Coatings Academy®

Webinar 1.
Why electronics fail and what problems are we trying to solve?

Presented By: Vlad DAVID

Powered By HumiSeal®

Agenda

- Introduction to webinar series
- Industry trends
- Failure Mechanisms in Electronics
- Environmental & Operational Stress Factors
- Real-World Failure Examples
- Cost of Failure vs Cost of Protection
- What Problems Are We Trying to Solve?
- Transition to Webinar 2
- Q&A

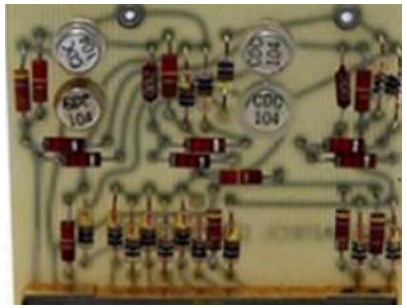
Introduction to webinar

8th of April	• **Webinar 1.** Why electronics fail and what problems are we trying to solve?
22nd of April	• Webinar 2. Conformal coating fundamentals. How can electronics be protected?
6th of May	• Webinar 3. How to select the right conformal coating material for your application
20th of May	• Webinar 4. How to integrate the coating application in the manufacturing process
3rd of June	• Webinar 5. Reliability, compliance and delivering the right business value

Evolution of Electronics Manufacturing

01

Before 1950s
Point to point construction
Limited applications

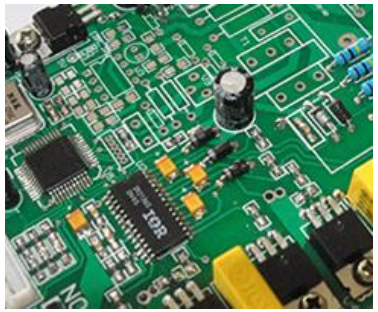


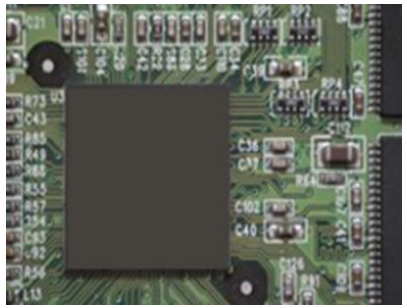
02

1950 - 1960
Through-Hole Technology
Axial and radial leads

03

1960 - 2000
Advancement in PCB
size reduction





2000 -
SMT components with
low profile package

04

Pictures source: Internet

Electronics are everywhere

- Electronics are exposed
- Higher voltage, smaller spacing
- Longer warranty periods (10–15 years automotive)
- Outdoor exposure increasing
- Higher reliability expectations

Reliability is no longer optional

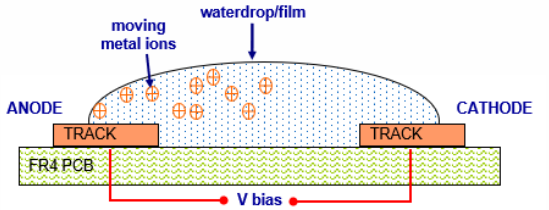
Most failures we see in the field falls into these four categories

- Moisture and corrosion
- Thermal stress and cracking
- Chemicals and Gases exposure
- Mechanical and vibration stress

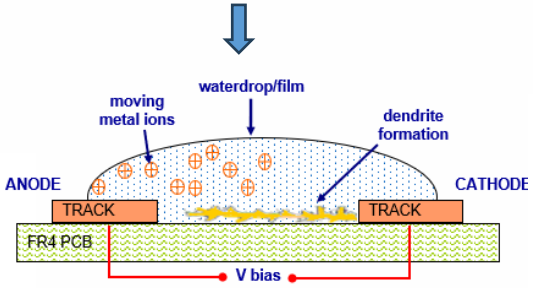
Moisture and corrosion

Moisture as waterdrop film

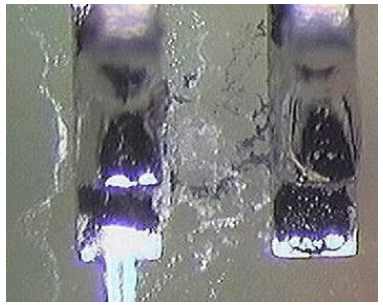
- Ionic contamination + bias voltage
- SIR drop with 85°C / 85% RH instability
- Dendritic growth



Operation in high humidity/condensation of unprotected assembly or with inadequate protection. Metal ions start to be formed



Dendrite formation



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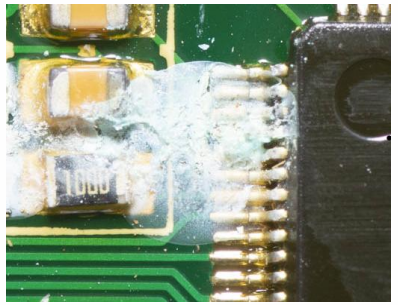

Failures on unprotected electronics

Moisture and corrosion

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- SIR drop with 85°C / 85% RH instability
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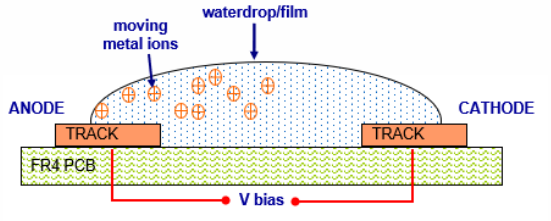

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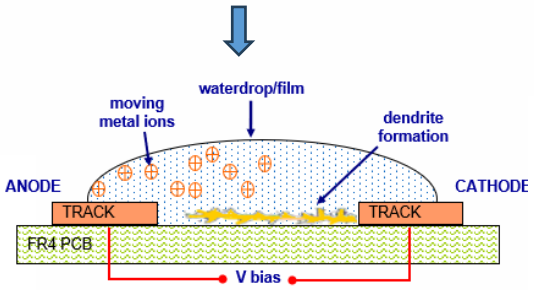

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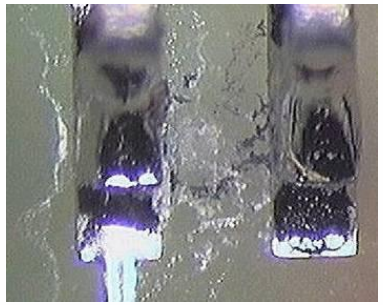

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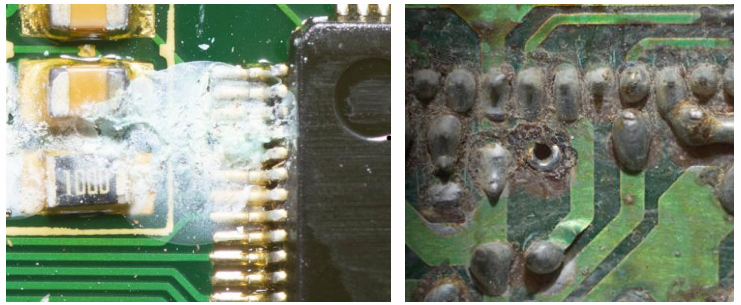
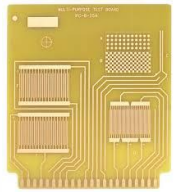


Failures on unprotected electronics

IPC-B-24



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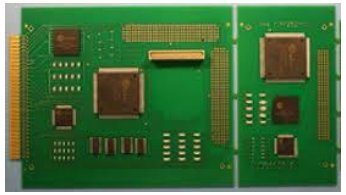

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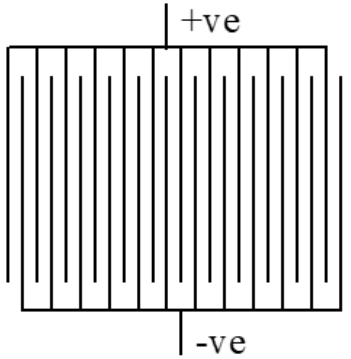
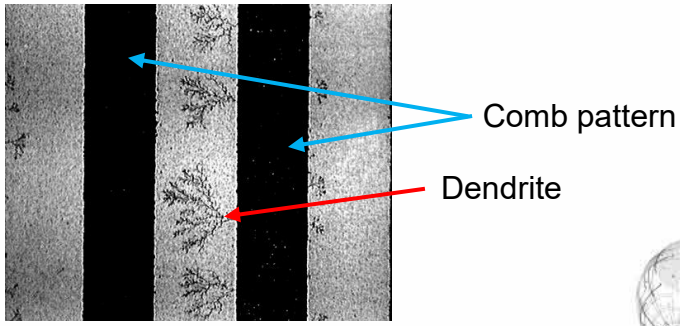


Comb pattern



Comb pattern under microscope. Dendrite formation

Moisture and corrosion

Moisture as waterdrop film
- Ionic contamination + bias voltage
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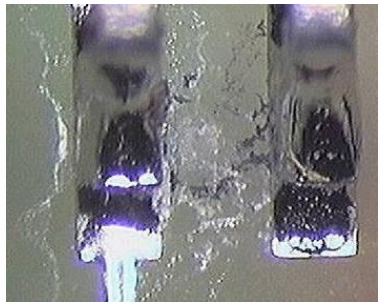

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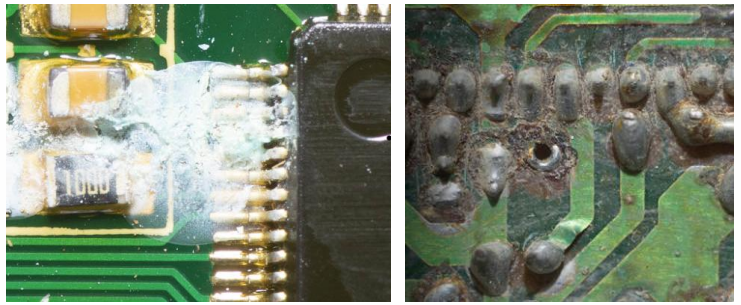
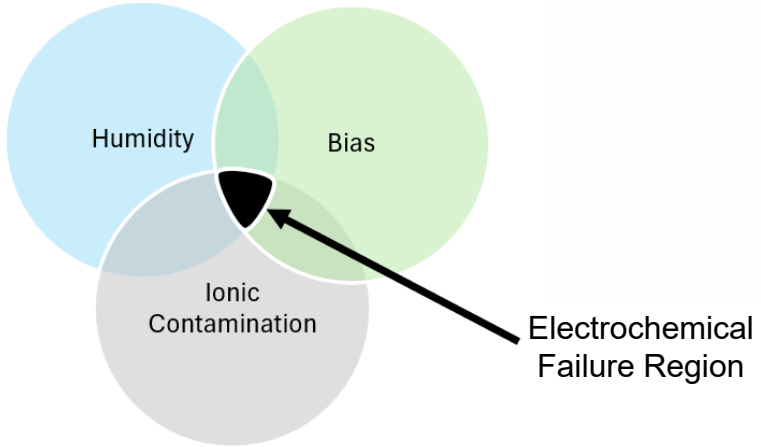


Failures on unprotected electronics

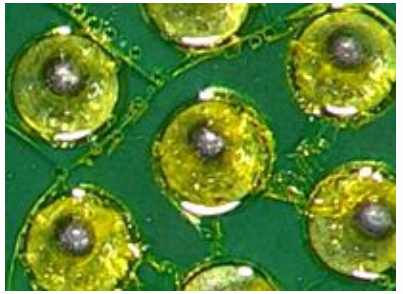


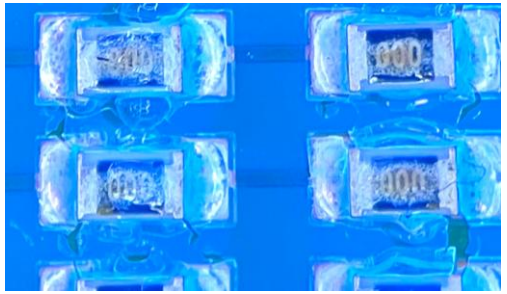
Remember!
Electrochemical failure occurs in presence of humidity, contamination and a voltage bias

What is the solution?
Ensure adequate electronics protection e.g. conformal coatings or encapsulation

Thermal stress and cracking

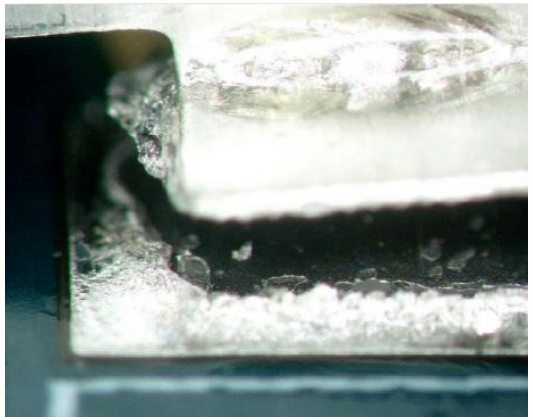
- Coefficient of Thermal Expansion (CTE) mismatch
- Thermal cycling
- Component profile
- Incompatible materials
  - Underfill, potting, adhesives and coatings with different CTEs build internal stress





Thermal stress defect as result of incorrect application/curing or testing in conditions outside the original specification

- Hard protective materials crack
- Crack → moisture path → failure

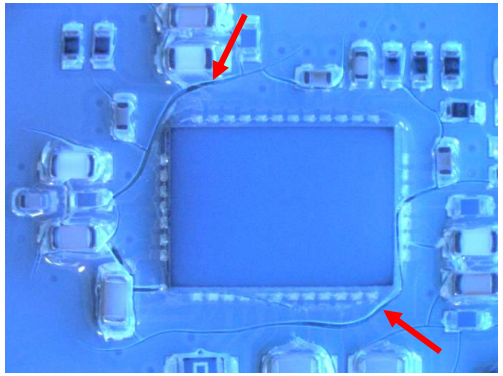


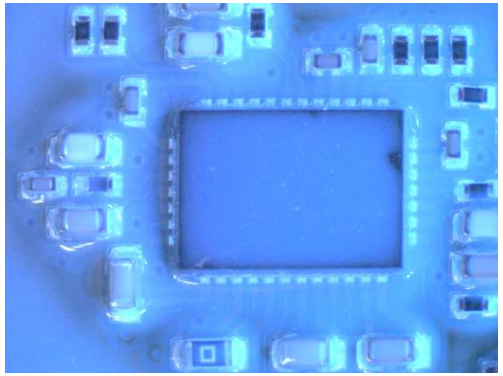
Solder joint failure
Source: Bob Willis – Guide to PCB surface finish
Link here

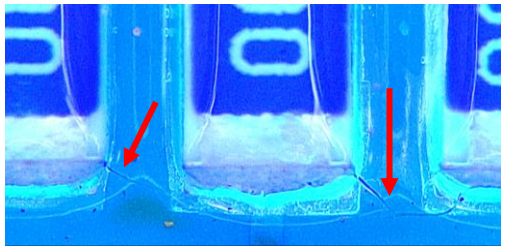
A crack is not cosmetic. Harder materials does not always mean are better

Thermal stress and cracking

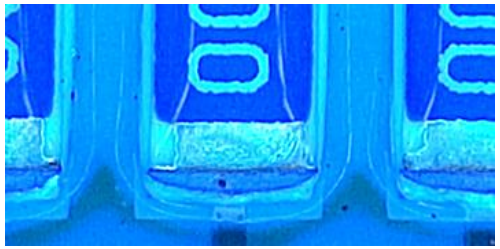
Example of thermal shock test results
Test condition: -40C to +85C, 30 min dwell
Number of cycles: 500



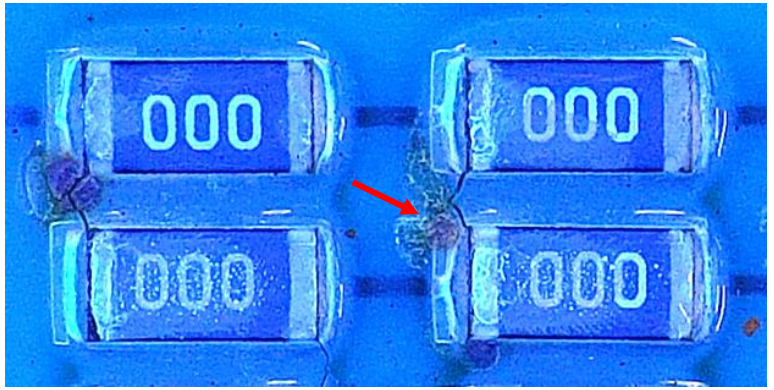




Hard and tough coating
Cracks can be observed



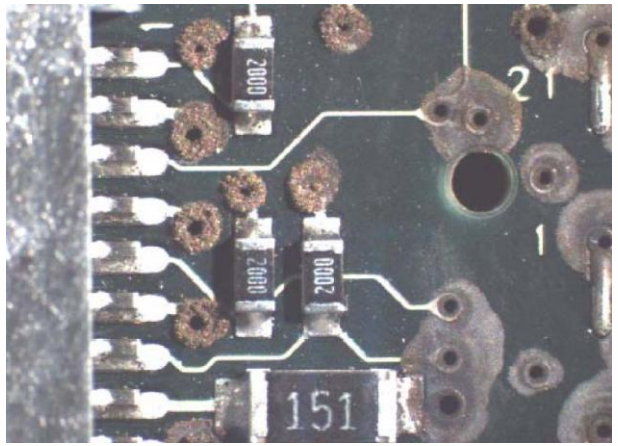
More flexible coating
No cracks

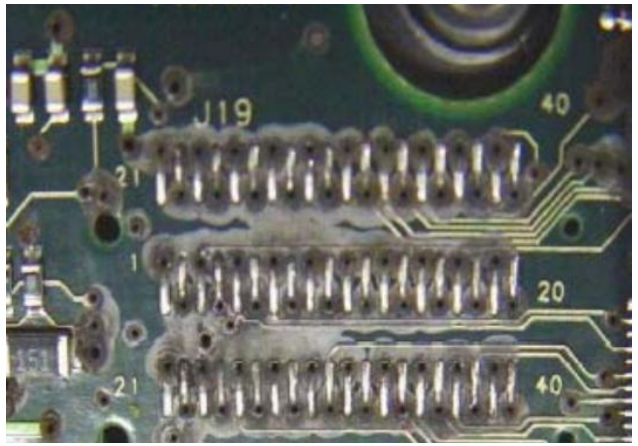


Hard and tough coating on uncleaned assembly
Example of **dendrite formation** during moisture test performed after the thermal shock

Chemical and gas exposure

- Salt spray
- Sulfur environments
- NOx / SOx (G3)
- Cleaning agents
- Under-hood automotive vapors





Pictures source: Saudi Aramco 2007
Corrosion of Electronic Corrosion of Electronic Control Systems in Gas Control Systems in Gas Treating Environments Treating Environment

Chemical and gas exposure

- Salt spray
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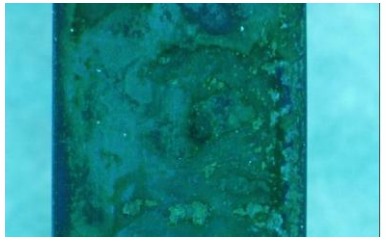
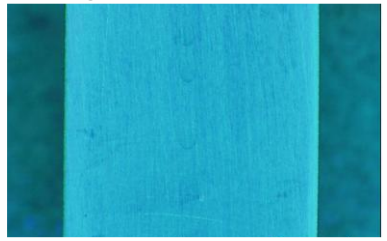
- NOx / SOx (G3)
- Cleaning agents
- Under-hood automotive vapors

G3 Harsh noxious gas

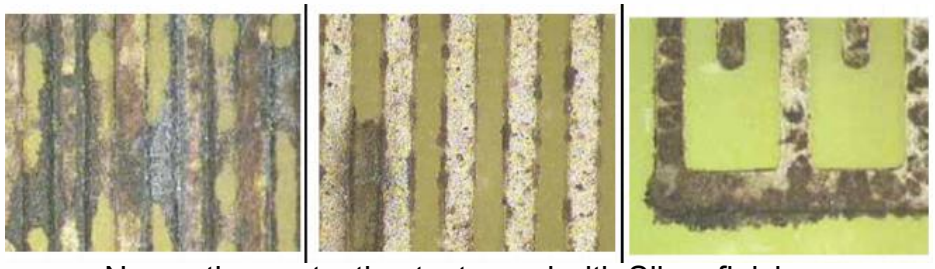


Uncoated Copper after exposure
Complete corrosion



Coated Copper after exposure
Complete protection

Mixed Flowing Gas 10 days exposure to simulate heavy city pollution



No coating protection test panel with Silver finish

UV curable coating on test panel with Silver finish

Table 1.
Definitions from ANSI/ISA-S71.04-1985
"Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants"

Severity Level		G1 Mild	G2 Moderate	G3 Harsh	GX Severe
Copper Reactivity Level (angstroms)		< 300	< 1,000	< 2,000	≥ 2,000
Contaminant Gas		Concentratio		(parts/billion)	
Group A	H_2S	< 3	< 10	< 50	≥ 50
	SO_2, SO_3	< 10	< 100	< 300	≥ 300
	Cl_2	< 1	< 2	< 10	≥ 10
	NOX	< 50	< 125	< 1,250	≥ 1,250
Group B	HF	< 1	< 2	< 10	≥ 10
	NH_3	< 500	< 10,000	< 25,000	≥ 25,000
	O_3	< 2	< 25	< 100	≥ 100

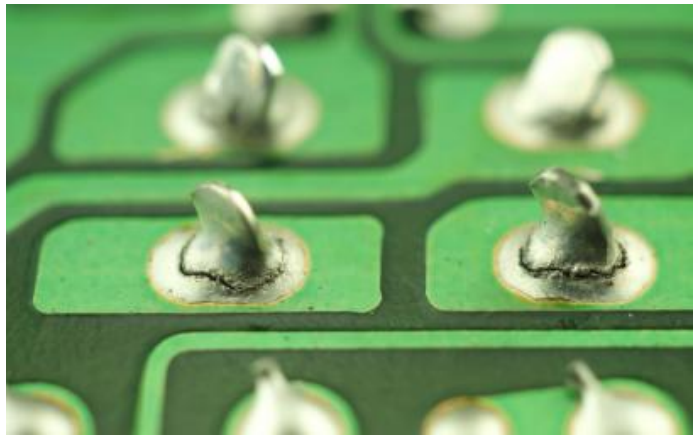
Gas concentrations are for reference purpose only and are believed to approximate the reactivity levels assuming relative humidity is less that 50%. For each 10% increase in relative humidity above 50%, or change in relative humidity by greater then 6%/hr, the severity level can be expected to increase by one level.

