improved Thixotropic Response</th>
<th>X-Ray Opaque</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fillers</td>
<td>Calcium Carbonate</td>
<td>Alumina</td>
<td>Chopped Glass</td>
<td>Mica</td>
<td>Metallic fillers</td>
<td>Colloidal Silica</td>
<td>Barytes</td>
</tr>
<tr>
<td></td>
<td>Calcium Silicate</td>
<td>Flint powder</td>
<td>Alumina</td>
<td>Silica</td>
<td>Alumina</td>
<td>Bentonite clay</td>
<td>Iron</td>
</tr>
<tr>
<td></td>
<td>Powdered aluminum or</td>
<td>Carborundum</td>
<td>Powdered or flaked glass</td>
<td>Carbon fiber</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>copper</td>
<td>Silica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Molybdenum dissulfide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Trade-off: Abrasiveness / Hardness of Fillers

- MOH Hardness

- Diamond
- Alumina
- Silicon Dioxide
- Silica
- ATH
- CaCO₃
- Talc

Least → Most

1 → 10
Applications

Voltage regulator (off-road vehicles)
Urethane
Applications

Sprinkler Solenoid
Urethane
Applications

Automotive Light Sockets
Urethane
Applications

Windshield Washer
Fluid Heater

Camshaft Position
Sensor

Urethanes
Applications

Telephone Connector Blocks
Urethane
Applications

Ignition Coils

Automotive Brake Sensor

Epoxies
Applications

TPMS Remote Transmitter
Urethanes
Applications

Automotive ECM
Urethane
Applications

Automotive LED Tail Light Epoxy
Circuit Board Protection

Potting
Gasketing
Conformal Coating
  Epoxy (Hard, Abrasion resistant)
  Acrylic (low-VOC)
  Urethane (reworkable)
  Silicone (High-temp, UV/dual cure)
Low Pressure Molding
Thank You