"A Closer Look at why Cleaning prior to Conformal Coating becomes Key in Aspects of Climatic Reliability?"

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Abstract:
The ever-increasing use of high frequency in high density interconnect (HDI) assemblies, combined with the worldwide move towards lead-free manufacturing, has initiated a closer assessment of effective flux removal processes. Since adequate climatic operating conditions can't always be assured, system signal integrity maybe vulnerable to failure through induced capacitive effects of hygroscopic activator residues. Furthermore, such contamination is no longer detectable by ion-equivalent measurements alone.

Most failures of electronic components in humid environment are caused by electrochemical migration and corrosion induced leakage currents. In this paper, the origins and effects of such failure mechanisms are examined. In addition, we are also discussing the influence of alloy types with particular reference to lead-free formulations. The critical importance of contamination free surfaces in high frequency circuits is outlined and put into context with the quality of conformal coating.

Finally, we will describe different methods to determine climatic reliability as well as introduce a new and innovative test method.

Executive Summary:
As mentioned previously there are two main forms of failure on electronic components: electrochemical migration and corrosion induced leakage currents. To trigger such mechanisms four factors need to simultaneously be present:

- Differences in the electrical potential
- Sufficient atmospheric humidity
- Suitable metal alloys that can electro-chemically migrate
- Remaining contamination on the board surface

Effect of Humidity:
Electrochemical migration, known as the most common failure mechanism, can be initiated by as little as a few mono-layers of humidity. The latter can cause the corrosion process to begin at critical humidity levels of 60-70% RH at ambient temperature, which in turn depends on the polarity of the substrate and its respective surface energy. Historically, electronic assemblies were mostly used in controlled environments where the risk for electrochemical migration was limited. These days, that the electronics are applied in the harshest and critical environments, the risk of migration is indeed increasing.

Effect of Metal/Alloy:
In addition to the above-mentioned critical humidity film, a metallic alloy and its structure can also play a vital role. The electrochemical migration proceeds through three distinct steps:

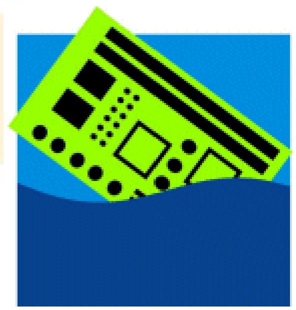
1. Anodic metal dissolution – transformation of metal atoms into metal ions and begin to migrate from the anode to the cathode
2. Diffusions of the metallic ions – characterizes the migration of dissolved metal ions from the anode to the cathode. The contamination on the PCB surface does not negatively affect the rate of diffusion.
3. Depositions of the metallic ions – dissolved metal ions are deposited at the cathode. The deposition is dominant where the electrical field is the highest.

Corrosion Induced Leakage Currents also promotes the building of “bridges” similarly to electrochemical migration. The most significant difference though is the underlying cause for the formation of leakage currents - this effect occurs mostly in contaminated atmospheres. Contamination induced leakage currents in contrast are caused by the intrinsic conductivity and electro-diffusion effects of most contamination which generally lowers the surface insulation resistance.

The second main part of the study focuses on the reliability of lead-free / silver-based solders and high frequency circuitry. Here, we are showing how the environmental conditions as well as the great demand for high frequency assemblies are influencing the reliability of the assemblies and the products they are built in. In the conclusive part we will introduce different test methods to determine the cleanliness of the printed board surface. There are several ways to determine the cleanliness level, i.e. the Ionic contamination test, the ZESTRON® Flux test or Climatic Reliability Test. The latter looks at the behavior of PCB under certain environmental conditions.

As the newest test method we will introduce the CoRe Test, which is an innovative method for an accelerated climatic reliability test using bare as well as coated electronic assemblies. This test provides an indication of whether and in which area the printed circuit board might fail. It also determines if coating is required to protect against humidity.

“A Closer Look at Why Cleaning Prior to Conformal Coating Becomes Key in Aspects at Climatic Reliability”



