Cleanliness Requirements prior to Conformal Coating

Speaker: Axel Vargas, Application Engineer, ZESTRON America
Content

- Influencing factors
- Failure mechanisms
- Coating defects
- Cleaning before coating
- Analytics and test methods
Impact on PCBs

- Climate changes
- Vibrations
- Humidity
- Corrosion
- Corrosive gases
- Automized salt spray
- Temperature
- Migration
Climatic Stress increases

- big components
- low density on the assemblies
- low environmental influences
- small components
- High density of low standoff components
- extreme environmental influences
Coating protects against:

- Electrochemical migration
- Creeping current
- Signal distortion on radio frequency (RF) circuits
Reasons for Failures

- Electrical connections: 33%
- Active Components: 30%
- Mechanical Connections: 8%
- Others: 4%
- Impurities: 8%
- Passive Components: 11%
- Body failures: 6%

Resource:
Modern Electronic Packaging
Integrated Circuits Engineering Corporation
## Possible Impurities

<table>
<thead>
<tr>
<th>PCB manufacture</th>
<th>Component manufacture</th>
<th>Assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Contamination from the etching process</td>
<td>- Contamination from Metallization-baths</td>
<td>- Solder pastes</td>
</tr>
<tr>
<td>- Developer chemical</td>
<td>- Rinse water quality</td>
<td>- Wave solder</td>
</tr>
<tr>
<td>- Alkaline cleaning agent</td>
<td>- Deflashing chemicals</td>
<td>- Rinse water quality</td>
</tr>
<tr>
<td>- HAL-residues</td>
<td>- Mold release agent</td>
<td>- Reflow oven</td>
</tr>
<tr>
<td>- Residues from ENiG-/ CSN-process</td>
<td></td>
<td>- Reflow condensate</td>
</tr>
</tbody>
</table>

- Outgassing
Critical Residues

Ingredients:

- Rosin or Resin
- Activators
- Solvents (thinner)
- Thixotropic agents

Fluxes/solder pastes

Handling residues

e.g.
- finger prints
- dust
- oil/grease
- salts
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Climatic Failure Mechanisms

- Electrochemical migration
- Creeping current
- Signal distortion on radio frequency (RF) circuits
Electrochemical Migration

Influencing factor: Stress voltage

steam/humidity
+ Ionic contamination (salts, flux activators)
= conductive electrolytes
+ Stress voltage
= Electro-chemical migration
Failure occurs when you have:

- Sufficient Atmospheric Humidity
  Promoted by Contamination on the Surface
- Electrical Potential Difference
- Alloys that can electrochemically migrate
Humidity Adsorption on Metallic Surfaces

Copper

Nickel

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Influence of the Amount of Adsorbed Water on SIR
Failure Mechanisms

Electrical dissociation of water

$2H_2O + 2e^- = H_2 + 2OH^-$

$2H_2O \rightarrow O_2 + 4e^- + 4OH^-$
Failure Mechanisms

Potential/pH diagrams for tin and lead
Corrosion of Inner Ag-layer on Hybrids

AgS$_2$-crystals on conductive glass
Step 1. Anodic Metal Dissolution $[M \rightarrow M^+ + e^-]$
Step 2. Metallic Ion Diffusion
Step 3. Cathodic Metal Deposition $[M^+ + e^- \rightarrow M]$

Mechanism of dendrite growth
Failure Mechanisms

Dendrite morphology
Climatic Failure Mechanisms

- Electrochemical Migration
- Creeping current
- Signal distortion on radio frequency circuits
Visualization of creeping current through charge contrast measurement

Optically clean

Electrically contaminated
Resin/Rosin Residues

Important: no humidity, only temperature cycles – day/night

→ Activators cause creeping currents and influence climatic reliability
Climatic Failure Mechanisms

- Electrochemical Migration
- Creeping current
- Signal distortion on radio frequency circuits
Bit Failures in RF Connections

Cleaned PCB → no transmission failure

Di-electricity of the rosin/resin disturbs transmission

Bit failure
Content

- Influencing factors
- Failure mechanisms
- Coating defects
- Cleaning before coating
- Analytics and test methods
Coating Failures

- Delamination
- Migration under coating
- Pores and delamination
- Influencing factors
- Failure mechanisms
- Coating defects
- Cleaning before coating
- Analytics and test methods
Cleaning before Coating

- Contamination under coating is hygroscopic
- Limited adhesion of coating on uncleaned PCBs
- Coating alone is inadequate because of vapor permeability
- Coating is applied to increase climatic reliability