Extracted from ANSI/ISA-S71.04 standard

Mechanical and vibration stress

- Micro-cracking
- Tin whiskers
- Connector fatigue
- High-frequency vibration

Tin whiskers
Courtesy of Caplinq: link here

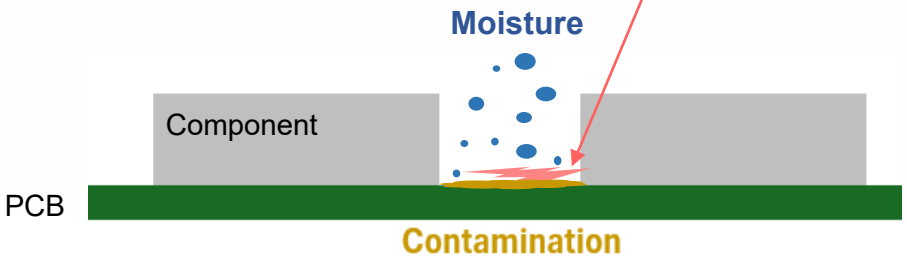


Picture source: Mouser. Vibration Damage Mitigation in Electronics is Key to Optimum Performance
Link here

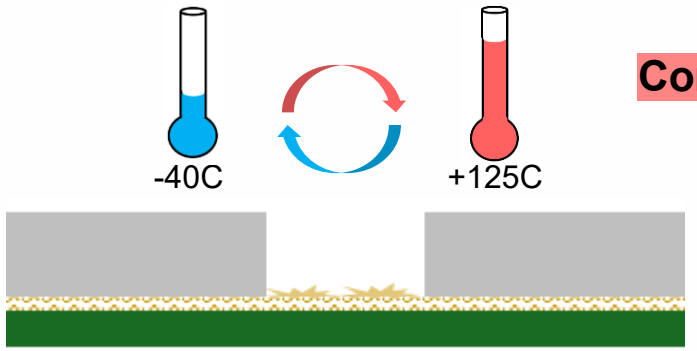
UV20Gel vibration test

Overview most common environmental stress factors

Contamination + Moisture + Bias + Time = Electrochemical Migration (ECM)



Thermal Cycling + Brittle Material = **Cracks** → **Moisture Ingress** → **Corrosion / ECM**



Environmental exposure by industry

One protective coating does not fit all scenarios

Industry	Predominant stress factors
Automotive	Thermal stress, condensation and chemicals
Industrial	Gas corrosion and vibration
Rail	Salt and extreme temperatures
White goods	Condensation and chemical detergents
Energy	Outdoor humidity and high voltage

Estimated 20%
of electronics failures in the field are caused by water-induced corrosion

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Breakdown costs for failure in the field:

- Production interruption
- Warranty replacement
- Logistics
- Service labour
- OEM score impact
- Brand reputation

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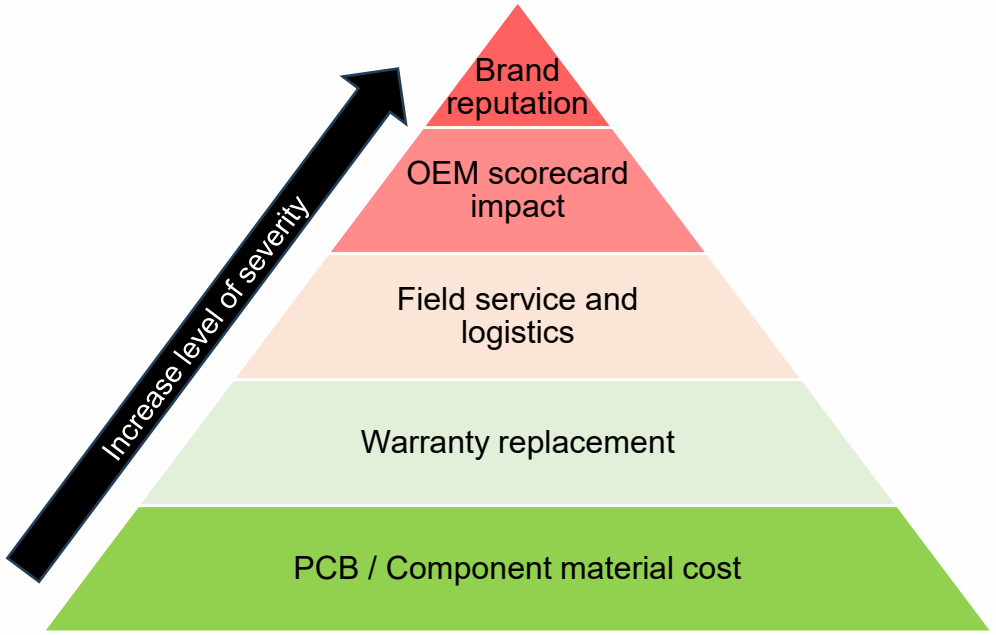

Failure cost escalates exponentially

Customer problem statement

Feedback from real conversations with customers

- The 85C/85%RH tests results are unstable
- We see corrosion after 18–24 months
- Coating cracks during thermal shock test
- We passed the tests but failed in the field
- We don’t know which standard applies to our industry

What a protective material must deliver

- ✓ Moisture protection
- ✓ Electrical insulation stability
- ✓ Condensation resistance
- ✓ Chemical resistance
- ✓ Thermal shock durability
- ✓ Process compatibility

What's next? Webinar 2

22nd of April

Time zones:
10:00 New York, USA
15:00 London, UK
16:00 Paris, France
20:30 Delhi, India
23:00 Shanghai

Webinar 2. Conformal coating fundamentals. How can electronics be protected?

- Conformal Coating Fundamentals
- How Can Electronics Be Protected?
- Coatings as practical and proven solution

Register to the next webinar using the QR code

Q&A

Coatings Academy®

Webinar 2.
Conformal coating fundamentals.
How can electronics be protected?

Presented By: Vlad DAVID

Powered By HumiSeal®

Agenda

- Introduction to webinar series
- Review failure mechanisms in electronics from webinar 1
- Conformal coating definition and chemistries
- Conformal coating key properties
- How a conformal coating protects
- What is a successful protection and other types of protective materials
- Transition to Webinar 3
- Q&A

Introduction to webinar

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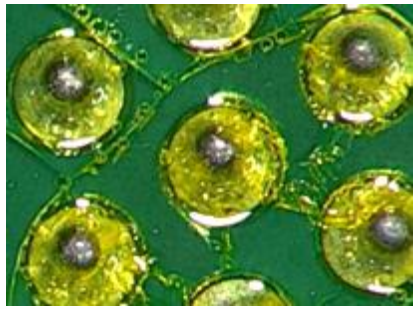
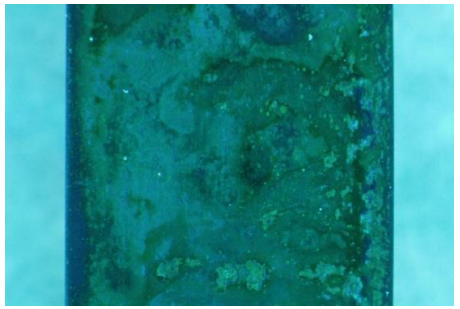
Webinar 1. Overview failure mechanisms

- Moisture and corrosion
- Thermal stress and cracking
- Chemicals and Gases exposure
- Mechanical and vibration stress

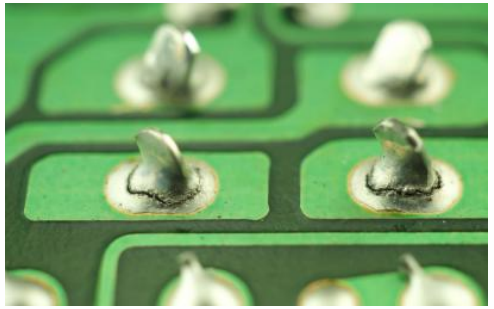
Moisture → corrosion



Thermal cycling → cracks



Chemical gas → Degradation and corrosion



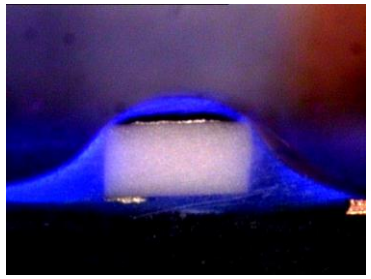
Vibration → micro-cracks and fatigue

Picture source: Mouser. Vibration Damage Mitigation in Electronics is Key to Optimum Performance. Link here

What is a conformal coating?

- Thin protective film
- “Conforms” to the varied profile of an electronic circuit assembly
- Membrane that filters water vapour and solid debris
- Protects the assembly from corrosion in harsh environments
- Electrical insulating properties allows reduced conductor spacing
- Glows blue under UV light for easy inspection

Coating application. Selective spray method

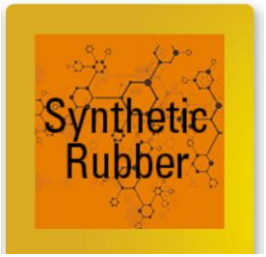


Cross section view of coating coverage

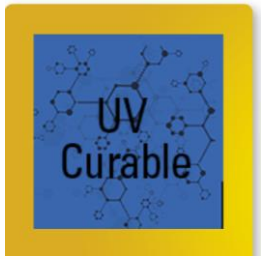
Coated assembly. Side view

Conformal coating chemistries

SOLVENT-BASED



SOLVENT-FREE *



Main features

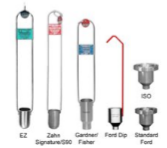
• General protection	• Chemical resistance	• Excellent electrical and condensation protection	• Excellent electrical and environmental protection	• Operation up to 200C

- Each chemistry has advantages and limitations. That is the focus of Webinar 3

Conformal coating key properties

Liquid state properties

- Viscosity
- Solids
- Density
- VOC (Volatile Organic Compound)

Test Method	VISCOMETER	FLOW CUPS (Zahn, DIN, etc)
Type	Static	Kinematic
Principle	Measure the resistance of a spindle rotating at a constant speed in the liquid	Measure a flow time of a liquid through a cup with a known volume
Measurement Units	Centipoise Or mPa.s	Seconds
Purpose of Use	Quality Control Laboratory Testing	Indicative only On field Testing
Accuracy	Excellent	Fair
Example		

Methods of viscosity measurement for conformal coatings

Conformal coating key properties

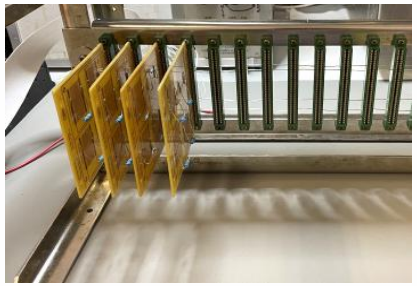
Cured state properties

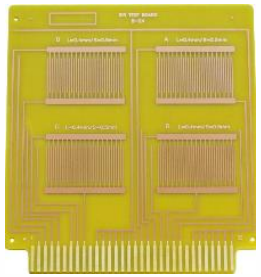
Electrical properties:
- Dielectric Withstand Voltage (DWV)
- Dielectric Breakdown Voltage (DBW)
- Surface Insulation resistance (SIR)

Mechanical properties:
- Elongation
- Modulus
- CTE

Environmental properties:
- Moisture Vapour Permittivity (MVP)
- Chemical resistance
- Thermal shock resistance


SIR Chamber

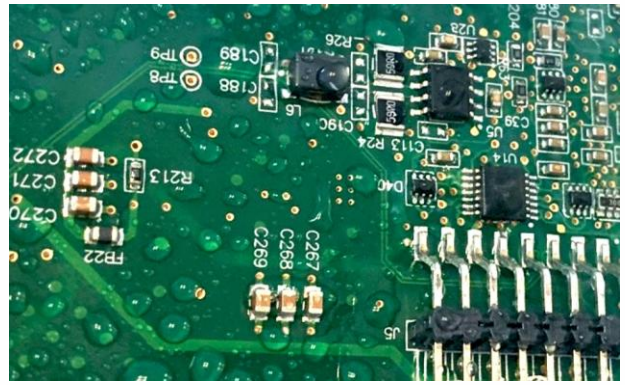

Test boards in SIR Rack

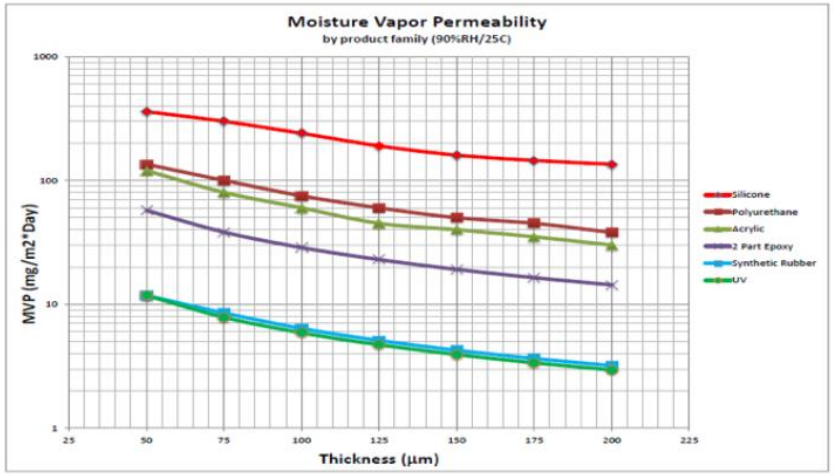

Test board IPC-B-24

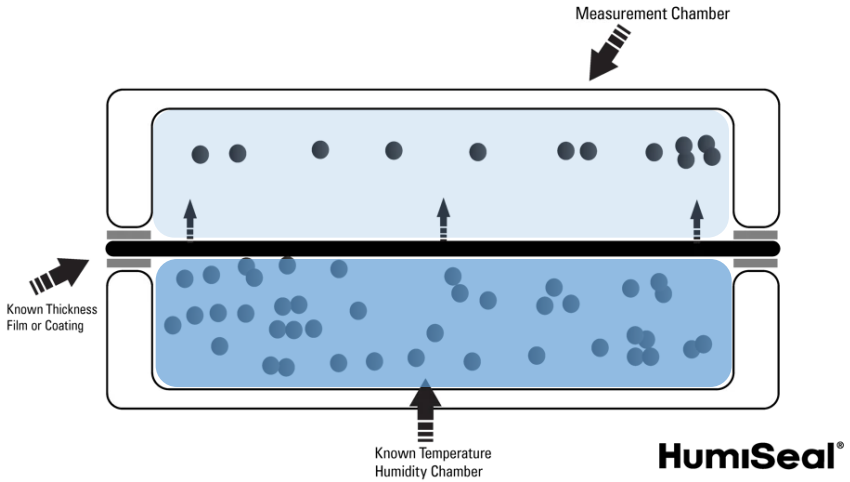
How coatings protect - MVP

Conformal coating as moisture barrier

- **Lower Moisture Vapour Permittivity (MVP) means better protection and better long-term corrosion resistance**
- Improved electrical stability especially Surface Insulation Resistance (SIR)







Moisture Vapour Transmission Measurement

How coatings protect - MVP

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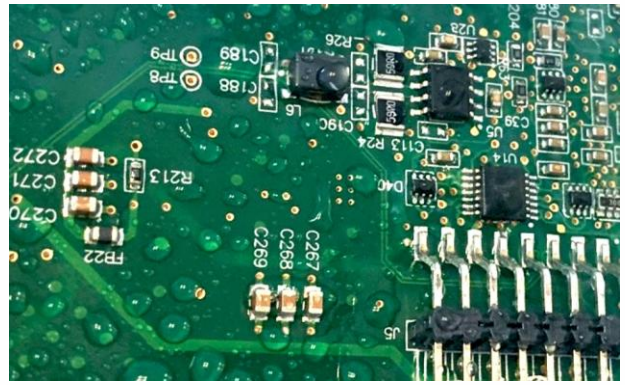
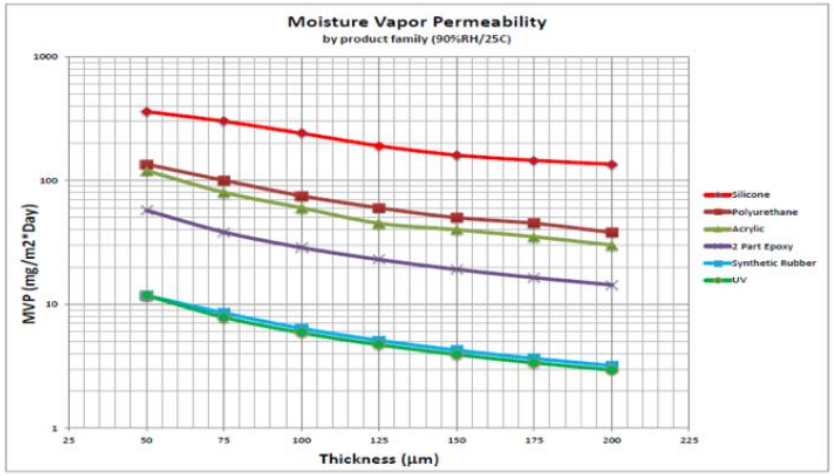
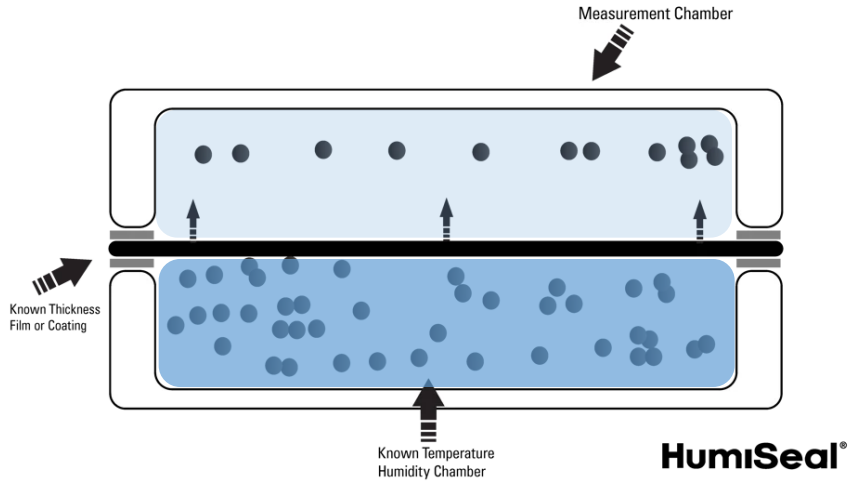




Chemistry	MVP Value in mg/m2*Day based on coating thickness				Condensation performance *
	50 µm	75 µm	100 µm	150 µm	
Acrylics	110	90	75	No data	Good
Urethane	120	100	80	No data	Good
Synthetic Rubber	12	9	8	No data	Excellent
UV Curable	12	8	7	6	Excellent
Silicone Resin	600	500	350	250	Poor



Moisture Vapour Transmission Measurement

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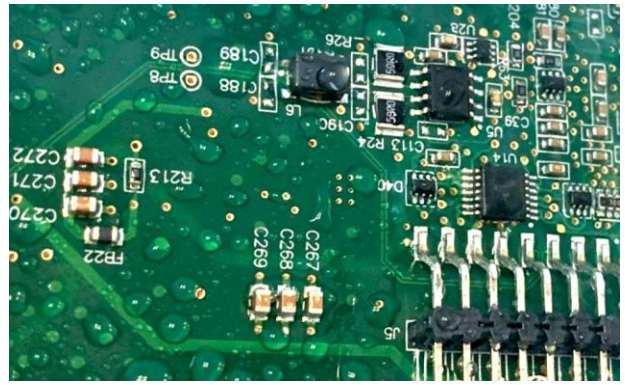
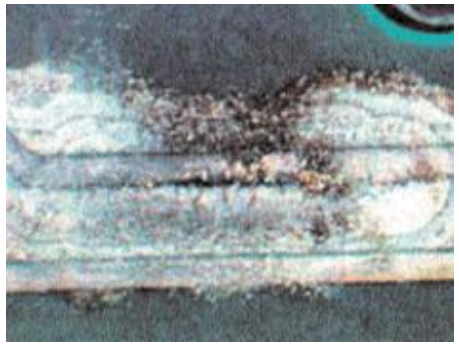
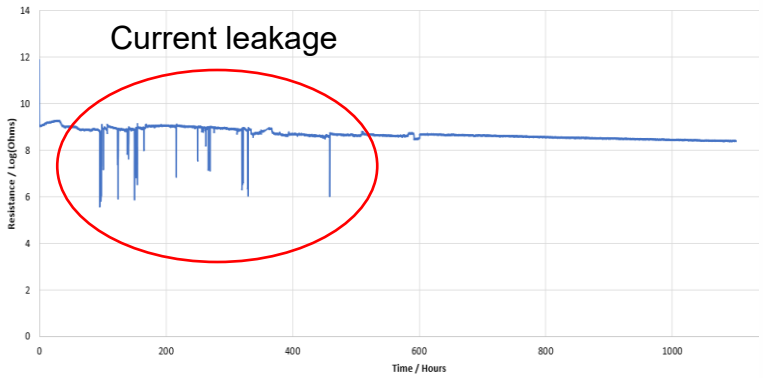
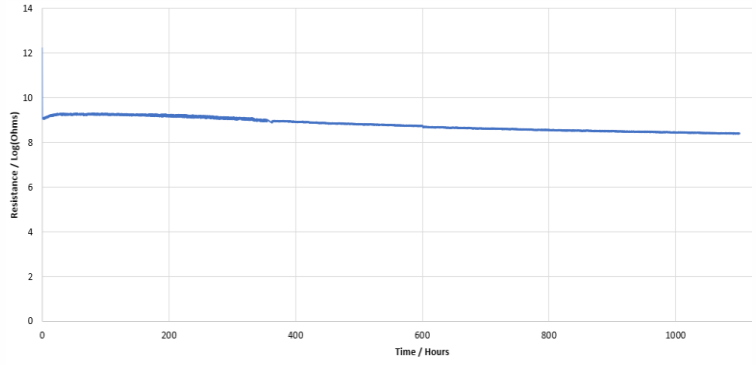