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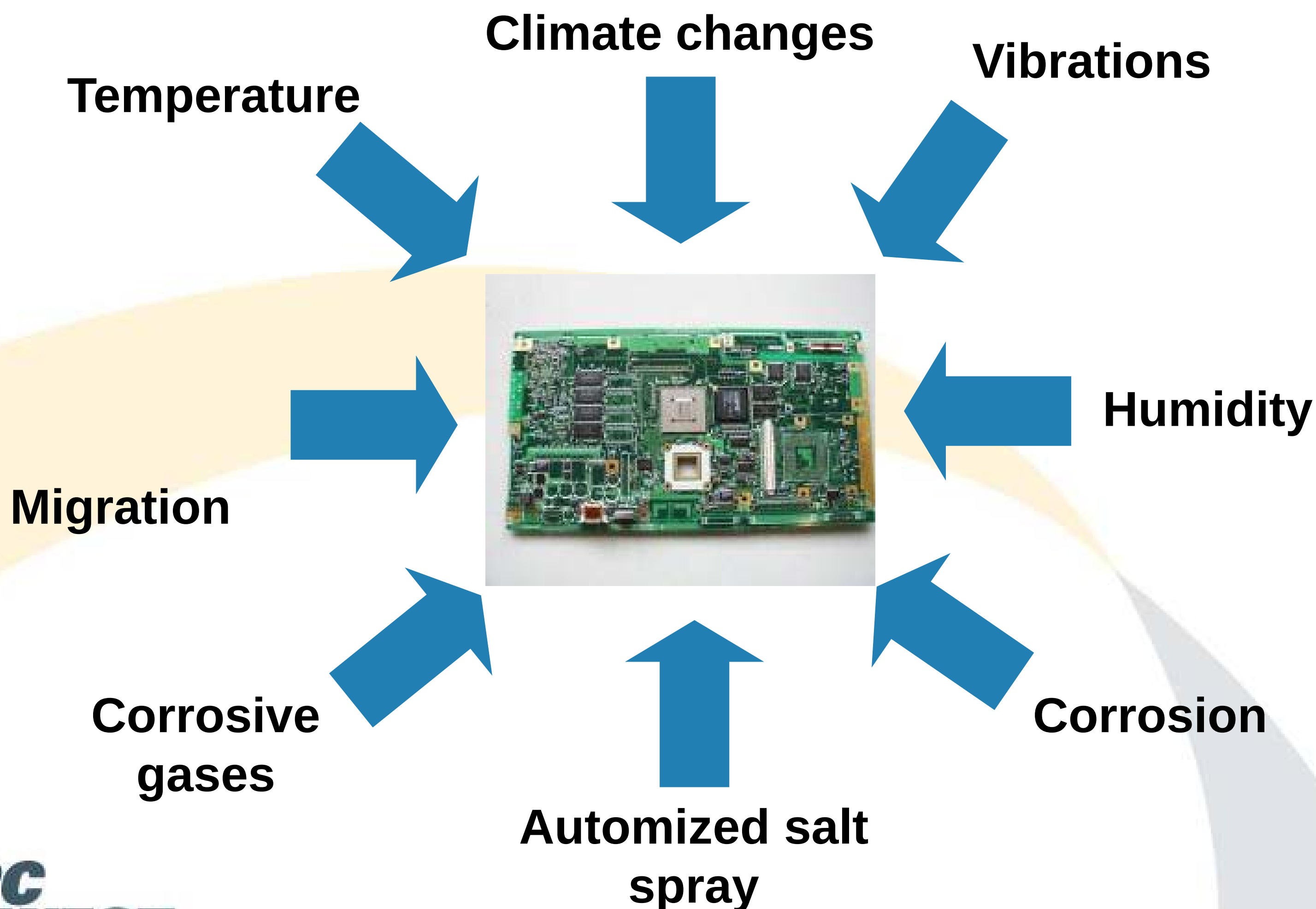
Application Engineer
Email: J.Patel@zestronusa.com

Content

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

Impact on PCBs



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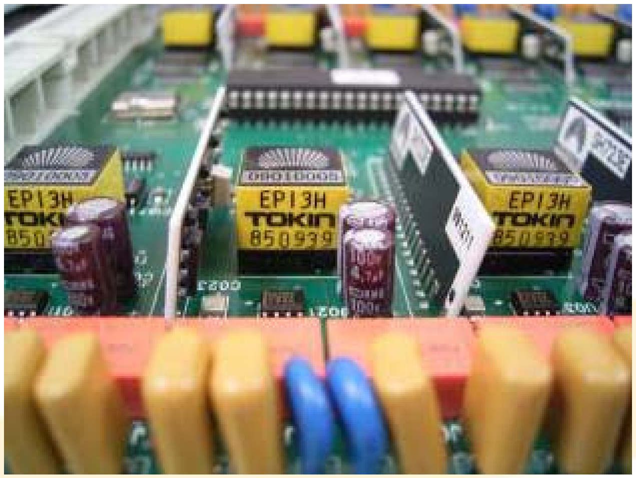
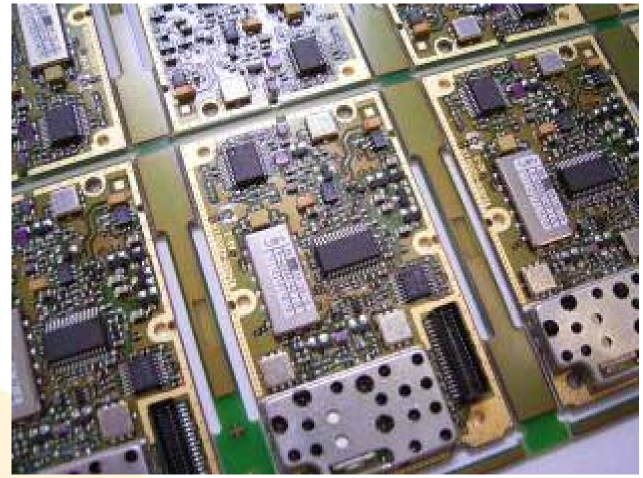
Climatic Stress increases