→ Reliable coatings require cleaning
## Cleaning before Coating

<table>
<thead>
<tr>
<th>Cleaning Type</th>
<th>Method</th>
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</tr>
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<tbody>
<tr>
<td>Aqueous cleaning</td>
<td>Spray-In-Air</td>
<td>Ultrasonic</td>
<td>Spray-Under-Immersion</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Spray-In-Air" /></td>
<td><img src="image" alt="Ultrasonic" /></td>
<td><img src="image" alt="Spray-Under-Immersion" /></td>
</tr>
<tr>
<td>Semi-aqueous cleaning</td>
<td>Ultrasonic</td>
<td>Spray-Under-Immersion</td>
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<td></td>
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</table>
Aqueous Spray-In-Air Inline Process

Process characteristics:
- High or medium throughput
- Spray pressure > 40 psi
- High space requirements
Water-based Multi Chamber

**Process characteristics:**
- Medium or high throughput
- Low consumption
- Integrated water treatment system
- Option: full-automatic handling system
- Ultrasonic power: > 10 W/l (40 kHz)
Aqueous Spray-In-Air Batch Process

Process characteristics:
- Low and medium throughput
- Spray pressure:< 40 psi
- Requires little space
- Fully automatic

Parts to be cleaned

Heating

VIGON® A 250

Tank for cleaning agent

Rinsing 1 with tap water
Rinsing 2 with DI-water
Influencing factors
Failure mechanisms
Coating defects
Cleaning before coating
Analytics and Test methods
## Conditions for Reliable Coatings

**Cleanliness qualification before coating:**

<table>
<thead>
<tr>
<th>Test</th>
<th>Normal value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionic contamination</td>
<td>&lt; 0.4 µg/cm²</td>
</tr>
<tr>
<td>Surface tension</td>
<td>&gt; 40 mN/m</td>
</tr>
<tr>
<td>ZESTRON® Flux Test</td>
<td>Residue-free</td>
</tr>
<tr>
<td>ZESTRON® Resin Test</td>
<td>Residue-free</td>
</tr>
<tr>
<td>Crosslinking poisons: Sn …</td>
<td>Residue-free</td>
</tr>
</tbody>
</table>
Test method – Ionic Contamination

Measurement with contaminometer
Wettability and Surface Cleanliness

Bad wettability = contaminated surface

Good wettability = clean surface

Test method – Ink Test
No encapsulation of organic activators in the rosin layer

Rosin residues are not discolorating
Results after ZESTRON® Resin Test

Discoloration of resin residues

Before

After
Test Method – Tin Test

- Detection of tin components
- Based on color reaction

Tin Test positive

Tin Test negative
## Coating Tests

### Coating:

<table>
<thead>
<tr>
<th>Test</th>
<th>✔</th>
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<tbody>
<tr>
<td>Climatic Reliability Test</td>
<td>✔</td>
</tr>
<tr>
<td>Coating Reliability Test</td>
<td>✔</td>
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Climatic Reliability Test

Test according to IEC 68-2
40°C, 93% RH, 21 days

Simulates climatic conditions under influence of temperature
Coating Reliability Test

Coating Reliability Test (CoRe Test)

Gas Development at weak points
Coating Reliability Test
Test implementation:

- Place PCB in DI-water or DI-water with additives
- Normal operating voltage
- Measure the operating current and plot against time
- PCB could be examined visually to detect presence of electrochemical migration and corrosion
Coating Reliability Test

Electrochemical migration based on delamination of protective coating
Coating Reliability Test

- Point of weakness analysis not a life cycle test
- Quick and cost-effective analysis during the development phase avoids expensive changes to the circuit layout during the production phase
- Combined with the lifetime test reduces development time and ensures a cost-effective development process
- Max 10 hours of testing is sufficient to get reliable results
Answers to the following questions:

- Is climatic reliability endangered by remaining contamination?
- Is coating against humidity necessary?
- Is existing coating reliable against humidity?
Advantages of Coating Reliability Test

<table>
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<tr>
<th>Weak point analysis (Coating Reliability Test)</th>
<th>Life time test (e.g. IEC 68-2 Standard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ During development</td>
<td>- Post development (type approval)</td>
</tr>
<tr>
<td>+ Quick (max. 10 hours)</td>
<td>- Time-consuming (up to 6 Months)</td>
</tr>
<tr>
<td>+ Low Cost</td>
<td>- High cost</td>
</tr>
<tr>
<td>+ Identification of all weak points</td>
<td>- Failures may remain undetected</td>
</tr>
<tr>
<td>- Pseudo-failure rate</td>
<td>+ Exempt from pseudo-failure rate</td>
</tr>
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</table>
Conclusion

- Coating against humidity is necessary
- Residues endanger reliable coatings
- Easy-to-use test methods for quality testing
- Reliability of the assembly is improved by cleaning
- Different cleaning processes are available