Corrosion on metal conductor



FAIL Example unstable SIR test
Current leakage drop to 6 Log Ohms *



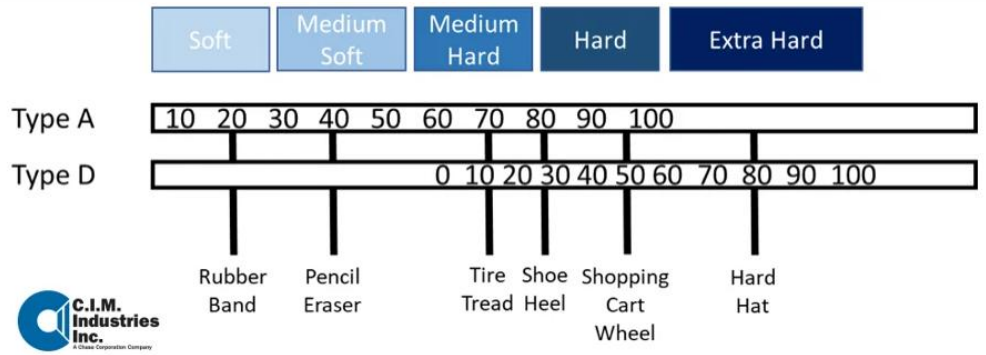
PASS Example stable SIR test.
No current leakage

* According to IPC, target for SIR testing with solder paste is minimum 8 Log Ohms

How coatings protect – mechanical/chemical stress

Mechanical and chemical resistance

- **Flexible coatings absorb mechanical stress**
  - **Key properties: elongation, modulus, Glass Transition Temperature (Tg)**
- Chemical resistance depends on polymer chemistry



Conformal coating chemistry	Hardness
Solvent-based Acrylics	Shore D50
Solvent-based Urethane	Shore D60
Solvent-based Synthetic Rubber	Shore D25
UV Curable (type 1)	Shore D70
UV Curable (type 2)	Shore A70 (D15)
Silicone Resin	Shore A30

How coatings protect – mechanical/chemical stress

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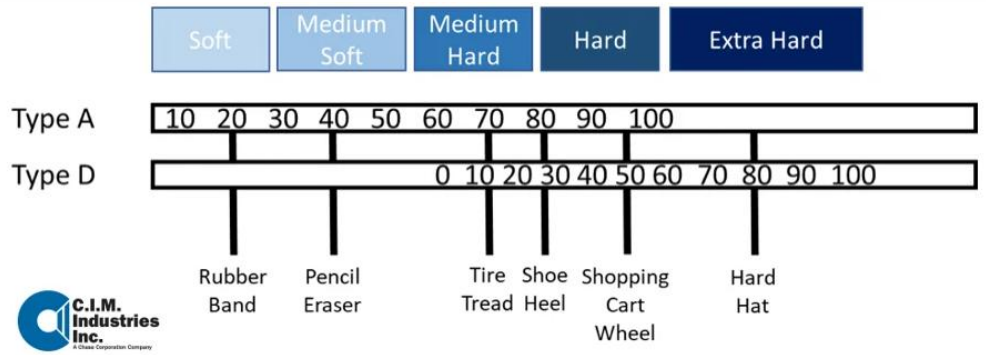

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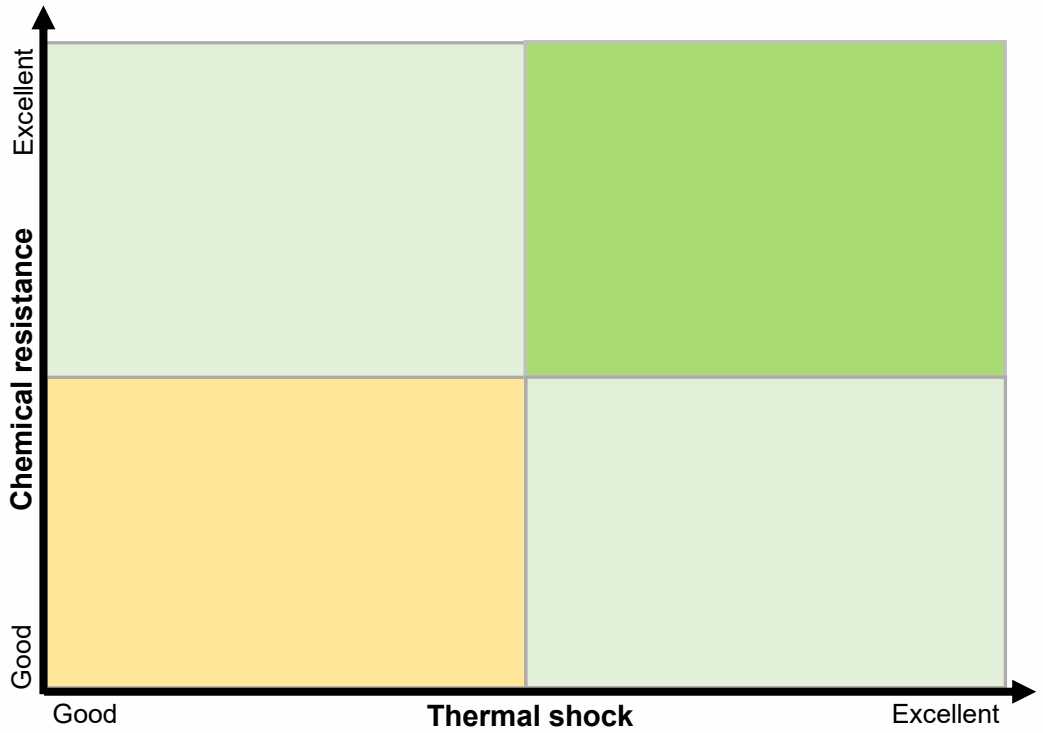

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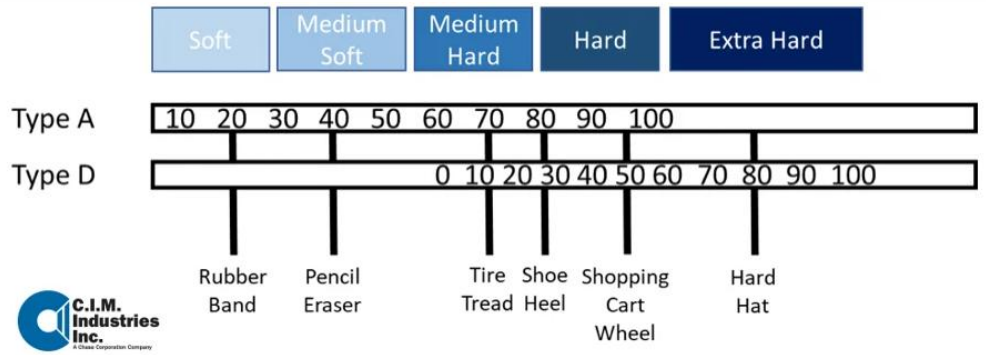

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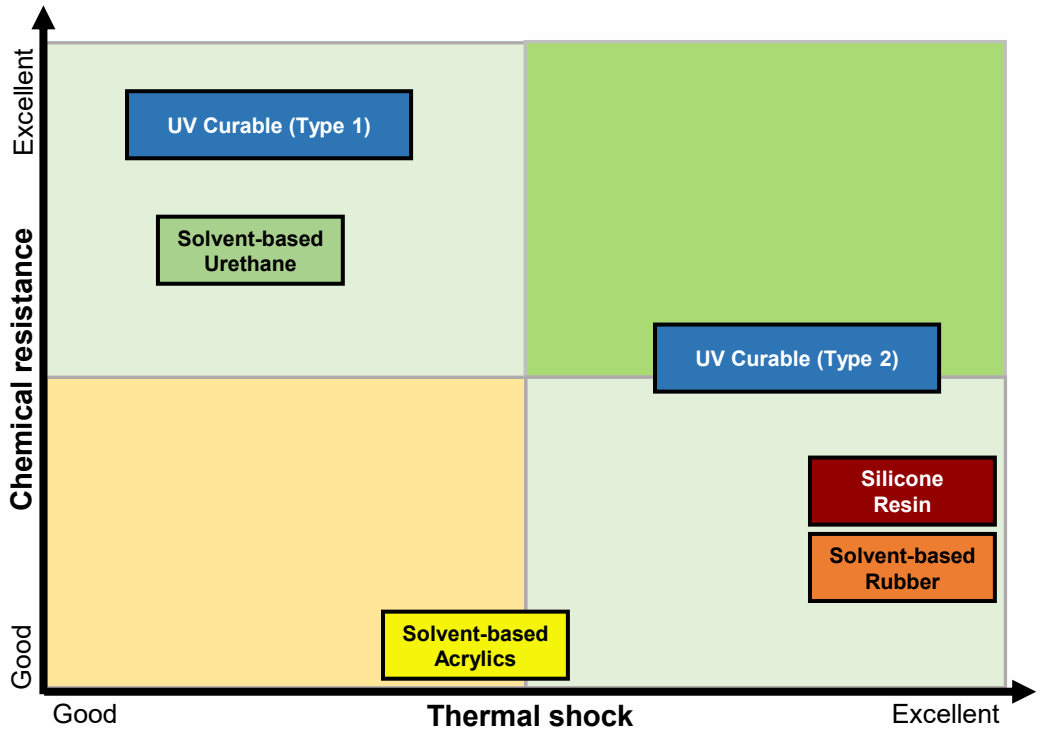


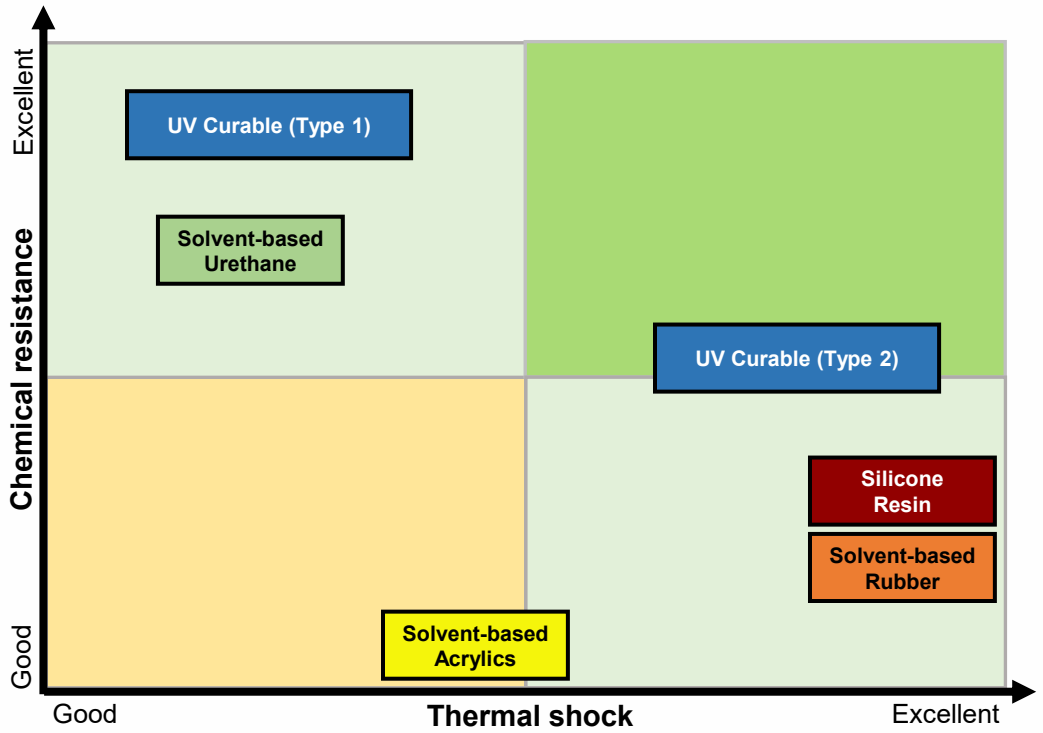
Remember: Select the right conformal coating based on the balance between thermal shock performance and chemical resistance needed

How coatings protect – chemical resistance

Mechanical and chemical resistance

- Flexible coatings absorb mechanical stress
  - Key properties: elongation, modulus, Glass Transition Temperature (Tg)
- **Chemical resistance depends on polymer chemistry**

Chemistry	Limited	Moderate	Good	Very Good	Excellent
Solvent-based Acrylic	•				
Solvent-based Synthetic Rubber		•			
Solvent-based Urethane				•	
UV Curable Type 1					•
UV Curable Type 2			•		
Silicone Resin		•			



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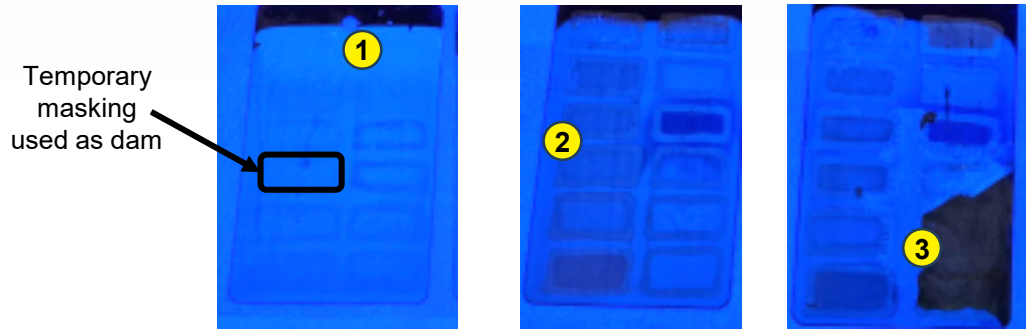
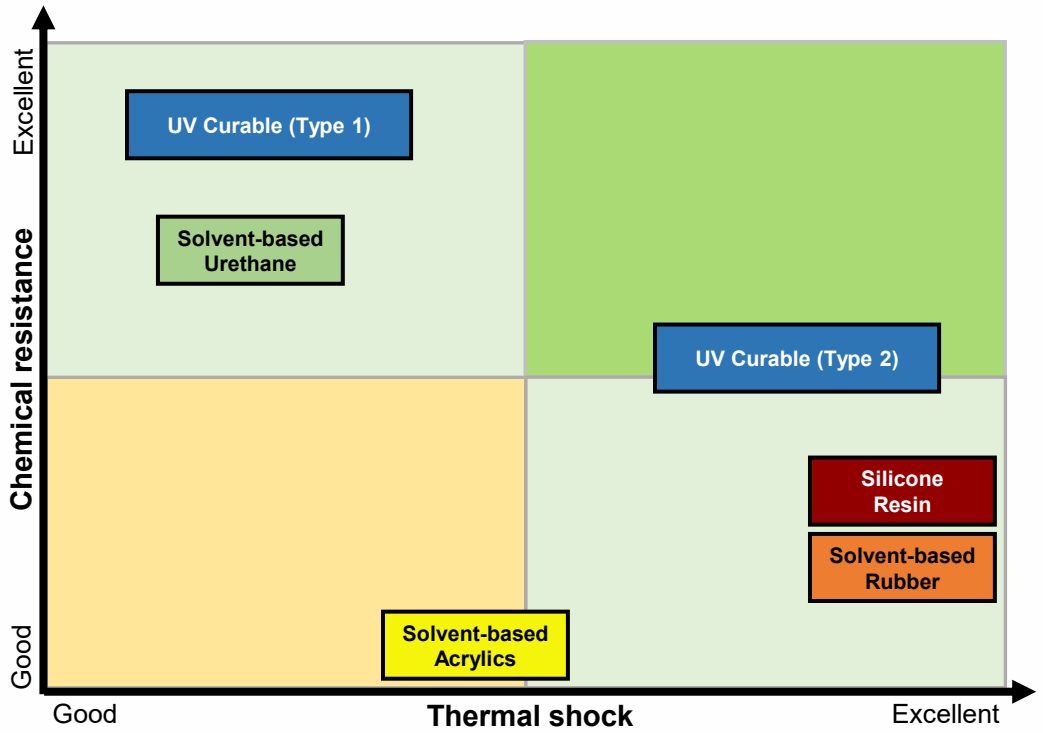


Chemical resistance test after 7 days exposure

1 No effect on coating 2 Change in appearance, no damage 3 Complete removal and corrosion



Remember: Select the right conformal coating based on the balance between thermal shock performance and chemical resistance needed

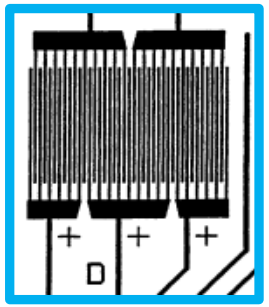
How coatings protect – DWV and DBV

Dielectric Withstand Voltage (DWV) and Dielectric Breakdown Voltage (DBW)

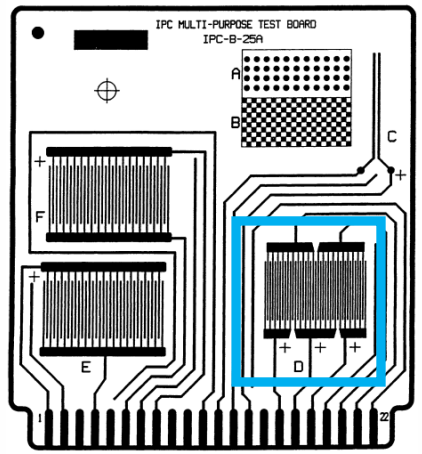
- Critical electrical performance indicators
- Evaluate conformal coating insulation properties

IPC-B-25

MIL-Y coupon

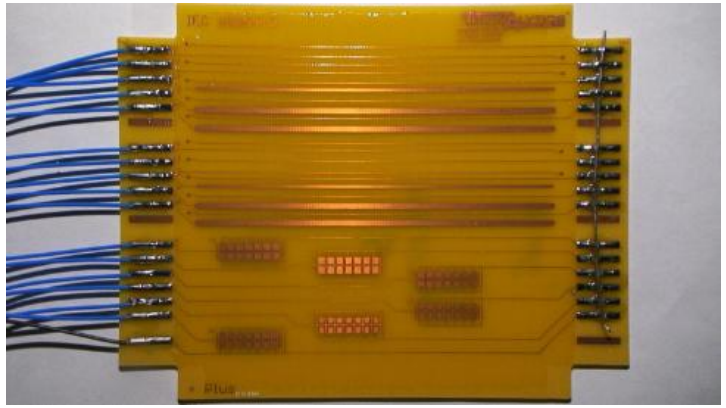


IPC-B-25 comb pattern D



IPC-B-25

IPC-B-54

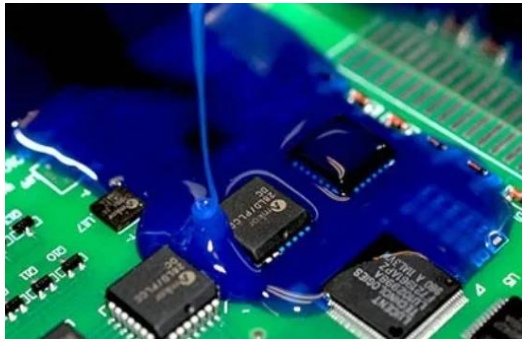


IEC60664-3 test vehicle

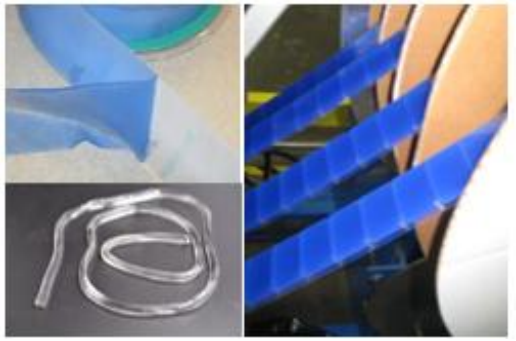
Other types of protective materials

Alternatives to conformal coatings:

- Encapsulation and potting compounds
- Gasketing for sealed enclosures



Encapsulation / Potting



Sealing / Gaskets

Other types of protective materials

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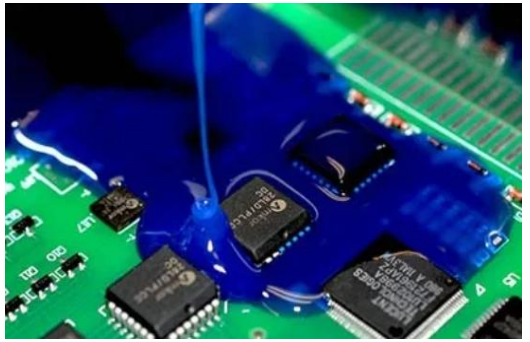
- Encapsulation and potting compounds
- Gasketing for sealed enclosures



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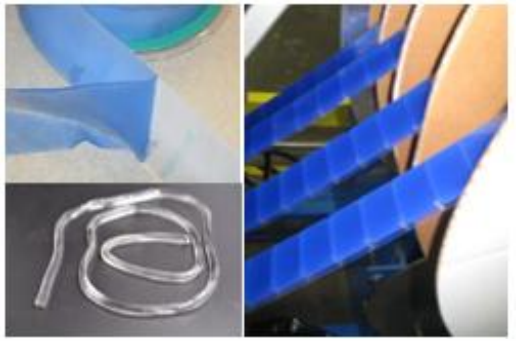


Sealing / Gaskets

Advantages of conformal coatings:

- Weight efficiency
- Repairability
- Design flexibility
- Cost effectiveness
- Reduced spacing capability

What determines a successful protection?