Trend



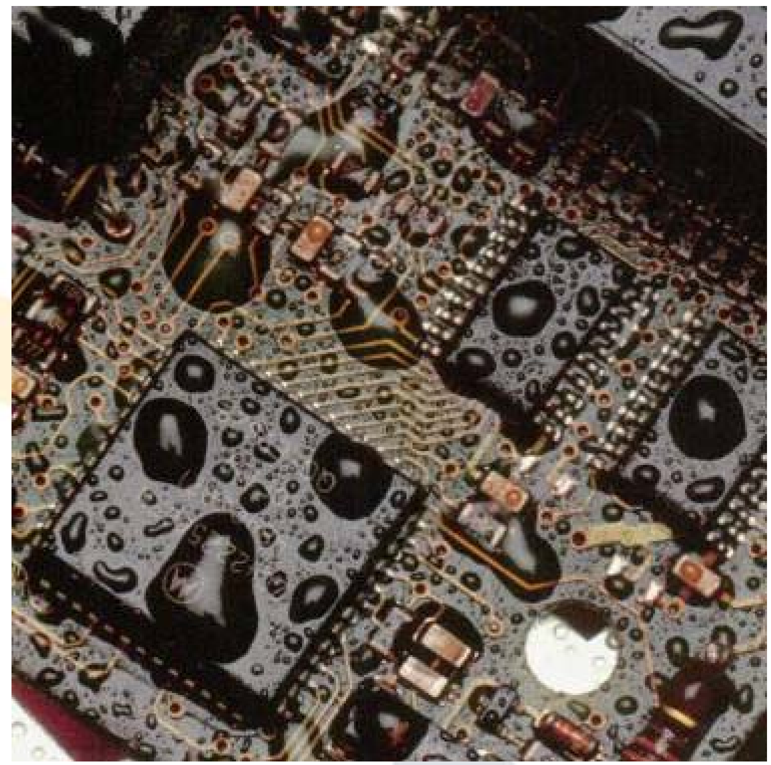
- Big components
- Low density on the assemblies
- Low environmental influences

- Small components
- High density of low standoff components
- Extreme environmental influences

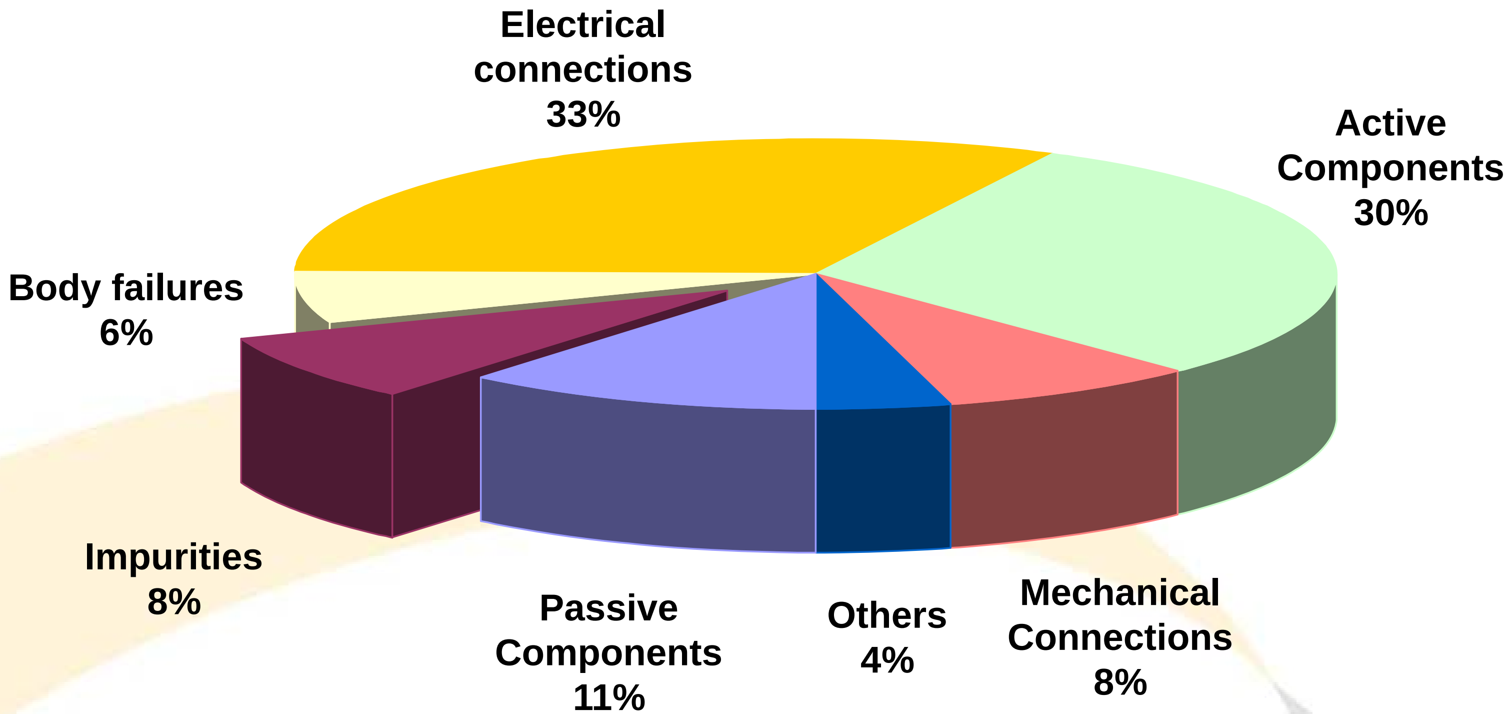
Advantages of Conformal Coating

Coating protects against :

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



Reasons for Failures



Resource:
Modern Electronic Packaging
Integrated Circuits Engineering Corporation

Possible Impurities

PCB manufacture	Component manufacture	Assembly

PCB manufacture

- Contamination from the etching process
- Developer chemical
- Alkaline cleaning agent
- HAL-residues
- Residues from

  ENiG-/ CSN-process

Component manufacture

- Contamination from Metallization-baths
- Rinse water quality
- Deflashing chemicals
- Mold release agent

Assembly

- Solder pastes
- Wave solder
- Rinse water quality
- Reflow oven
- Reflow condensate
- Outgassing

Critical Residues

Fluxes/solder pastes

Ingredients:

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

Handling residues

e.g.

- finger prints
- dust
- oil/grease
- salts

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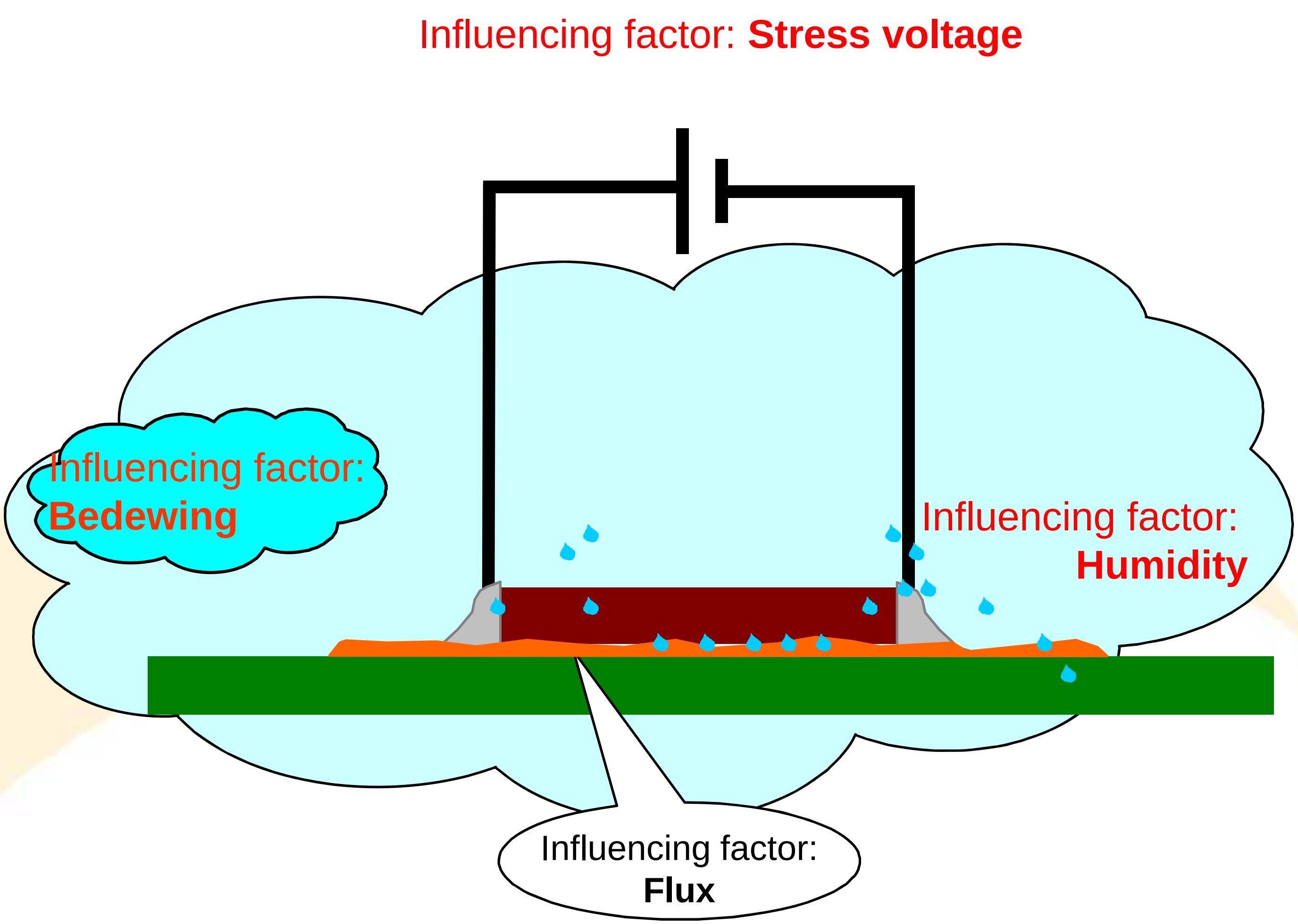
Climatic Failure Mechanisms

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

Electrochemical Migration



steam/humidity

+

Ionic contamination

(salts, flux activators)

=

conductive electrolytes

+

Stress voltage

=

Electro-chemical migration

Failure Mechanism – Electrochemical Migration

Failure occurs when you have:

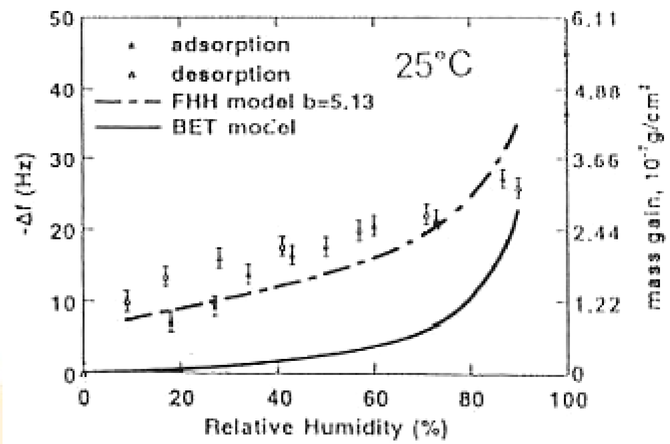
- Sufficient Atmospheric Humidity
  Promoted by Contamination on the Surface