- ✓ Correct chemistry
- ✓ Correct thickness
- ✓ Proper curing
- ✓ Good adhesion
- ✓ Clean assembly
- ✓ Proper inspection

What's next? Webinar 3

6th of May

Time zones:
10:00 New York, USA
15:00 London, UK
16:00 Paris, France
20:30 Delhi, India
23:00 Shanghai

- **Webinar 3**. How to select the right conformal coating material for your application
  - Selecting the right coating for the application
  - Matching chemistry to customer qualification tests
  - Application relevance based on environment and usage conditions

Register to the next webinar using the QR code

20th of May

- Webinar 4. How to integrate the coating application in the manufacturing process

3rd of June

- Webinar 5. Reliability, compliance and delivering the right business value

Q&A

Coatings Academy®

Webinar 3.
How to select the right conformal coating material for your application

Presented By: Vlad DAVID

Powered By HumiSeal®

Agenda

- Introduction to webinar series
- Review previous webinars
- Considerations on how to select the right conformal coating material
  - Define the environment
  - Define reliability requirements
  - Understand coating chemistries
  - Application methods and process constraints
- Transition to Webinar 4
- Q&A

Introduction to webinar

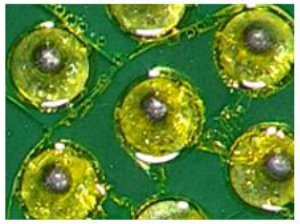
8th of April	• Webinar 1. Why Electronics Fail and what problems are we trying to solve?
22nd of April	• Webinar 2. Conformal coating fundamentals. How can electronics be protected?
6th of May	• **Webinar 3**. How to select the right conformal coating material for your application
20th of May	• Webinar 4. How to integrate the coating application in the manufacturing process
3rd of June	• Webinar 5. Reliability, compliance and delivering the right business value

Webinar 1. Overview

Failure mechanisms on electronics

- Moisture and corrosion
- Thermal stress and cracking
- Chemicals and Gases exposure
- Mechanical and vibration stress

Moisture → corrosion



Thermal cycling → cracks

Chemical gas → Degradation and corrosion

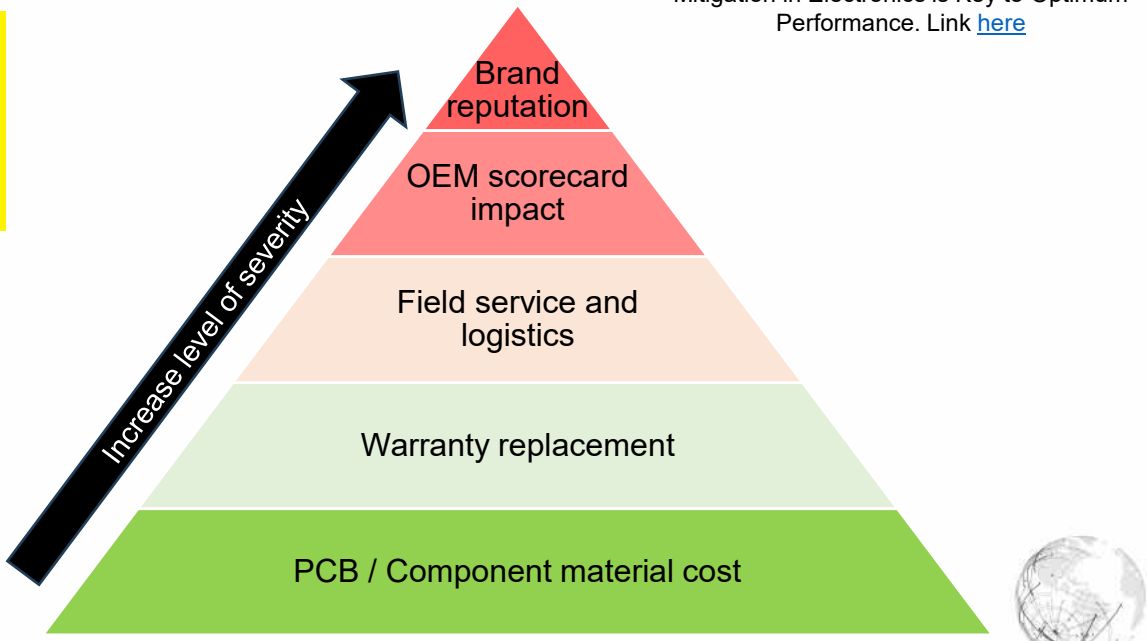
Vibration → micro-cracks and fatigue

Picture source: Mouser. Vibration Damage Mitigation in Electronics is Key to Optimum Performance. Link here

Environmental exposure by industry

Industry	Predominant stress factors
Automotive	Thermal stress, condensation and chemicals
Industrial	Gas corrosion and vibration
Rail	Salt and extreme temperatures
White goods	Condensation and chemical detergents
Energy	Outdoor humidity and high voltage

Estimated 20%
of electronics failures in the field are caused by water-induced corrosion



Failure cost escalates exponentially

Webinar 2. Overview

What is a conformal coating?

- Thin protective film
- “Conforms” to the varied profile of an electronic circuit assembly
- Membrane that filters water vapour and solid debris
- Protects the assembly from corrosion in harsh environments
- Electrical insulating properties allows reduced conductor spacing
- Glows blue under UV light for easy inspection

Coated assembly. Side view

Conformal coating properties

MVP (Moisture Vapour Permittivity)

Chemical resistance and thermal shock graph

Chemistry	MVP Value in mg/m2*Day based on coating thickness				Condensation performance *
	50 µm	75 µm	100 µm	150 µm	
Acrylics	110	90	75	No data	Good
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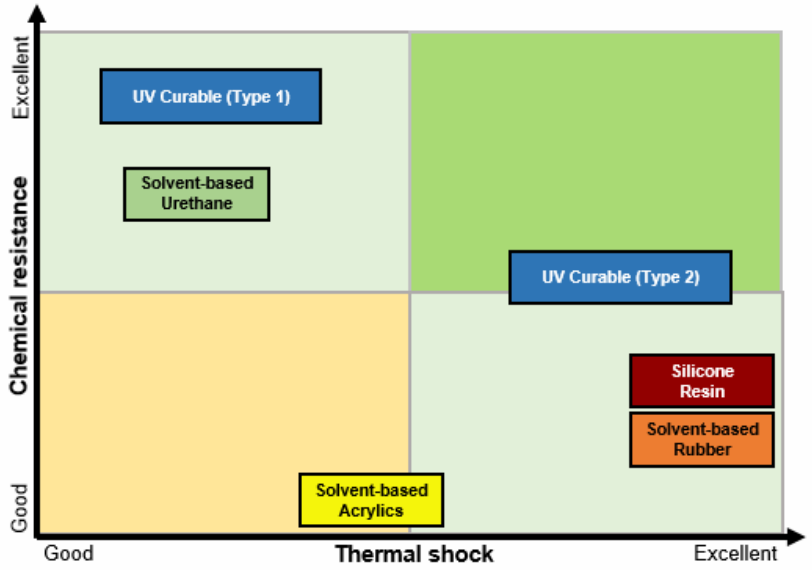
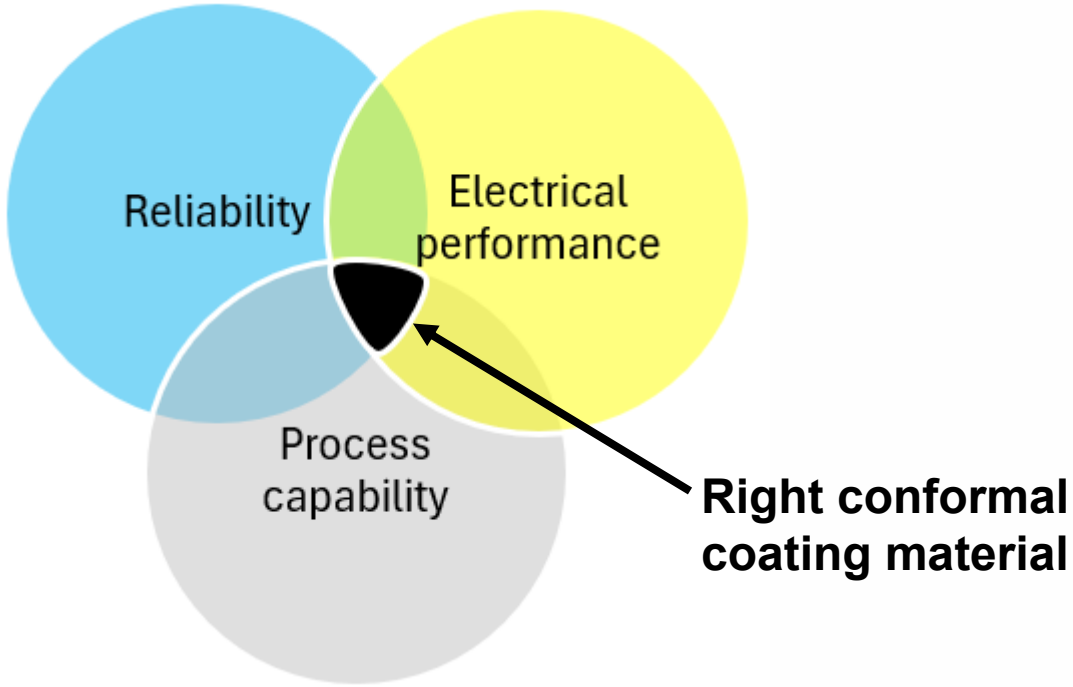


How to select the right conformal coating material



How are we going to achieve this?

- Define the environment
- Define reliability requirements
- Understand coating chemistries
- Process constraints

Define the environment

Step 1 is to identify stress drivers
Questions to ask:

- Is the product exposed to condensation cycles?
- Is there corrosive gas (e.g. G3)?
- Is there exposure to chemicals?
- Are there rapid temperature changes?
- Is there high voltage?
- Is condensation likely to appear?

Define the environment

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- Is there exposure to chemicals?
- Are there rapid temperature changes?
- Is there high voltage?
- Is condensation likely to appear?

This step answers the predominant stress factors we have covered in previous webinars

Industry	Predominant stress factors
Automotive	Thermal stress, condensation and chemicals
Industrial	Gas corrosion and vibration
Rail	Salt and extreme temperatures
White goods	Condensation and chemical detergents
Energy	Outdoor humidity and high voltage

Environment	Typical Preferred Chemistry
General indoor	Acrylic
High chemical exposure	Urethane or UV type 1
Automotive under-hood	UV / Synthetic Rubber / Urethane
Extreme high temperatures	Silicone
Mixed harsh environment	UV type 1 or type 2
High condensation	Synthetic Rubber / UV

Define the environment

Industry	Key Requirements								
	Insulation Resistance (ºC, %RH)	Condensation and moisture	Air pollution / noxious gas	Altitude and Ozone	Outgassing	Chemical resistance	High Voltage strength	Thermal cycle Thermal shock	Standards (e.g. IEC, OEM*)
Automotive	✓	✓	✓		✓	✓	✓	✓	✓
Aerospace and defence	✓	✓	✓	✓	✓	✓	✓	✓	✓
Consumer Electronics	✓	✓				✓			
Consumer white goods	✓	✓	✓			✓		✓	✓
Consumer brown goods	✓	✓				✓		✓	✓
General Industrial	✓	✓	✓			✓	✓	✓	✓
Industrial controls	✓	✓	✓			✓	✓	✓	✓
Energy and renewable energy	✓	✓	✓	✓		✓	✓	✓	✓
Oil & Gas, marine	✓	✓	✓			✓	✓		✓
Lighting	✓	✓	✓		✓	✓	✓	✓	✓
Medical, Food and Pharma	✓	✓				✓	✓	✓	✓
Agriculture and outdoor use	✓	✓	✓	✓		✓			

* OEM – Original Equipment Manufacturer

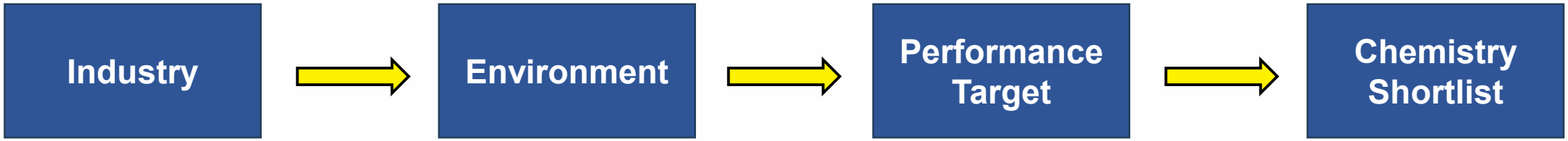
Define reliability and qualification requirements

Step 2 is to define the environmental testing required
Questions to ask:

- Which standards apply? IPC-CC-830? IEC? UL? OEM?
- Required 85ºC/85%RH duration?
- Thermal shock range and no of cycles?
- Chemical resistance spec?
- Noxious gas requirement?
- High voltage dielectric requirement?
- Target lifetime?

This step answers the level of protection required

Protection strategy



Protection strategy

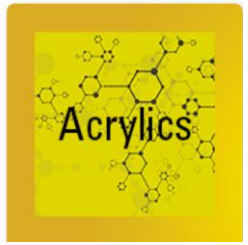
Industry	Environment	Performance Target	Chemistry Shortlist
Industrial controls power supply	G3 gas 1500V Chemical splash	10 years lifetime 500h corrosive gas	Solvent-based Urethane UV type 1 with high chemical resistance

Protection strategy

Industry	Environment	Performance Target	Chemistry Shortlist
Industrial controls power supply	G3 gas 1500V Chemical splash	10 years lifetime 500h corrosive gas	Solvent-based Urethane UV type 1 with high chemical resistance
Automotive interior instrument cluster	Rapid cabin heating High humidity Vibration from vehicle operation	10+ years lifetime +1000 thermal shock High condensation resistance Increased voltage	Solvent-based Synthetic Rubber UV type 2

Understand chemistries

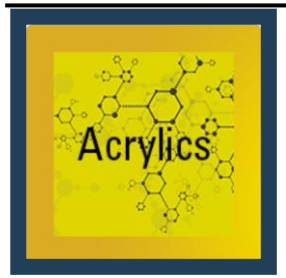
SOLVENT-BASED



SOLVENT-FREE *

Understand chemistries

SOLVENT-BASED

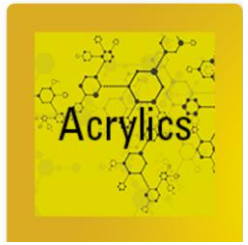


SOLVENT-FREE *

Strengths				
• Easy to apply and cure • Easy rework • Cost effective	• Very good chemical resistance • Durable coating	• Excellent moisture protection, electrical and thermal shock • Good flexibility	• Excellent electrical and moisture (type 1 and 2) • Excellent thermal shock (type 2) • Excellent chemical resistance (type 1)	• Excellent flexibility • Extreme high temperatures up to 200C
Limitations				
• Limited chemical resistance • Moderate moisture barrier	• Harder to rework • Can be brittle under temperature cycling	• Moderate chemical resistance	• Requires UV oven to cure • Harder to rework • Type 1 may crack easier in high thermal shock • Balanced properties (type 2)	• Higher moisture permeability • Lower chemical resistance than urethanes • Difficult to apply and cure • Risk of cross-contamination
Best for				
• General purpose electronics protection • Coating example: 1B31, 1B73, 1R32A-2	• Automotive and aerospace fluids • Harsh industrial applications • Coating example: 1A20, 1A33	• High condensation environments • High thermal shock • Coating example: 1B51, 1B59NSLU	• High through put • Harsh applications • Industrial and automotive • Coating example: UV40, UV50 (type 1) UV500 (type 2)	• Extreme temperatures • High thermal shock cycles • Coating example: 1C49, 1C51, 2C51

Understand chemistries

SOLVENT-BASED



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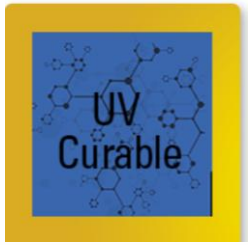

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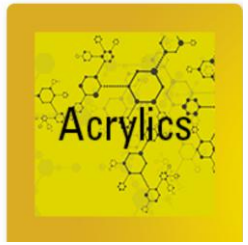

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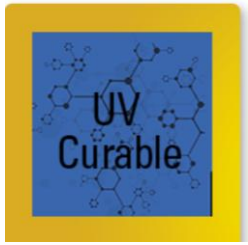

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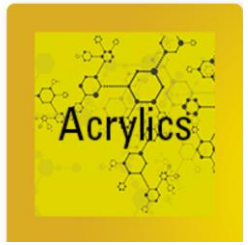

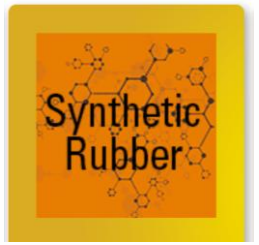

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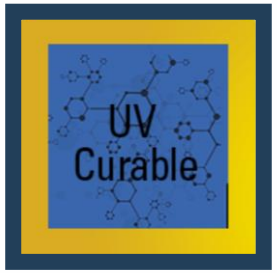

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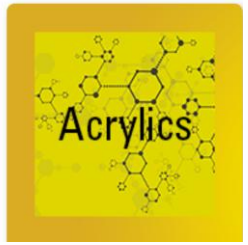

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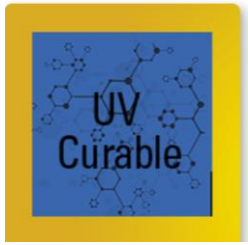

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Conformal coatings comparison matrix

Category	Factor	Solvent-Based Acrylic	Solvent-Based Urethane	Solvent-Based Synthetic Rubber	UV Curable Acrylated Polyurethane (Type 1)	UV Curable Acrylated Elastomer (Type 2)	Silicone Resin
Material related	Coating Thickness	Prone to cracking at high thickness	Brittle at high thickness	Flexible, tolerant to high thickness	Brittle and cracks easy at high thickness	Good resistance to cracking	Good resistance to cracking
	Flexibility / Modulus	Low modulus – crack-resistant	High modulus – prone to cracking	Very flexible – crack-resistant	Brittle – low flexibility	Low modulus – crack-resistant	Low modulus – crack-resistant
Substrate Conditions	Surface Cleanliness	Low to moderate sensitivity	Low to moderate sensitivity	Low to moderate sensitivity	Moderate sensitivity	Moderate sensitivity	High sensitivity
	Surface Energy	Medium – generally adheres well	Medium	Medium	Medium	Medium – generally adheres well	Easy to show dewetting
PCB and component design	Sharp Edges or meniscus	Prone to crack at high thickness	Prone to crack especially at high thickness	Superior protection	Prone to crack especially at high thickness	Good protection	Good protection
External Factors	Thermal Cycling	Good thermal tolerance	May crack over time	Excellent durability	May crack or delaminate over time	Good thermal tolerance	Excellent durability
	Chemical Exposure	Limited resistance	Excellent chemical resistance	Better than Acrylics	Excellent chemical resistance	Good chemical resistance	Good chemical resistance
Incorrect curing	Secondary moisture cure inhibition	Not applicable	Immediate chemical resistance is limited	Not applicable	Prone to cracking and delamination	Prone to poor performance	Prone to poor performance

Legend

- High performance
- Medium performance. Susceptible to failure under harsh conditions
- Low performance. Highest risk for failures

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Moisture Barrier	Good	Good	Very good	Very good	Very good	Poor
Chemical Resistance	Low	Very Good	Good	Excellent	Good	Good
Thermal Cycling	Good	Good	Very good	Good	Very good	Very good
Reworkability	Very good	Can be difficult without suitable stripper	Very good	Can be difficult without suitable stripper	Good	Can be difficult without suitable stripper
Process Speed	Good	Can take longer for oxidative cure	Good	Very good	Very good	Can take longer if surface is contaminated

Legend

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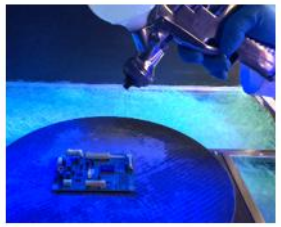
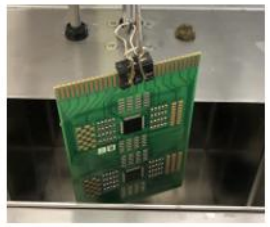
Application methods

Methods of applications

Manual and semi-automated

Hand Brush	Hand Spray	Hand Dispensing	Dip Coating
			
Mainly used for solvent-based coatings touch-up Slow process Operator dependent Inconsistent coating thickness	**Solvent-based coatings only** Very good coverage High exposure to solvents 100% masking	**Solvent-based and UV coatings** Slow process Operator dependent Medium and high viscosity materials	**Mainly for solvent-based coatings** Very good coverage Difficult to maintain viscosity 100% masking