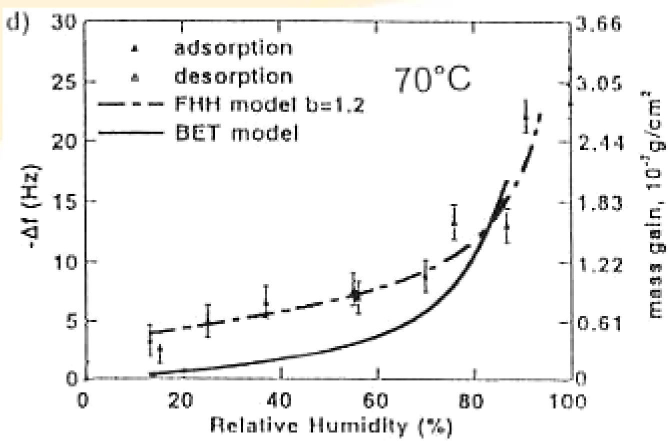
- Electrical Potential Difference

- Alloys that can electrochemically migrate

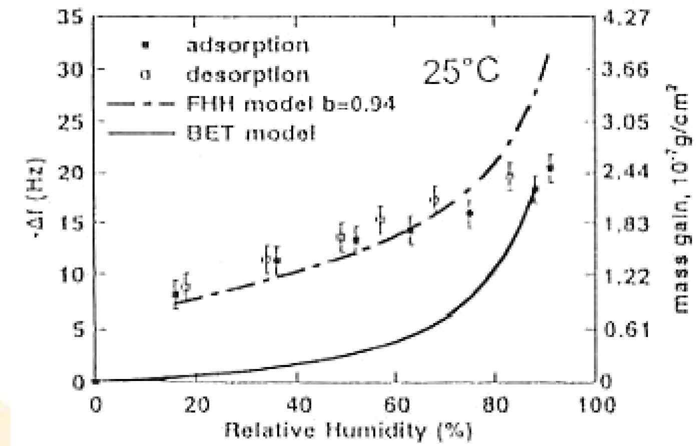
Humidity Adsorption on Metallic Surfaces

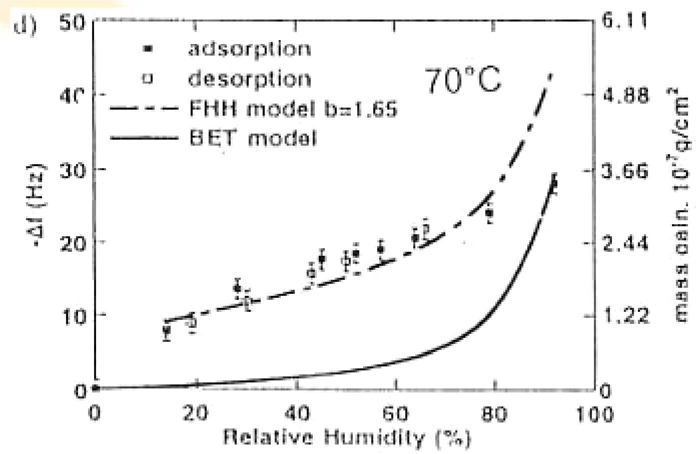
Copper





Nickel





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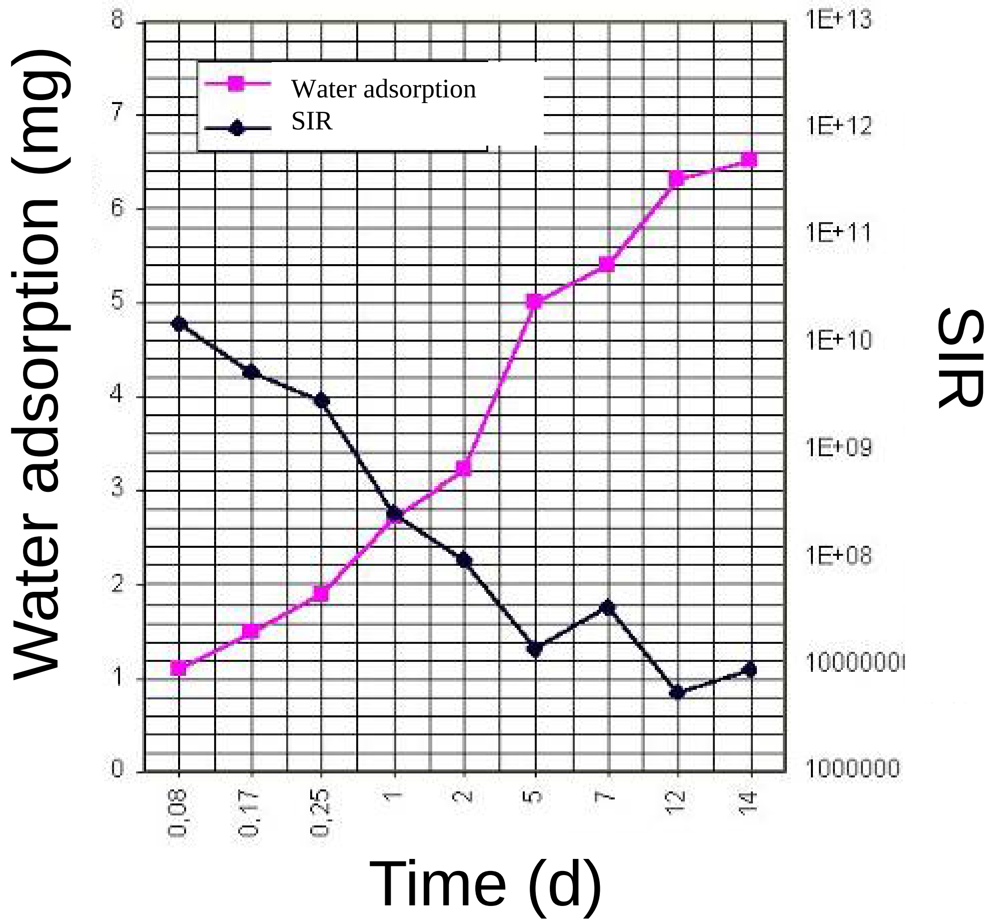
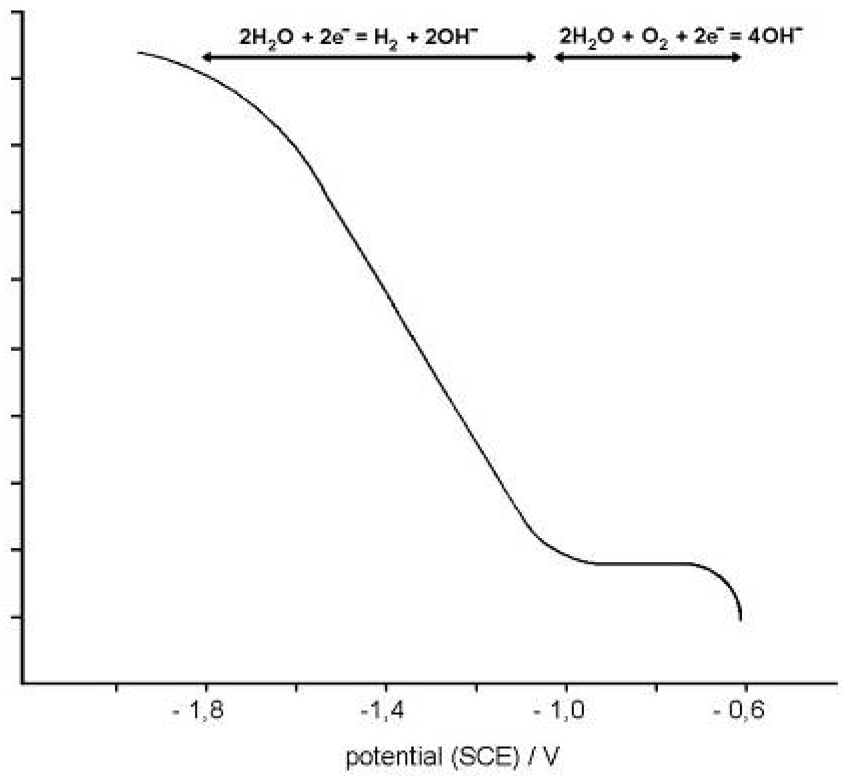
Failure Mechanisms

Influence of the Amount of Adsorbed Water on SIR

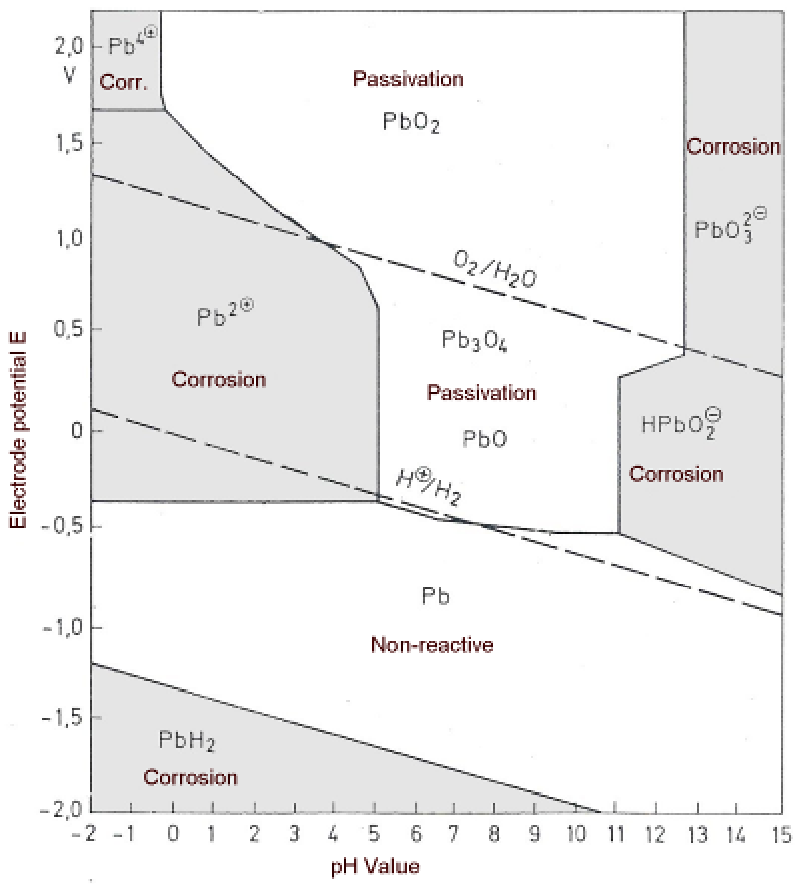


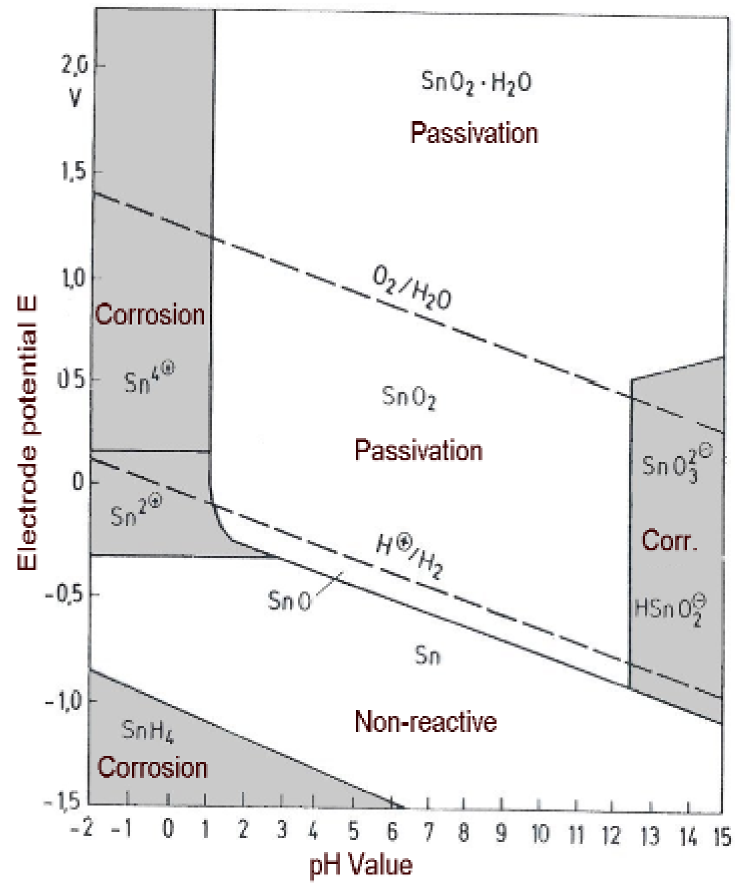
Failure Mechanisms



Electrical dissociation of water

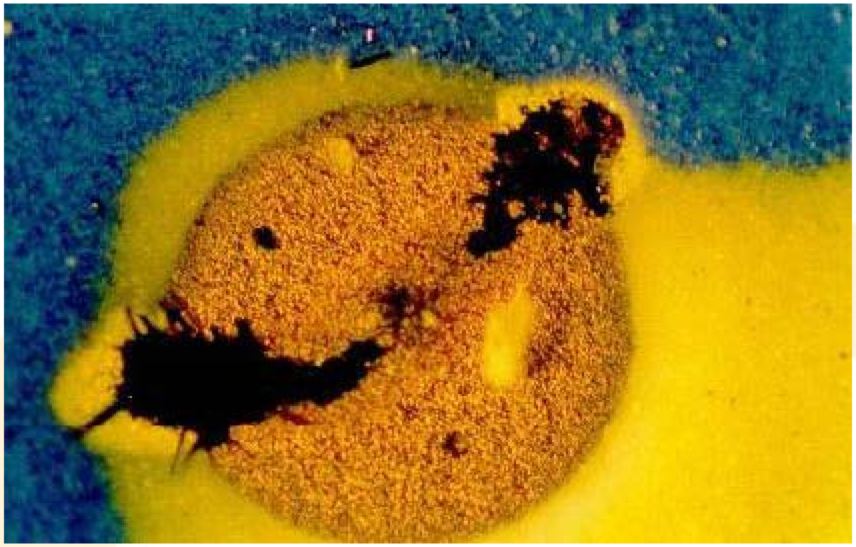
Failure Mechanisms

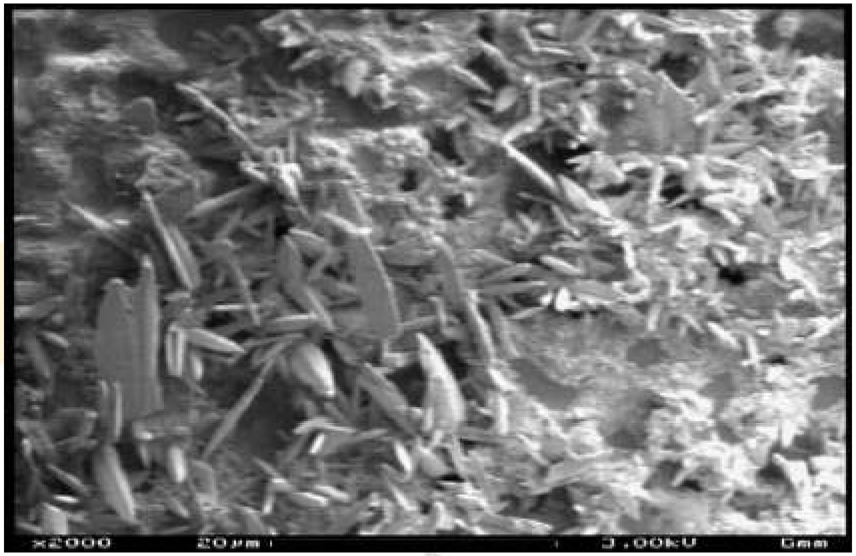