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	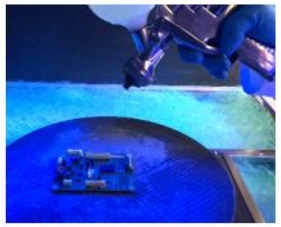		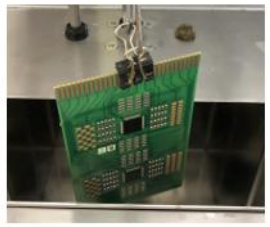
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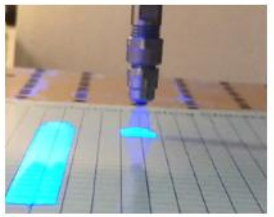
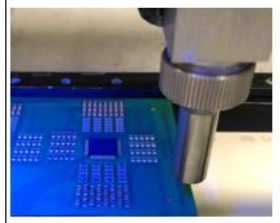
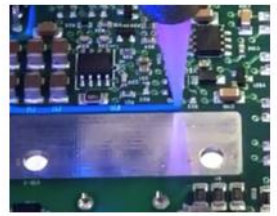
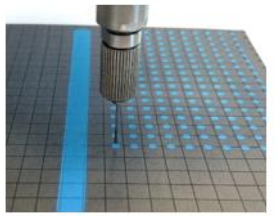
Automated selective

Film coat	Spray	Dispensing	Jetting
			
50-120 cPs ideal viscosity Superior line definition Deposits very high wet thickness Tends to generate more bubbles	**20 to 2,000 cPs viscosity** Single or multiple layers application Challenges with overspray and sharp line definition	**Low to very high viscosity** Coating or gel single layer application Easy access in tight areas Used for dam and fill	**50 to 2,000 cPs viscosity** High accuracy and repeatability Allows controlled and low thickness on connector solder joints

Application method and process constraints

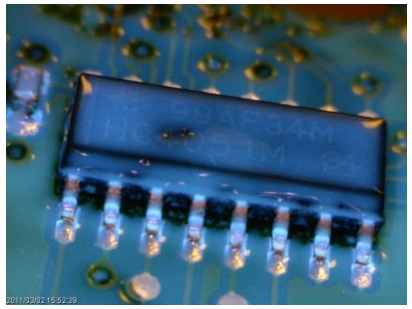
Chemistry	Brush	Manual Spray	Dip	Automated Selective	IR Oven	UV Cure Oven
Solvent-based Acrylic	✓	✓	✓	✓	✓	✕
Solvent-based Urethane	✓	✓	✓ for 1-part	✓	✓	✕
Solvent-based Synthetic Rubber	✓	✓	✓	depends on material/viscosity	✓	✕
UV Acrylated Polyurethane (Type 1)	✕	✕	✕	✓ depends on application method	✕	✓
UV Acrylated Elastomer (Type 2)	✕	✕	✕	✓ depends on application method	✕	✓
Silicone Resin	✓	✓	✓	✓	depends on material	depends on material
Considerations	• Low cost • Good for prototypes • Ideal for repair	• Moderate investment • Suitable for small batches	• Simple process • Complete coverage	• High repeatability • Controlled thickness • Traceable process	• Fast tack-free cure • Reduced WIP	• Instant cure • High throughput • Reduced WIP
	• Operator dependent • Not scalable	• Overspray • Masking required	• High masking requirement • Material waste	• High capital investment • Programming expertise	• Equipment investment • Longer footprint • Defects due to incorrect profile	• Equipment investment • Requires compatible chemistry

Legend

- High performance
- Medium performance. Susceptible to failure under harsh conditions
- Low performance. Highest risk for failures

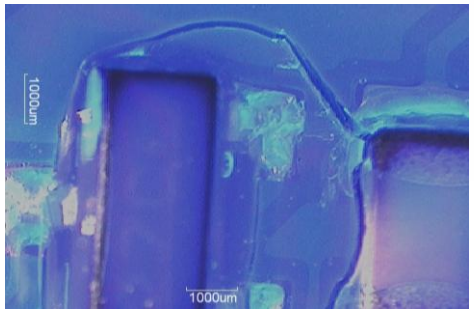
Conformal coatings thickness matters

Too thin:
- Less protection
- Higher moisture permeability

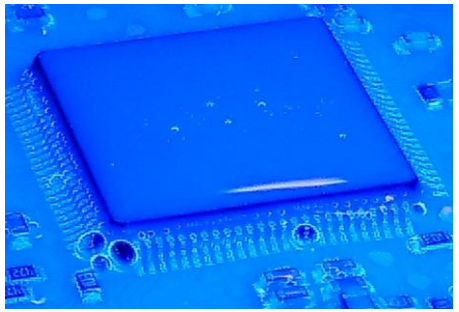


Exposed metal conductors
Insufficient coverage

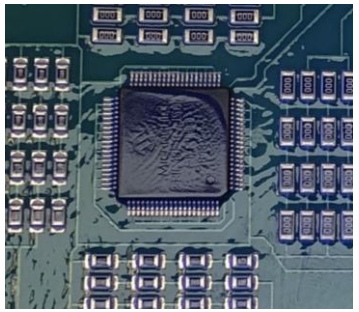
Too thick:
- Stress accumulation
- Bubbles
- Cracking risk
- Cure issues



Mechanical stress and cracks

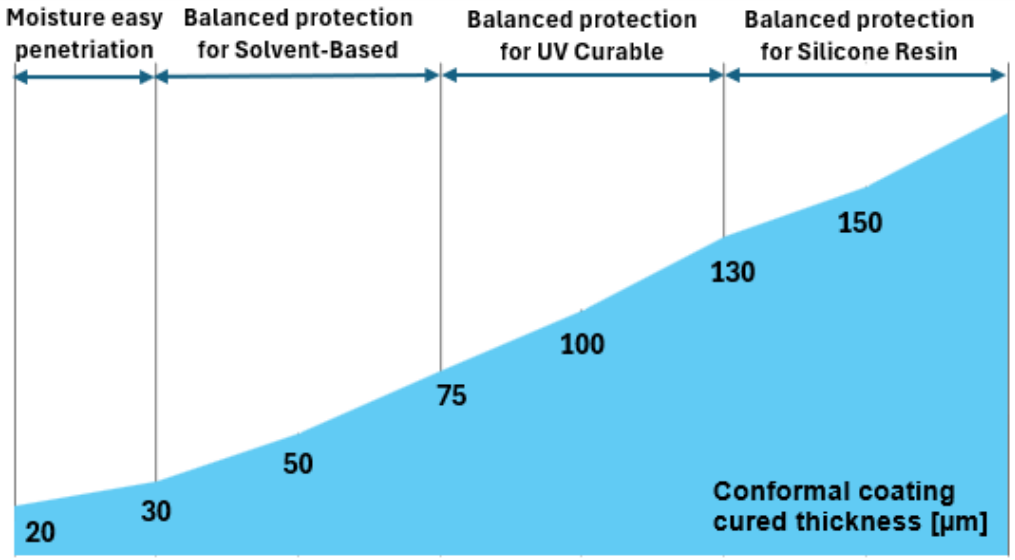


Bubbles during curing



Orange peel - thermal stress during curing

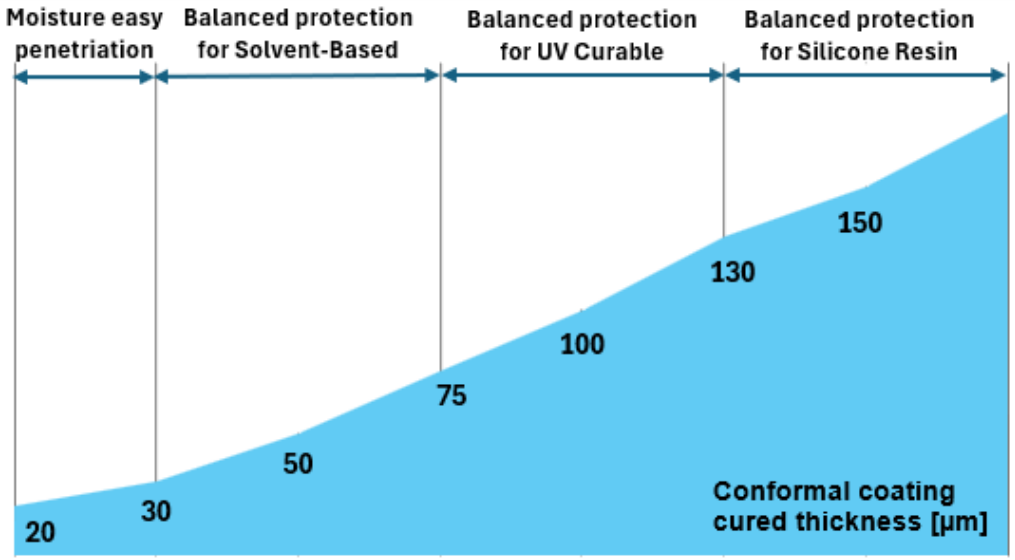
Conformal coatings thickness matters



Recommended thickness measurement method:

- **Wet Film:** Process setup on flat surfaces
- **Dry Film:** Eddy current / ultrasonic / laser for component-level validation
- **Advanced:** Cross-sectional and microscope for critical OEM qualification

Conformal coatings thickness matters



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Considerations

Thickness must be matched to:

- Chemistry modulus
- CTE of assembly
- Expected thermal cycling
- Voltage requirements#
- Condensation or humidity tests
- Process manufacturing and coating application method

Thickness optimization directly impacts:

- Warranty cost
- Scrap rate
- Yield
- Long-term brand perception

Common selection mistakes

- Choosing only based on IPC qualification
  "The material passes IPC-CC-830, so it's suitable."
- Ignoring real environmental exposure
  "It's inside the vehicle, so environment is mild."
- Over-specifying (cost without benefit)
  "Let's choose the highest chemical resistance possible."
- Ignoring process capability
  Selecting UV coating without adequate UV exposure
- Copying a Competitor's Material Without Context
  "OEM X uses silicone, so we will too."

When conformal coating is not sufficient

Conformal coating is designed to protect against:
- Moisture and condensation
- Corrosion
- Electrical leakage
- Moderate chemical exposure

But coating may be insufficient when facing:
- Direct water immersion
- Connector ingress
- Extreme chemical exposure
- Mechanical strain relief requirements

Levels of protection:

Level 1 – Conformal Coating
Best for: PCB surface protection, industrial electronics
Limitations: Not a full waterproof barrier, limited structural reinforcement

Level 2 – Gels (selective sealing)
Best for: Connector sealing, edge barrier, solder joint protection
Limitations: Not easy reworkable, longer curing time for solvent-based type

Level 3 – Encapsulation
Best for: Stronger environmental barrier, mechanical protection
Limitations: reduced repairability, increased weight

Level 4 – Potting (ultimate protection)
Best for: outdoor electronics, marine, harsh industrial
Limitations: difficult or impossible to rework, added mass, stress by thermal expansion

What's next? Webinar 4

20th of May

Time zones:
10:00 New York, USA
15:00 London, UK
16:00 Paris, France
20:30 Delhi, India
23:00 Shanghai

- **Webinar 4**. How to integrate the coating application in the manufacturing process
  - In detail application methods and curing
  - Impact on production flow
  - Rework and cost of ownership

Register to the next webinar using the QR code

3rd of June

- Webinar 5. Reliability, compliance and delivering the right business value

Q&A

Coatings Academy®

Webinar 4.
How to integrate the coating application in the manufacturing process

Presented By: Vlad DAVID

Powered By HumiSeal®

Agenda

- Introduction to webinar series
- Review previous webinars
- Process integration
  - Application methods
  - Process Controls
  - Rework and cost of ownership
- Transition to Webinar 5
- Q&A

Introduction to webinar

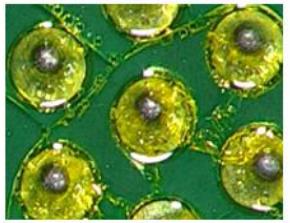
8th of April	• Webinar 1. Why Electronics Fail and what problems are we trying to solve?
22nd of April	• Webinar 2. Conformal coating fundamentals. How can electronics be protected?
6th of May	• Webinar 3. How to select the right conformal coating material for your application
20th of May	• **Webinar 4**. How to integrate the coating application in the manufacturing process
3rd of June	• Webinar 5. Reliability, compliance and delivering the right business value

Webinar 1. Overview

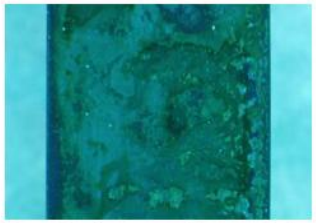
Failure mechanisms on electronics

- Moisture and corrosion
- Thermal stress and cracking
- Chemicals and Gases exposure
- Mechanical and vibration stress

Moisture → corrosion



Thermal cycling → cracks



Chemical gas → Degradation and corrosion

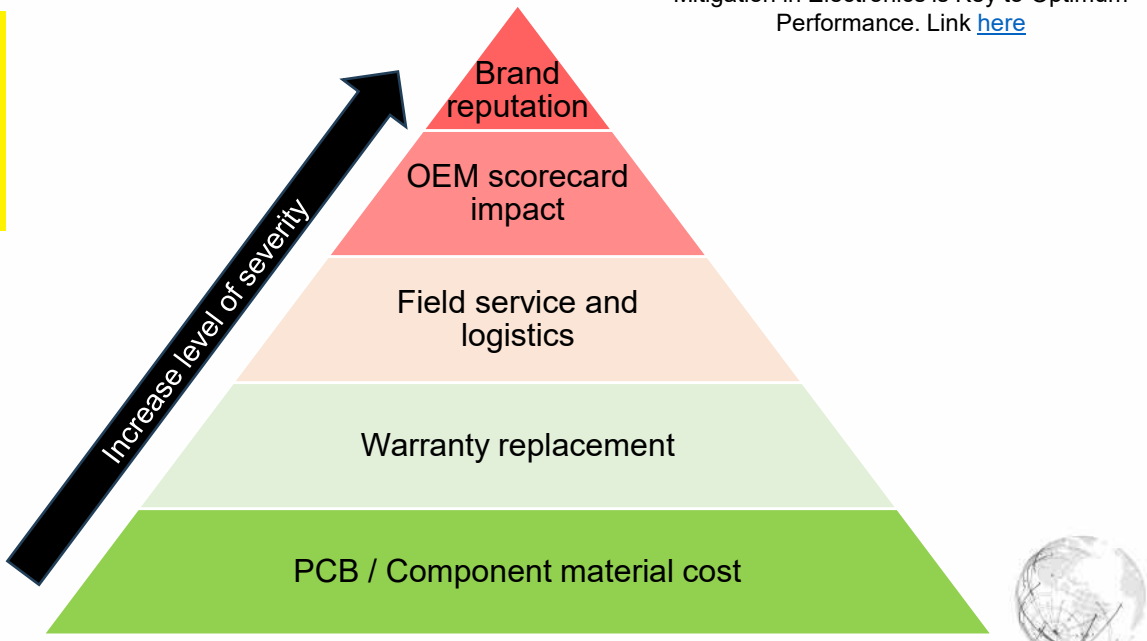
Vibration → micro-cracks and fatigue

Picture source: Mouser. Vibration Damage Mitigation in Electronics is Key to Optimum Performance. Link here

Environmental exposure by industry

Industry	Predominant stress factors
Automotive	Thermal stress, condensation and chemicals
Industrial	Gas corrosion and vibration
Rail	Salt and extreme temperatures
White goods	Condensation and chemical detergents
Energy	Outdoor humidity and high voltage

Estimated 20%
of electronics failures in the field are caused by water-induced corrosion



Failure cost escalates exponentially

Webinar 2. Overview

What is a conformal coating?

- Thin protective film
- “Conforms” to the varied profile of an electronic circuit assembly
- Membrane that filters water vapour and solid debris
- Protects the assembly from corrosion in harsh environments
- Electrical insulating properties allows reduced conductor spacing
- Glows blue under UV light for easy inspection

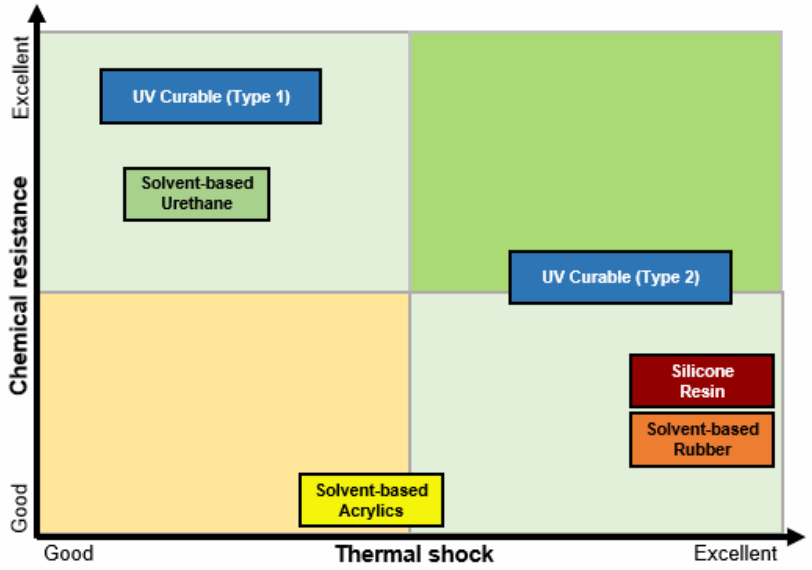
Coated assembly. Side view

Conformal coating properties

MVP (Moisture Vapour Permittivity)

Chemical resistance and thermal shock graph

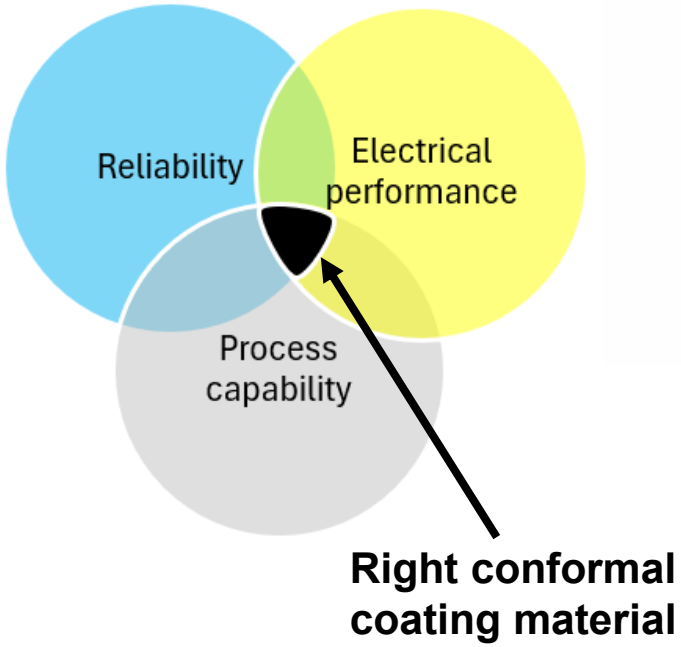
Chemistry	MVP Value in mg/m2*Day based on coating thickness				Condensation performance *
	50 µm	75 µm	100 µm	150 µm	
Acrylics	110	90	75	No data	Good
Urethane	120	100	80	No data	Good
Synthetic Rubber	12	9	8	No data	Excellent
UV Curable	12	8	7	6	Excellent
Silicone Resin	600	500	350	250	Poor



Webinar 3. Overview

SOLVENT-BASED

SOLVENT-FREE *



Industry	Key Requirements								
	Environmental (ºC, %RH)	Condensation and moisture	Air pollution / noxious gas	Altitude and Ozone	Outgassing	Chemical resistance	High Voltage strength	Thermal cycle Thermal shock	Standards (e.g. IEC, OEM*)
Automotive	✓	✓	✓		✓	✓	✓	✓	✓
Aerospace and defence	✓	✓	✓	✓	✓	✓	✓	✓	✓
Consumer Electronics	✓	✓				✓			
Consumer white goods	✓	✓	✓			✓		✓	✓
Consumer brown goods	✓	✓				✓		✓	✓
General Industrial	✓	✓	✓			✓	✓	✓	✓
Industrial controls	✓	✓	✓			✓	✓	✓	✓
Energy and renewable energy	✓	✓	✓	✓		✓	✓	✓	✓
Oil & Gas, marine	✓	✓	✓			✓	✓		✓
Lighting	✓	✓	✓		✓	✓	✓	✓	✓
Medical, Food and Pharma	✓	✓				✓	✓	✓	✓
Agriculture and outdoor use	✓	✓	✓	✓		✓			

Selecting the right material is only the first step

Environment → Performance Target → Chemistry Shortlist

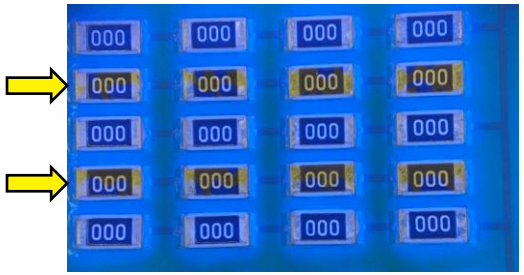
↓

- Application
- Cure Process
- Thickness Control
- Inspection

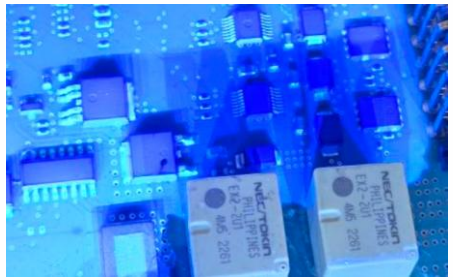
= Reliable Protection

Why process integration matters

Common challenges seen in production:

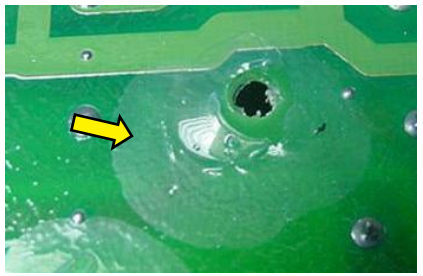


Uneven coating thickness

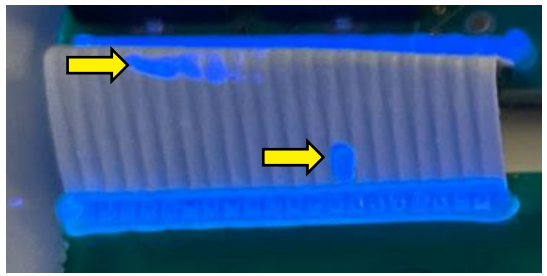


Shadowing during UV cure

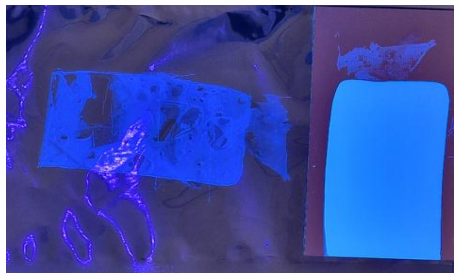
Overspray contamination



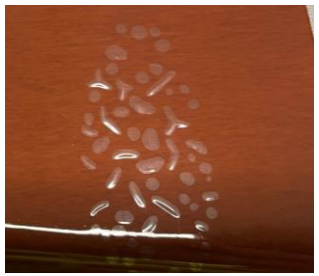
Masking errors



Process variability between operators



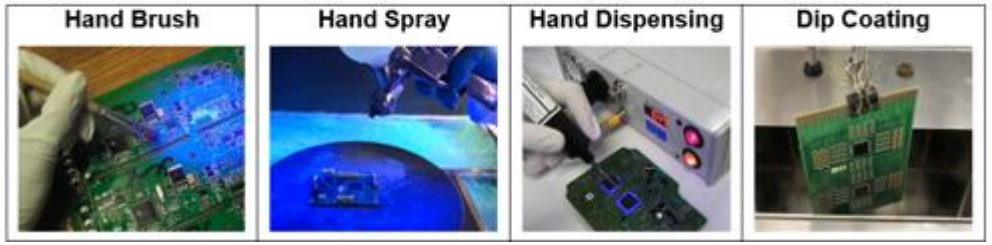
Incomplete curing



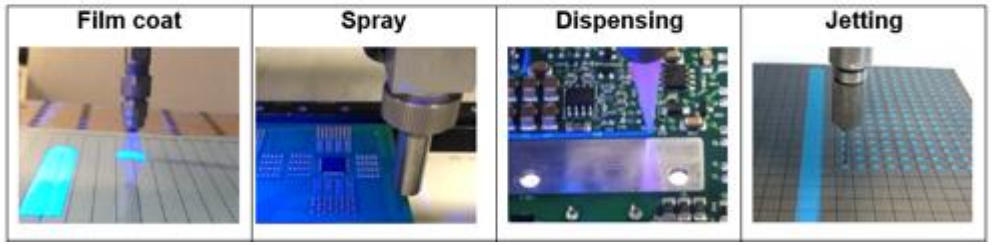
Poor adhesion
due to contamination

Key questions before implementing a coating process

Manual and semi-automated



Automated selective



Questions to ask:

- What is the annual production volume?
- Which application method is feasible?
- Is the assembly designed for coating?
- What masking is required?
- What curing method is available?
- What inspection method will be used?
- What is the budget allocated for investments?

Manual and semi-automated application

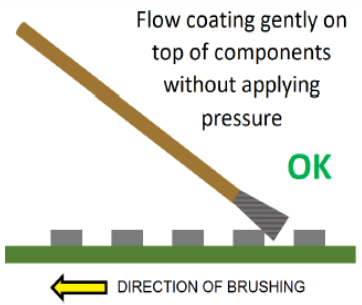
Application Method	Strengths	Limitations
Hand Brush	• **Medium to high viscosity** • Simple application, ideal for **localized coating / rework** • No curing constraints beyond material type	• **Low repeatability** (operator dependent) • **Inconsistent thickness control** • Slow cycle time
Hand Spray	• Good for **low viscosity coatings** (uniform coverage) • Efficient to cover complex geometries • Compatible with standard thermal curing	• **Overspray and masking required** • Limited control for selective areas • **Moderate repeatability**, operator dependent
Hand Dispensing	• **Medium to high viscosity** • Targeted application in defined areas • Compatible with UV curable and solvent-based coatings	• **Slow and manual process** • Limited thickness consistency • **Low repeatability** vs automated systems
Dip Coating	• **Low to medium viscosity** • **Complete and uniform coverage** • Simple curing integration (oven/ambient)	• **High masking requirement** • Not recommended for UV curable coatings • Difficult viscosity control

Manual and semi-automated applications are recommended for:

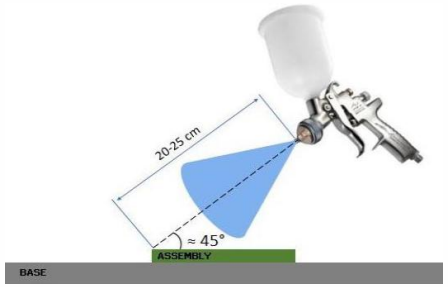
- Low volume production
- Prototyping
- Repair

Manual and semi-automated process integration

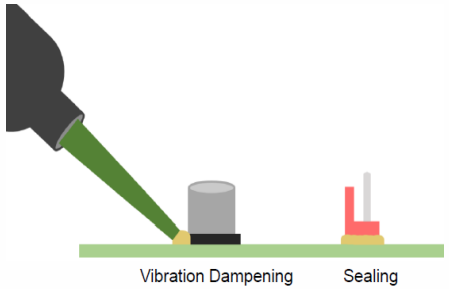
Hand brush



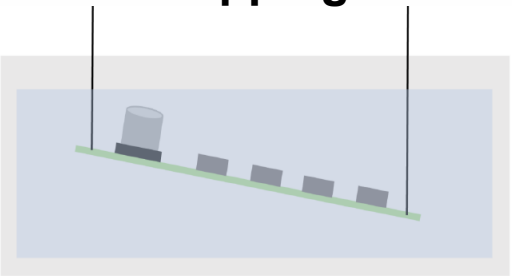
Hand spray



Hand dispense



Dipping



Considerations:

- <u>Best for solvent-based coatings</u>
- 9:1 to 4:1 coating : thinner ratio
- Medium/high evaporation thinner
- Always keep the brush in solvent when not in use

- <u>Best for solvent-based</u>
- High Volume Low Pressure gravity spray gun
- 1:1, 1.5:1 coating to thinner ratio
- Medium to low evaporations
- 2-3 coating layers required based on the thickness

- <u>Solvent-based and solvent-free</u>
- Use the appropriate nozzle
- Define the shot size
- Vacuum control can reduce the material overflow

- <u>Best for solvent-based</u>
- Single component coating
- 50-120 cPs most common range for solvent-based, up to 700 cPs for Silicone Resin
- Immersion and withdrawal speeds are essential for a repeatable process

What to avoid:

- Long periods without checking viscosity, quality of the brush and contamination accumulated in the jar

- Cobwebbing due to viscosity and fast evaporation Thinner
- Clogged filters and delayed maintenance

- Cured material in the nozzle
- Uneven thickness application

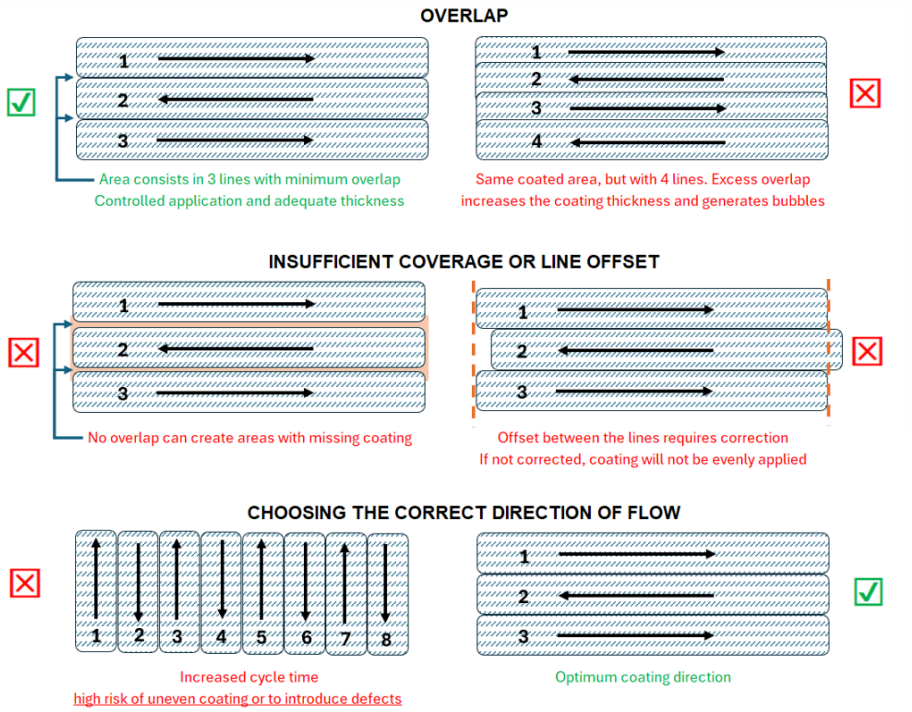
- UV curable coatings
- Vertical dipping with low viscosity and low evaporation thinner

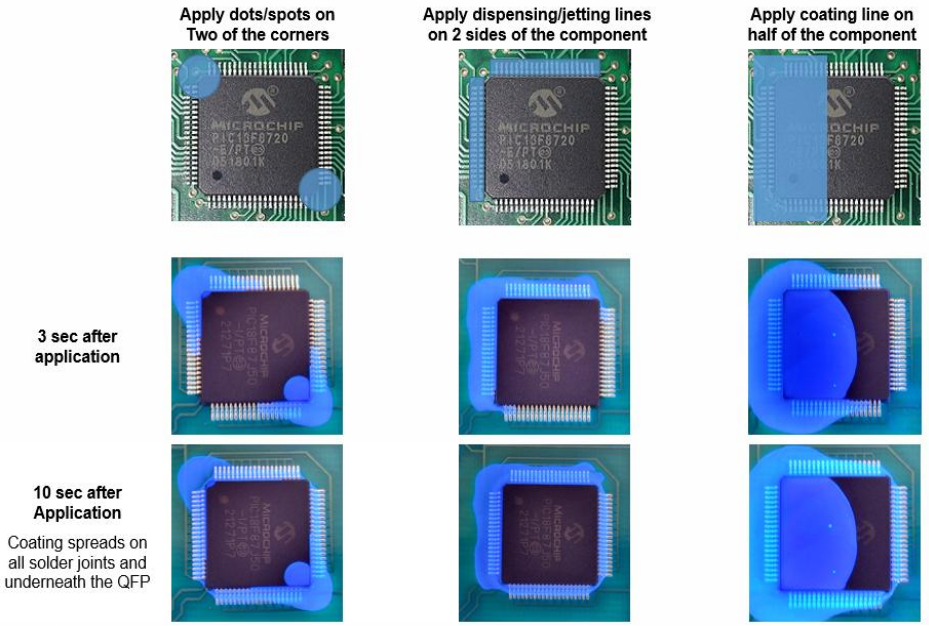
Automated selective application

Application Method	Strengths	Limitations
Film Coat	• Ideal for **controlled viscosity range 50–120 cPs** • Excellent **line definition and thickness control** • High deposition rate (fast coverage)	• Limited to **specific viscosity window** • Risk of **bubble formation** • Requires controlled process setup
Selective Spray	• Handles **wide viscosity range 20–2000 cPs** • High **repeatability and programmable control** • Scalable with consistent cycle time	• **Overspray and edge definition challenges** • **Cobweb on fast evaporation solvent-based**
Dispensing	• Suitable for **low to very high viscosity materials** • Precise application in **tight areas** • Good compatibility with UV and gel materials	• **Slower than spray for large areas** • Limited area coverage efficiency • Thickness build-up requires multiple passes
Jetting	• Works best with **viscosity range 50–1000 cPs** • **High accuracy and repeatability** • Controlled thin layers on small areas	• Limited to **localized application** • Not suitable for full board coverage • **Requires tight process control**

Selective film coat considerations

- Circulation and heating ensures stable and repeatable process
- Solvent-based coatings require slow temperature ramp-up and longer curing time
- Nozzle and application parameters based on coating type and viscosity
- Use techniques for stable application and optimum coverage

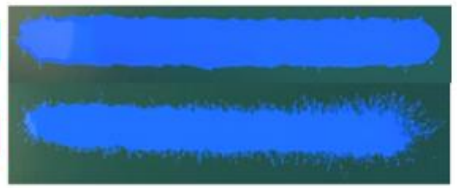


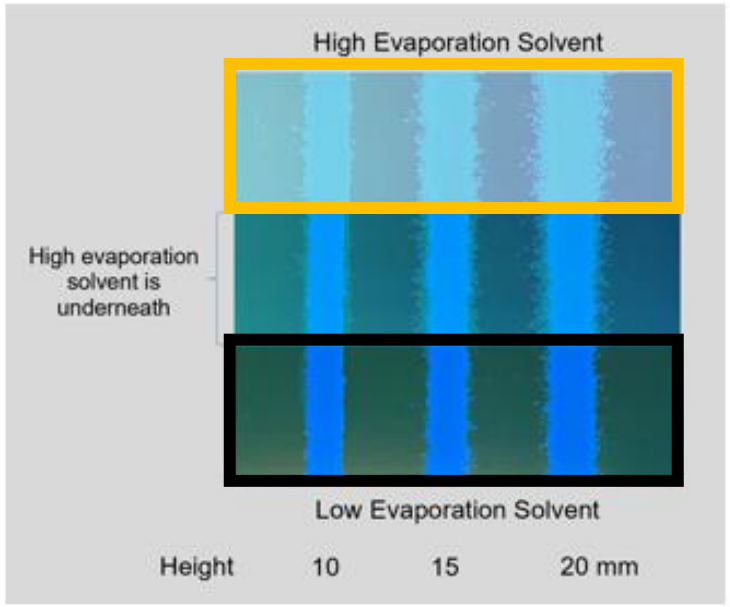


Selective spray considerations

- Use low evaporation thinner for repeatable spray application
- Line edge definition is not as precise as with film coat
- With UV curable coatings is easier to maintain coating thickness

- For solvent-based, Thinner selection is critical
  - **Over-spray**
  - Cobwebbing
  - **Edge definition**
  - Nozzle clogging





Unstable process
Check Thinner and viscosity

Stable process

Solvent based coating 40 cPs viscosity

- Selective spray vs film coat

FEATURE	FILM COAT	SPRAY
Suitable for solvent based coatings and low viscosity UV	YES	YES
Suitable for high viscosity materials (Silicone, UV, 2k)	NO	YES
Complex PCA design with low to high components variation	NO	YES
High speed application	YES	NO
Edge definition of the applied pass	YES	NO
Low thickness deposition to control capillarity, wicking	NO	YES

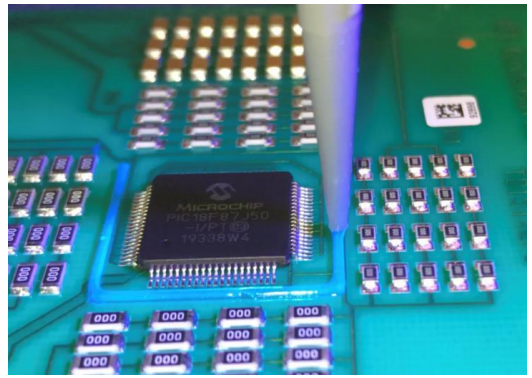
Selective dispensing/jetting considerations

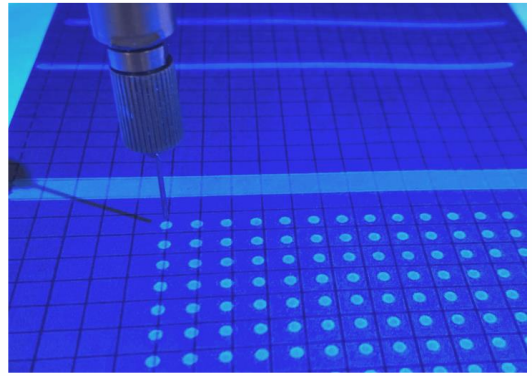
- Suitable from low to high viscosity materials
- Often used as complimentary process to selective film coat or spray
- Thixotropic materials used to create dam around keep out areas
- Easy to reach in narrow areas and in between components
- Use the right type of nozzle


Tapered plastic


Plastic with metal cannula


Complete metal


Dispensing


Jetting

Process controls. Viscosity

- Viscosity = flow behavior
- Impacts coverage, defects, thickness
- Must be controlled from application
- Implement viscosity measurements for manual mixed solvent-based coatings

Parameter	Solvent-Based Coatings	Solvent-Free Coatings
Key considerations	• Maintain stable viscosity (monitor evaporation) • Control thinner ratio (typically 1:1–2:1) • Match viscosity to application method (spray/dip)	• Select correct viscosity grade • Ensure compatibility with dispensing/spray system • Maintain temperature stability for controlled flow
What to avoid	• Uncontrolled solvent evaporation → drift • Using incorrect thinner → defects (cobwebbing, overspray, orange peel) • High variability between batches	• Temperature fluctuations affects application • Using wrong viscosity (e.g. too low for jetting) • Poor equipment maintenance and verification

Process controls. Thickness

- Flat vs component thickness
- Define minimum thickness
  - Too thin = risk of poor protection
  - Too thick = risk of cracking especially on hard coatings

Parameter	Solvent-Based Coatings	Solvent-Free Coatings
Key considerations	• Control via volume and viscosity • Monitor minimum thickness • Solvent flash-off between layers	• Precise deposition via automation (spray/dispense) • Build thickness through controlled passes • Optimize for uniform curing
What to avoid	• Single high-volume pass → overflow uneven thickness, bubbles, orange peel • Assess only on flat surfaces	• Overbuilding thickness (risk of stress/cracking) • Assuming uniform coverage in one pass • Ignoring shadow areas

Process controls. Curing

- Thermal cure
- UV cure
- Dual cure
- Cure completeness

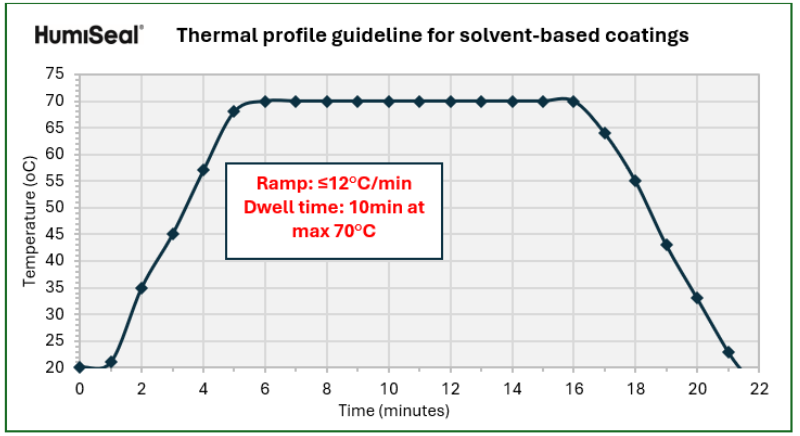
Parameter	Solvent-Based Coatings	Solvent-Free Coatings
Key considerations	• Ensure proper solvent evaporation before cure • Control oven profile (time/temperature) • Verify full cure (no solvent entrapment)	• Ensure full UV exposure (intensity + time) • Use dual cure for shadow areas • Validate cure depth
What to avoid	• Fast curing without flash-off → bubbles/voids • Poor ventilation • Inconsistent oven profile	• Shadowing (no UV access) • Assuming surface cure = full cure • Inadequate UV intensity monitoring

Curing

Solvent-based in-line cure with IR oven

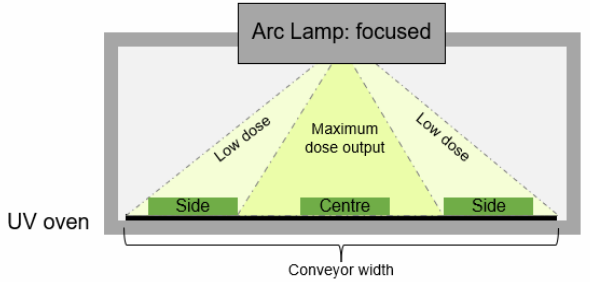
- Balance the line by matching cycle time on individual equipment
- Define flash-off time prior oven cure
- Avoid too high coating thickness unless is specified
- Ensure slow ramp up temperature

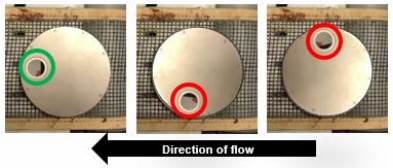
In-line IR oven temperature profile guideline and setup for solvent-based coatings



UV curable oven

- Set correctly the lamp and focus point
- Define conveyor speed, height and lamp power
- Use low intensity UV light inside the coating machine





Radiometer position on 150 mm conveyor belt
Correct position sensor placed in the centre of conveyor belt

Process controls. Cleanliness before coating

- Flux residues
- Ionic contamination
- Handling and contamination
- Drives for ECM

Parameter	Solvent-Based Coatings	Solvent-Free Coatings
Key considerations	• Control flux residues (ionic contamination) • Validate compatibility (SIR testing) • Clean if required for high reliability	• Even more critical (adhesion sensitive systems) • Ensure surface energy compatibility • Clean for optimal adhesion and performance
What to avoid	• Coating over contamination → ECM risk • Ignoring solder paste interaction • No cleanliness specification	• Coating over contamination → ECM risk • Poor adhesion due to residues • Cross-contamination (Silicone Resin)

Remember!
A conformal coating material cannot compensate for poor surface conditions.