Potential/pH diagrams for tin and lead

Corrosion of Inner Ag-layer on Hybrids

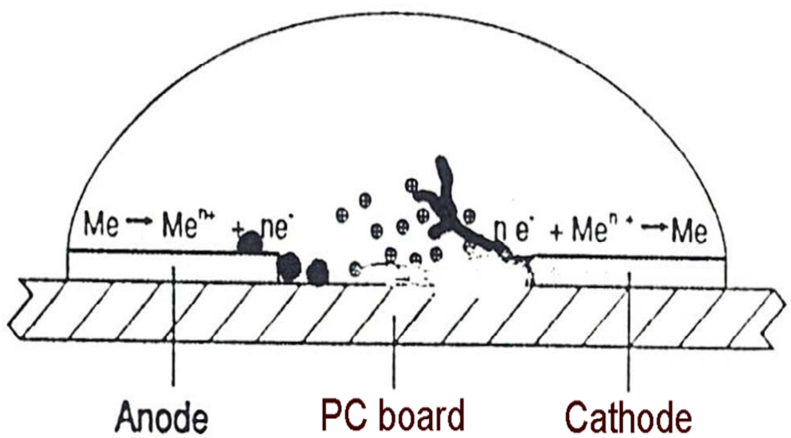




AgS_2-crystals on conductive glass

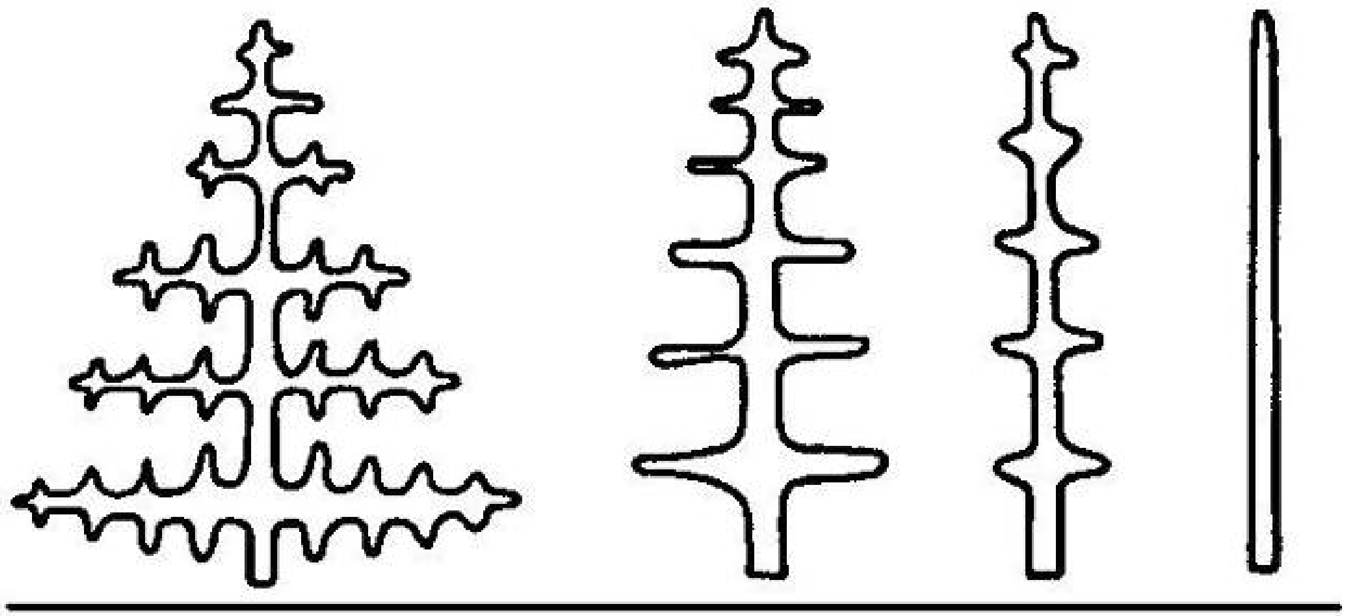
Failure Mechanism – Electrochemical Migration

Step 1. Anodic Metal Dissolution [M to $M^+ + e^-$]
Step 2. Metallic Ion Diffusion