Process controls. Inspection and Quality

- UV inspection
- Thickness measurement
- Process monitoring

Parameter	Solvent-Based Coatings	Solvent-Free Coatings
Key considerations	• Black and white light for inspection • Thickness measurement (dry film) • Monitor process parameters (viscosity, environment)	• Use UV traceable systems • Inline inspection (automated preferred) • Validate cure (tack-free, hardness)
What to avoid	• Visual inspection only • No thickness verification • No process control tracking	• Skipping cure validation • Ignoring localized defects • No feedback loop to process

Why process integration matters

Considerations	Solvent-Based Coatings	UV Curable Coatings	Silicone Resins
Primary Sensitivity	Evaporation & viscosity drift	Application precision & UV curing	Adhesion, contamination & handling
Process Drivers	Solvent evaporation rate	UV exposure & shadow management	Surface preparation & cure stability
Typical Defects	• Overspray and cobwebbing • Orange peel • Bubbles / voids • Uneven thickness	• Incomplete cure in shadow areas • Excessive thickness build-up • Cure inhibition • Localized adhesion loss	• Poor adhesion • Surface contamination sensitivity • Difficult spray control • Uneven flow / premature cure for RTV
Critical Engineering Process Controls	• Thinner ratio control for manual use • Temperature / humidity control • Flash-off optimization • IR oven temperature profile	• UV intensity validation • Cure profile monitoring • Precise robotic programming • Secondary cure validation	• Strict cleanliness control • Dedicated process area • Material mixing / stability control • Adhesion validation
Key Process Risks	• Process drift during production • Solvent entrapment • Thickness inconsistency	• Shadow cure failure • Partial polymerization • Localized weak insulation areas	• Cross-contamination • Unnecessary handling before cure • Adhesion loss
Inspection Priorities	• Thickness consistency • Surface finish defects • Viscosity tracking	• Cure completeness • UV inspection in shadow zones • Thickness control	• Adhesion testing • Coverage consistency • Contamination monitoring
Best Manufacturing Fit	• Flexible production • Medium to high volume	• High-volume automated production • Environmentally friendly	• Harsh temperature use

Why process integration matters

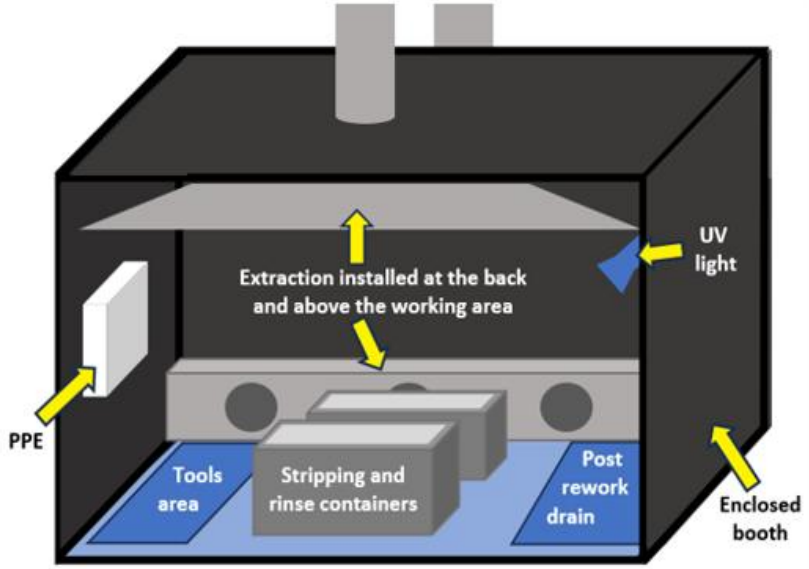
Considerations	Solvent-Based Coatings	UV Curable Coatings	Silicone Resins
Infrastructure Requirements	• Ventilation system • Solvent extraction • VOC compliance controls • Explosion-safe handling areas	• UV curing equipment • Light-shielded curing zones • Automated selective coating systems	• Dedicated silicone room preferred • Cross-contamination prevention • Controlled storage and handling
Health & Safety	• VOC exposure • Flammable solvents • Operator ventilation required	• UV intensity and exposure controls	• Silicone contamination control • Process isolation requirements
Cost of Ownership	• Medium operating cost • Solvents extraction • Easier maintenance	• Capital investment when change from solvent-based • Lower operating cost (faster ROI) • Faster throughput	• Higher process management cost • Contamination controls • Dedicated infrastructure
Production Efficiency	• Moderate to high throughput • Cure dependent	• Very high throughput • Instant cure	• Moderate throughput • Longer process stabilization • Additional attentions for handling

Rework & Cost of Ownership

The lowest material cost does not always have the lowest process cost

Main cost drivers

- Ease of removal and repair
- Scrap rate and yield loss
- Cure time and production flow
- Equipment and infrastructure
- Operator skill and inspection effort
- Reliability risk after rework



Remember!

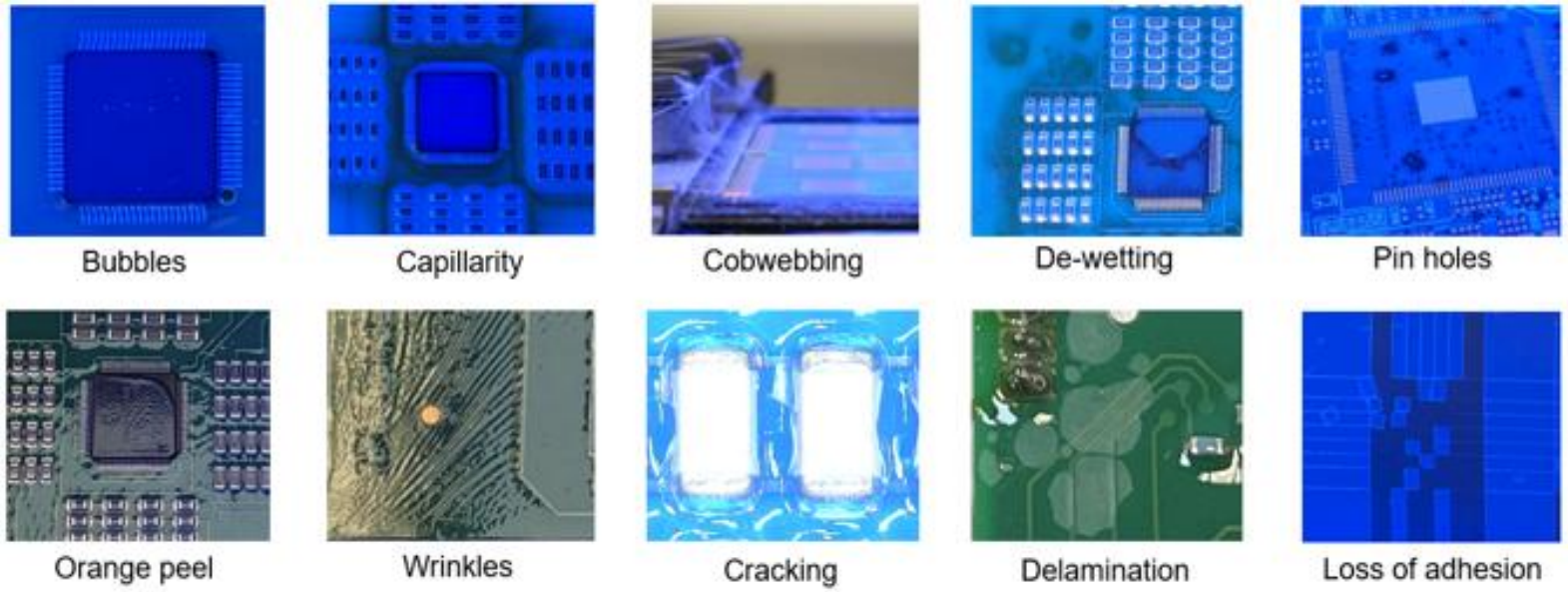
Reworkability should not be considered after qualification
It must be addressed early in design phase and coating selection

Rework & Cost of Ownership

Chemistry	Rework Difficulty	Cost-of-Ownership Risk	Business Impact	Key Constraints
Acrylic	Low	• Limited chemical resistance • Increase field failure risk in harsh environments	• Lower repair labour cost • Reduced scrap during rework • Flexible for mixed production	• Limited resistance to fuels/solvents • Lower long-term margin in harsh environments • Solvent handling and VOC management
Urethane	High	• Difficult removal • Longer curing • Increase repair cost	• Reduced warranty risks • Better durability in harsh industrial and automotive	• Longer cure for optimum performance • More difficult localized repair than Acrylics • Solvent handling and VOC management
Synthetic Rubber	Low–Medium	• Process management requirements same as Acrylics	• Balance between reliability and operational flexibility • Reduced failure risk from moisture and thermal cycling	• Lower chemical resistance than urethanes • Requires solvent-based infrastructure • Viscosity stability must be controlled • Solvent handling and VOC management
UV Curable	Medium–High	• Capital investment when changing from solvent-based • Cure validation requirements	• Faster production flow • Improved repeatability • Lower cost at high volume	• UV curable oven investment required • Shadow cure management is critical • Repair process must be standardized
Silicone Resins	Medium–High	• Dedicated infrastructure • Contamination management • Operational complexity	• Excellent long-term durability in harsh thermal environments	• Dedicated process area often preferred • Cross-contamination risk • Adhesion and cleanliness process dependent

Conformal Coating Defects

Most common conformal coating defects



Conformal Coating Defects

Coating defect	Solvent-based		Solvent-free	
	Root cause	Solution	Root cause	Solution
Bubbles	• Viscosity and thinner • Wet thickness and curing	• Check material and curing • Ensure full cure prior tests	• Incorrect application and curing • Incorrect material storage	• Check pressures and air quality • Review application and curing
Capillarity	• Low surface energy • Open via / fine pitch	• Check assembly cleanliness • Apply at different thicknesses	• Low surface energy • Open via / fine pitch	• Check assembly cleanliness • Apply at different thicknesses
Cobwebbing	• High viscosity/evaporation • High pressure and height	• Review viscosity and thinner • Review application	• Not applicable	• Not applicable
De-wetting	• Low surface energy • Open via / fine pitch	• Check assembly cleanliness • Apply at different thicknesses	• Low surface energy • Open via / fine pitch	• Check assembly cleanliness • Apply at different thicknesses
Pin holes	• Dust particles • Too thin coating thickness	• Ensure no FOB present on assembly • Review process and application	• Dust particles • Too thin coating thickness	• Ensure no FOB present on assembly • Review process and application
Orange peel	• Viscosity and thinner used • Application and curing	• Use slow evaporation thinner • Reduce thickness/oven temp	• Not applicable	• Not applicable
Wrinkles	• Not applicable	• Not applicable	• Incorrect thickness/curing • High moisture in coating	• Review process parameters • Ensure optimum storage/handling
Cracking	• Assembly cleanliness • Incorrect process	• Check contamination • Ensure curing as per TDS	• Assembly cleanliness • Incorrect process	• Check contamination • Ensure curing as per TDS
Delamination	• Low surface energy • Contamination and curing	• Check assembly cleanliness • Ensure optimum process	• Low surface energy • Contamination and curing	• Check assembly cleanliness • Ensure optimum process
Loss of adhesion	• Contamination/component • Curing, handling, storage	• Review cleanliness/component type • Check application and curing	• Contamination/component • Curing, handling, storage	• Review cleanliness/component type • Check application and curing

Takeaways - process defines performance

Chemistry Shortlist

↓

- Application
- Cure Process
- Thickness Control
- Inspection

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Reliable Protection

What's next? Webinar 5

03rd of June

Time zones:
10:00 New York, USA
15:00 London, UK
16:00 Paris, France
20:30 Delhi, India
23:00 Shanghai

- **Webinar 5**. Reliability, compliance and delivering the right business value

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Q&A

Coatings Academy®

Webinar 5.
Reliability, compliance and delivering the right business value

Presented By: Vlad DAVID

Powered By HumiSeal®

Agenda

- Introduction to webinar series
- Review previous webinars
- Considerations for reliability and compliance
- What's next?
- Q&A

Introduction to webinar

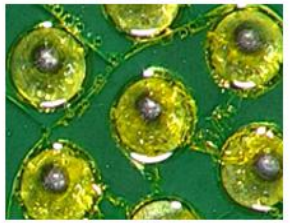
8th of April	• Webinar 1. Why Electronics Fail and what problems are we trying to solve?
22nd of April	• Webinar 2. Conformal coating fundamentals. How can electronics be protected?
6th of May	• Webinar 3. How to select the right conformal coating material for your application
20th of May	• Webinar 4. How to integrate the coating application in the manufacturing process
3rd of June	• **Webinar 5**. Reliability, compliance and delivering the right business value

Webinar 1. Overview

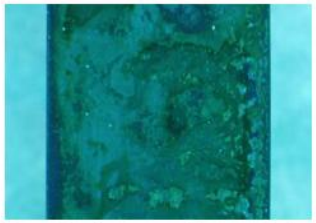
Failure mechanisms on electronics

- Moisture and corrosion
- Thermal stress and cracking
- Chemicals and Gases exposure
- Mechanical and vibration stress

Moisture → corrosion



Thermal cycling → cracks



Chemical gas → Degradation and corrosion

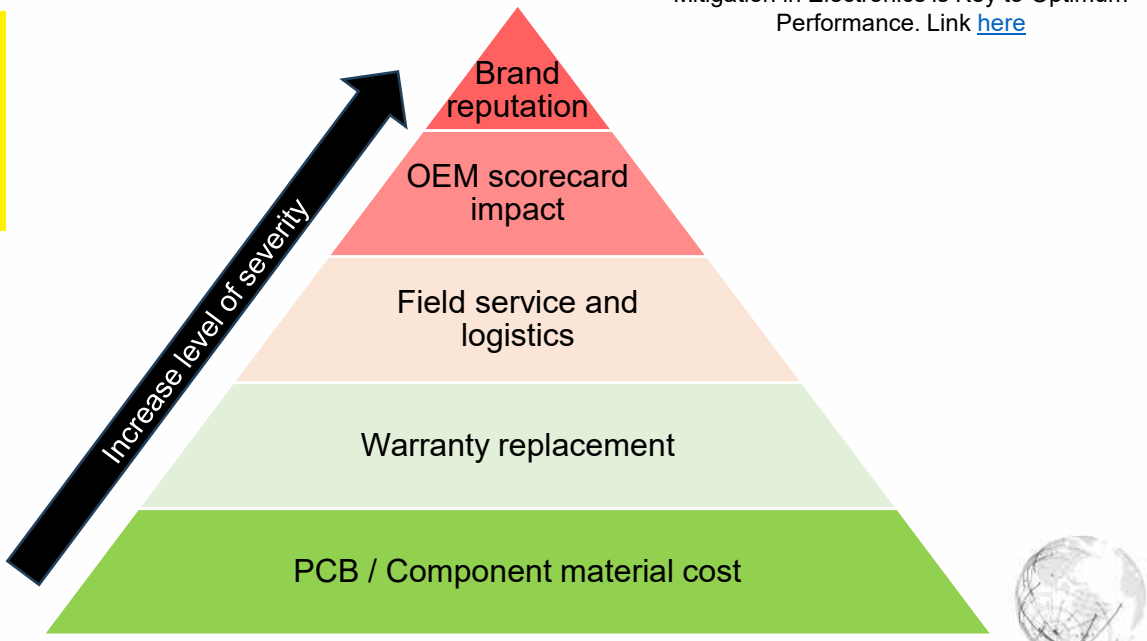
Vibration → micro-cracks and fatigue

Picture source: Mouser. Vibration Damage Mitigation in Electronics is Key to Optimum Performance. Link here

Environmental exposure by industry

Industry	Predominant stress factors
Automotive	Thermal stress, condensation and chemicals
Industrial	Gas corrosion and vibration
Rail	Salt and extreme temperatures
White goods	Condensation and chemical detergents
Energy	Outdoor humidity and high voltage

Estimated 20%
of electronics failures in the field are caused by water-induced corrosion



Failure cost escalates exponentially

Webinar 2. Overview

What is a conformal coating?

- Thin protective film
- “Conforms” to the varied profile of an electronic circuit assembly
- Membrane that filters water vapour and solid debris
- Protects the assembly from corrosion in harsh environments
- Electrical insulating properties allows reduced conductor spacing
- Glows blue under UV light for easy inspection

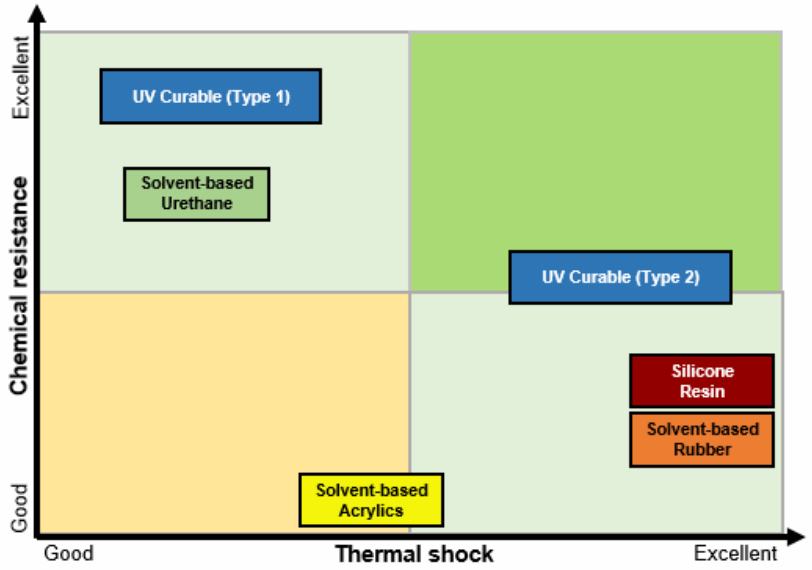
Coated assembly. Side view

Conformal coating properties

MVP (Moisture Vapour Permittivity)

Chemical resistance and thermal shock graph

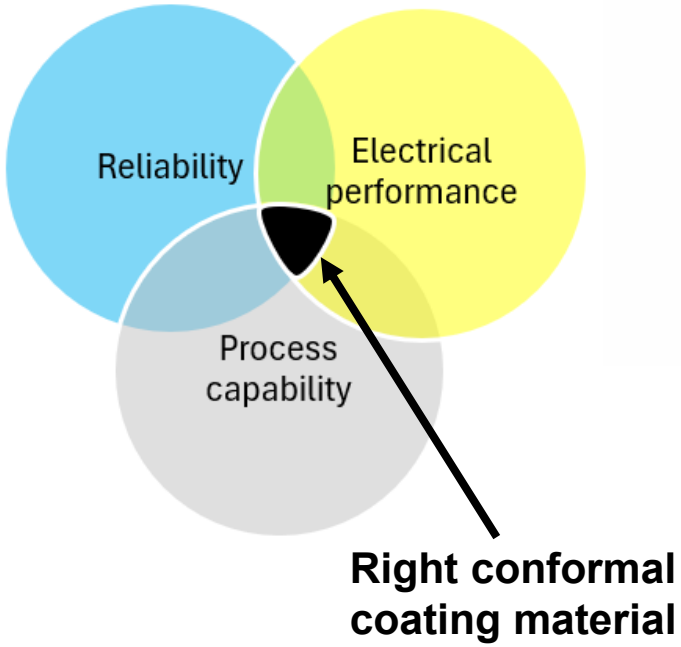
Chemistry	MVP Value in mg/m2*Day based on coating thickness				Condensation performance *
	50 µm	75 µm	100 µm	150 µm	
Acrylics	110	90	75	No data	Good
Urethane	120	100	80	No data	Good
Synthetic Rubber	12	9	8	No data	Excellent
UV Curable	12	8	7	6	Excellent
Silicone Resin	600	500	350	250	Poor



Webinar 3. Overview

SOLVENT-BASED

SOLVENT-FREE *



Industry	Key Requirements								
	Environmental (ºC, %RH)	Condensation and moisture	Air pollution / noxious gas	Altitude and Ozone	Outgassing	Chemical resistance	High Voltage strength	Thermal cycle Thermal shock	Standards (e.g. IEC, OEM*)
Automotive	✓	✓	✓		✓	✓	✓	✓	✓
Aerospace and defence	✓	✓	✓	✓	✓	✓	✓	✓	✓
Consumer Electronics	✓	✓				✓			
Consumer white goods	✓	✓	✓			✓		✓	✓
Consumer brown goods	✓	✓				✓		✓	✓
General Industrial	✓	✓	✓			✓	✓	✓	✓
Industrial controls	✓	✓	✓			✓	✓	✓	✓
Energy and renewable energy	✓	✓	✓	✓		✓	✓	✓	✓
Oil & Gas, marine	✓	✓	✓			✓	✓		✓
Lighting	✓	✓	✓		✓	✓	✓	✓	✓
Medical, Food and Pharma	✓	✓				✓	✓	✓	✓
Agriculture and outdoor use	✓	✓	✓	✓		✓			

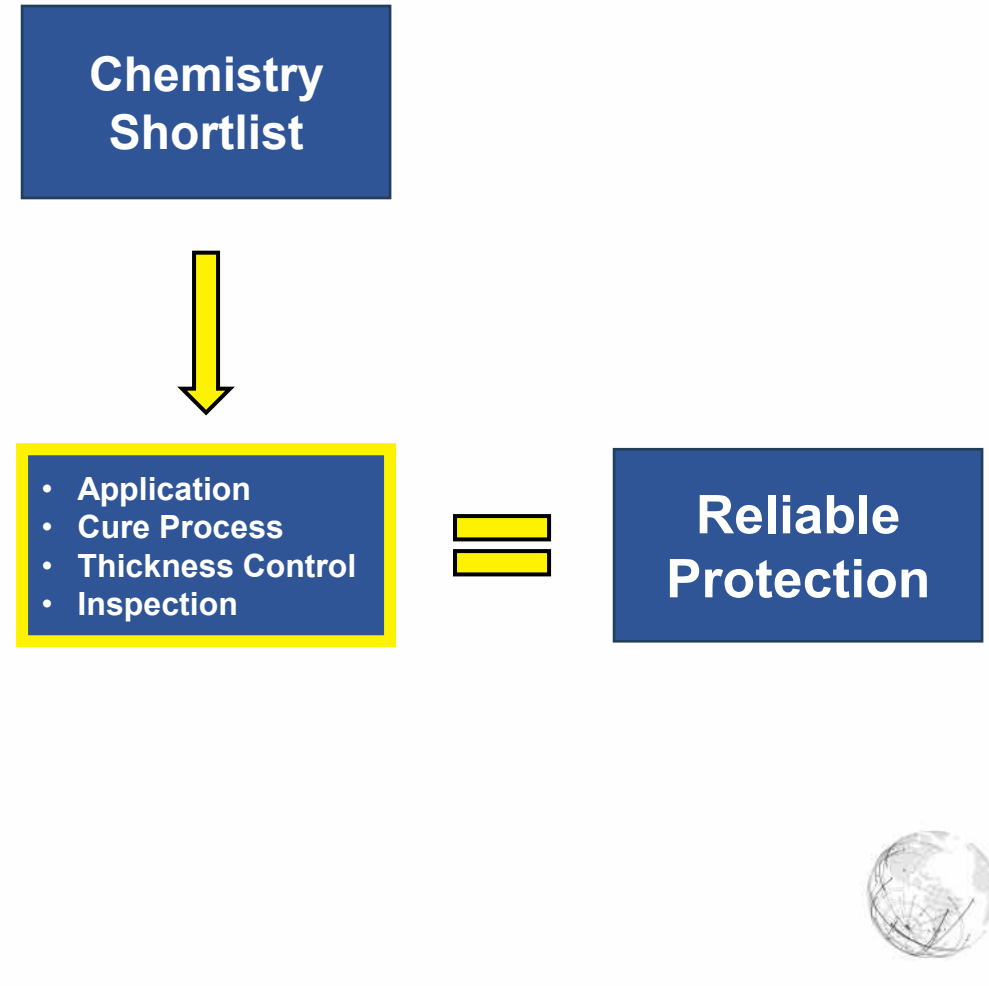
Webinar 4. Overview

Strong Process Control

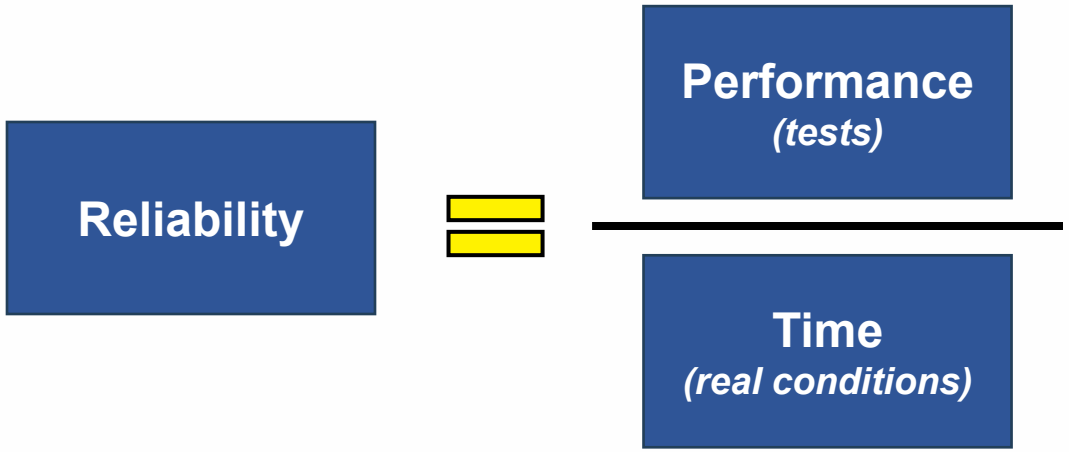
- Higher yield
- Lower field failures
- Stable production
- Reduced scrap
- Long-term reliability

Poor Process Control

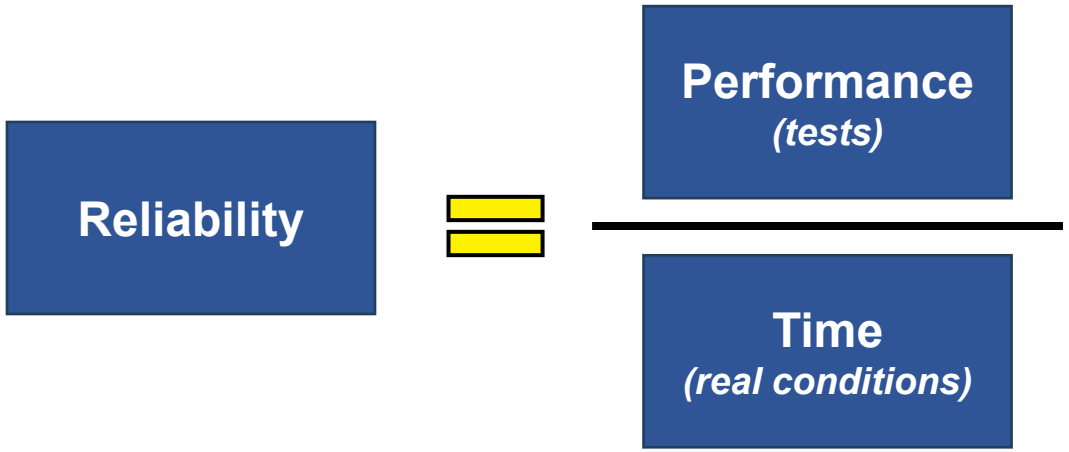
- Increased rework
- Warranty risk
- Process variability
- Customer complaints
- Hidden operational cost



What does reliability mean?



What does reliability mean?



Testing validates:

- Material performance
- Process consistency
- Design robustness

Key Reliability tests for conformal coatings

- 85°C / 85%RH humidity testing
- Thermal cycling
- Surface Insulation Resistance (SIR)
- Dielectric Withstand Voltage (DWV)
- Chemical resistance testing
- Corrosive gas exposure
- Condensation cycling

From compliance to reliability and cost of failure

Compliance
Confirms baseline requirements

Regulatory
REACH, RoHS, EH&S
Engineering controls

Standards Passed
IPC / IEC/ UL/ OEM requirements are met

Lab tests completed
Test methods performed under controlled conditions

Meets minimum performance
Electrical, environmental and mechanical

Reliability Gap
Real world reliability

Material selection / testing
Correct chemistry
Combined stress factors
Long term exposure
Material performance
Lifetime alignment
Field variability

Process Control
Controlled thickness
Process variability
Material performance
Lifetime alignment

Validation Strategy
Long-duration testing
Worst-case scenarios
Application-specific

Financial impact

Brand damage
Loss of trust
Market share

Cost of failure
Engineering analysis
Replacement costs
Components cost
Service and logistics

Production disruption
Downtimes
Missed deliveries

Regulatory Compliance and Long-Term Sustainability

Regulation	Main Objective	Impact on Conformal Coatings
RoHS	Restrict hazardous substances	Limits lead, mercury, cadmium, chromium VI, PBB, PBDE and other substances
REACH Registration, Evaluation, Authorization, and Restriction of Chemicals	Chemical safety & substance transparency	Controls SVHC substances and supply chain chemical reporting
TSCA Toxic Substances Control Act	Regulated by EPA (Environmental Protection Agency) to track industrial chemicals imports to USA	Controls substances and supply chain chemical reporting
UL	Safety & flammability	Electrical and fire safety validation
OEM Environmental Requirements	Sustainability & lifecycle compliance	Approved substance lists

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Chase Corporation and HumiSeal sustainability programs include:

- KPI Target 6% annual reduction in carbon emissions
- Energy reduction program based on equipment efficiency and waste reduction
- ISO 14001 Environmental Management System certification
- Environmental Social Governance (ESG) compliance initiative engagement
- Supplier engagement to cascade objectives throughout the supply-chain
- Employee engagement in energy saving and carbon reduction initiatives

Testing vs real life expectations

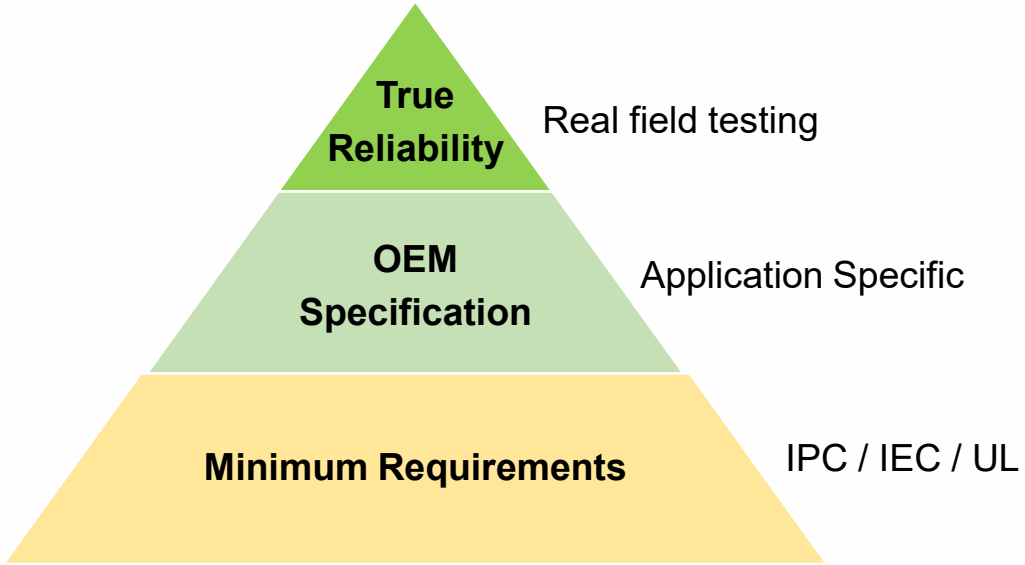
Lab conditions ≠ **Field conditions**

- Controlled humidity
- Single stress
- Short duration
- Limited conditions

- Humidity + temperature + vibration
- Contamination and debris present
- Long-term exposure
- Variable conditions

Many failures occur because test conditions do not fully represent real environments.

- Testing only to pass standards
- Ignoring combined stresses
- Not testing worst-case scenarios
- Short test duration vs long lifetime



Remember
Validation must reflect real-world conditions, not just compliance

The reliability gap

Traditional Validation Approach

- Humidity only
- Thermal cycling only
- Vibration only
- Short duration qualifications

Reliability Gap
Missing aspects

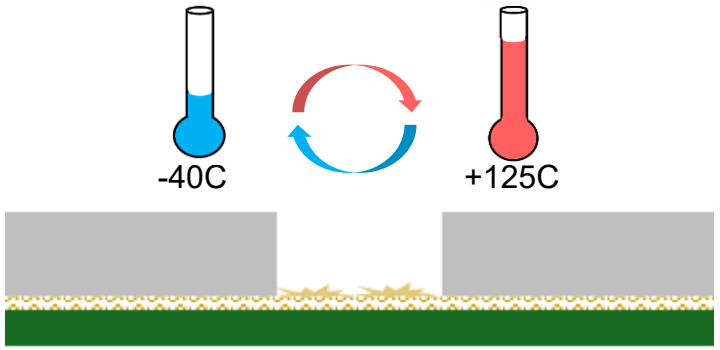
- Combined stresses
- Long-term aging
- Material degradation over time
- Process drift
- Real contamination conditions

Real Field Environment

- Moisture + electrical bias
- Thermal cycling + vibration
- Chemical exposure + humidity
- Long lifetime + aging

Remember
Most field failures are not caused by a single stress — they result from the interaction of multiple stresses acting over time

Thermal Cycling + Brittle Material = Cracks



Moisture Ingress

Corrosion / ECM

Process to reliability. Quality actions

Solder paste & cleanliness → Hidden failure driver

Question often asked
- Do I really need to clean?

Reality
- Flux residues = ionic contamination
- Strong dependency between coating and solder paste compatibility

Quality actions
- Define cleanliness limits
- Validate with SIR test
- Control: reflow profile, flux residues, PCB surface energy, handling and storage in between processes

Application method → Process consistency

Questions often asked
- Can I achieve a repeatable process?
- Will thickness be consistent?

Reality
- Manual application has variability
- Selective gives higher control but needs right setup

Quality actions
- Define process window
- Use process capability
- Standardize equipment parameters

Condensation resistance → Moisture barrier reality

Question often asked
- Will the coating protect in humidity and condensation?

Reality
- Moisture ingress depends on MVP, thickness and coverage
- Curing (partial = higher permeability; thin = faster permittivity

Quality actions
- Define minimum thickness
- Verify full cure
- Validate with condensation and SIR testing

Chemical resistance → Long-term degradation

Question often asked
- Will it survive real environments?

Reality
- Chemicals can soften coatings
- Combined with thermal cycling -> cracks + failure

Quality actions
- Select chemistry based on chemical exposure level
- Validate chemical resistance and thermal shock correlation
- Monitor coating degradation over time

Qualification standards

IPC-CC-830 – material qualification
Defines:
- Material requirements
- General performance tests
    - Narrows coating material selection

IPC does not simulate full field exposure

IEC60664 – electrical insulation reliability
Defines:
- Electrical insulation reliability and conductor spacing reduction
- To determine if coating can reduce conductor spacing

Compared with IPC, IEC goes further toward electrical reliability

OEM requirements – assembly / finished product testing
Automotive / Industrial OEM specs:
- More severe testing
- Longer duration
- Application-specific

OEM requirements often go beyond standard qualifications. Test protocol can include test sequences from IPC or IEC

IPC and IEC. Qualification standards

Standard	Main Purpose	Focus Area	Typical Industry Use
IPC-CC-830	Qualification of conformal coating materials	Material performance & environmental durability	General electronics, industrial, automotive baseline
IEC 60664-3	Insulation coordination using coatings	Electrical insulation reliability Conductor spacing reduction	High-voltage electronics, EV, industrial power, aerospace

IPC-CC-830

Test	Purpose
Moisture and insulation resistance	Evaluate electrical stability in humidity
Thermal shock	Evaluate cracking / adhesion after temperature cycling
Fungus resistance	Biological resistance
Flammability	Safety behavior
Dielectric withstand voltage (DWV)	Electrical insulation capability
Flexibility / adhesion	Mechanical integrity
Visual inspection	Coating quality after stress

IEC 60664-3

Test	Purpose
Humidity conditioning	Simulate moisture exposure
Electrical withstand testing	Validate insulation integrity
Tracking / insulation behaviour	Evaluate leakage path resistance
Thin coating verification	Validate minimum effective insulation thickness
Long-term electrical stress	Assess insulation degradation over time
Surface condition evaluation	Assess coating continuity and defects

Other referenced standards

Standard / Specification	Industry Focus	Main Purpose
MIL-STD-810	Defence / Aerospace	Environmental stress testing (thermal shock, vibration, humidity, altitude)
NASA Outgassing ASTM E595	Space / Aerospace	Control volatile contamination and outgassing in sensitive systems
ASTM Standards	All industries	Material characterization, chemical resistance, environmental durability
VW80000	Automotive OEM	Automotive environmental and electrical validation
UL Standards	All industries	Electrical safety and flammability compliance

Example OEM qualification test

Example of test sequence	Test criteria
1. Thermal shock	-40°C to +85°C, 500 cycles
2. Visual inspection	Inspect and record presence of bubbles, delamination and cracks
3. Damp heat cyclic	35C/90%RH (25h) → 65C/90%RH (75h) → 85C/85%RH (75h) → 35C/50%RH (25h)
4. Visual inspection	Inspect and record presence of bubbles, delamination and cracks
5. Condensation test	Variable temperature and humidity, cyclic test
6. Visual inspection	Inspect and record presence of bubbles, delamination and cracks
7. Electrical function test	Internal procedure including FCT
8. Breakdown voltage	Internal procedure including FCT
9. Visual inspection	Inspect and record presence of bubbles, delamination and cracks

Customer decision framework. Chemistry selection

Chemistry	Qualification alignment	Key reliability strengths	Limitations	Best-fit applications
Acrylic	Aligned with **IPC-CC-830** and general industry requirements. Suitable as baseline coating requirement.	• Good moisture resistance • Easy application • Easy repair, cost-effective	• Limited chemical resistance	• General industrial • commercial electronics • Lower-risk automotive interior
Urethane	Strong fit for **IPC-CC-830**, automotive OEM expectations, and harsh environment	• Very good moisture resistance • Very good chemical resistance • Good noxious gas protection	• Longer secondary curing • More difficult to repair	• Automotive • Industrial controls • Chemical exposure environments
Synthetic Rubber	Suitable for high-reliability electrical and condensation testing; can support demanding qualifications	• Very flexible • Excellent dielectrics • Strong condensation and thermal shock performance	• Lower solvent resistance than urethanes • Solvent-based infrastructure still required	• High condensation • Thermal shock applications in industrial and automotive
UV Curable	Strong alignment with automotive and industrial qualification programs; relevant for high-volume production.	• Fast cure, high throughput • Excellent dielectric performance • High condensation performance	• Requires correct UV setup • Secondary cure assessment • Repair can be more difficult	• Automotive electronics • EV power systems • High-volume industrial
Silicone	Relevant where high-temperature and flexibility requirements dominate.	• Excellent flexibility • High-temperature capability • Strong thermal shock cycling	• Poorer moisture barrier • Difficult application/rework • Contamination control required	• High-temperature electronics • Severe thermal shock cycling
High-viscosity coatings & gels	Not always a standalone qualification Valuable support to improve applications	• Improved coverage • Connector sealing • Enhanced protection in high-risk areas	• Process-dependent, requires specific considerations	• Connector sealing • Keep-out area control • Condensation-critical designs

Customer decision framework. Protection level

Protection Level	Typical Industries	Reliability Expectation	Common Coating Types	Main Environmental Risks	Typical Qualification & Validation Tests
Level 1 **General Protection**	• Consumer electronics • White goods • Indoor electronics	Basic environmental protection. 2–5 years expected life	• Acrylic	• Humidity • Dust • Mild condensation	• IPC-CC-830 qualification • Adhesion • Humidity exposure • Visual inspection
Level 2 **Enhanced Protection** Defence / Industrial / Automotive	• Industrial controls • LED drivers • Commercial outdoor • Automotive electronics	Moderate-to-high reliability. 5–10 years	• Acrylic • Synthetic rubber • Urethane • UV curable • Silicone	• Condensation • Pollution • Thermal cycling • Corrosive gases	• IEC 61086 • IEC 60664-3 • Thermal cycling • SIR / ECM & condensation • Chemical resistance
Level 3 **High Reliability** Automotive / Transportation	• Automotive electronics • EV power systems • Rail	High reliability 10–15 years	• Synthetic rubber • Urethane • UV curable	• High humidity • Rapid thermal shock • Vibration • High voltage	• OEM standards • IEC 60664-3 • DWV / dielectric testing • Vibration • Thermal shock • Combined stress testing
Level 4 **Mission-Critical** Aerospace / Defence	• Aerospace • Avionics • Defence • Space applications	Extreme reliability Safety-critical operation	• Advanced coatings • Specialized low-outgassing systems	• Extreme thermal cycling • Altitude • Vibration • Long-term aging • Corrosive environments	• MIL-STD-810 • NASA ASTM E595 • Extended thermal cycling • Long-duration humidity • Advanced insulation testing

Final takeaways

Technical Perspective

- Correct coating chemistry
- Controlled manufacturing process
- Realistic validation testing
- Cleanliness and inspection discipline
- Understanding combined stresses over time

Business Perspective

- Reduced field failures
- Lower warranty cost
- Higher manufacturing consistency
- Better customer confidence
- Improved long-term profitability

Webinar 1 - Failure mechanisms

Moisture, thermal stress, chemicals, vibration

Webinar 2 - How coatings protect

Barrier performance, dielectric strength, chemistry fundamentals

Webinar 3 - Material selection strategy

Environment → performance target → chemistry shortlist

Webinar 4 - Process defines performance

Application, curing, thickness, cleanliness, inspection

Webinar 5 - Validation & business impact

Testing, compliance, reliability margin, cost of failure

What's next?

Education

Webinar series

- Understand hidden reliability risks
- Learn how to select the right coating chemistry, application and process controls
- Discover how testing, process and quality work together for long-term reliability and reduced risk failures

Customer Engagement

Tell us more about:

- Your manufacturing process
- Experience with protective materials
- How do you identify reliability risks and the corrective actions
- What are your current challenges or a new process you try to implement

Long-term Reliability Partnership

Collaborate on:

- Process optimization
- Validation testing
- Long-term reliability improvement

Q&A