Step 3. Cathodic Metal Deposition [$M^+ + e^-$ to M]



Mechanism of dendrite growth

Failure Mechanisms



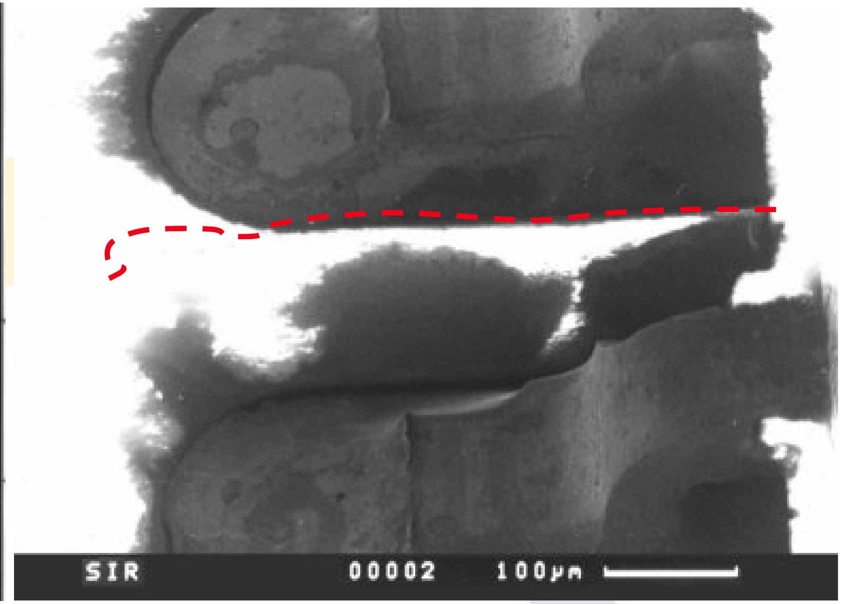
Dendrite morphology

Climatic Failure Mechanisms

- Electrochemical Migration
- **Creeping current**
- Signal distortion on radio frequency circuits

Creeping Current

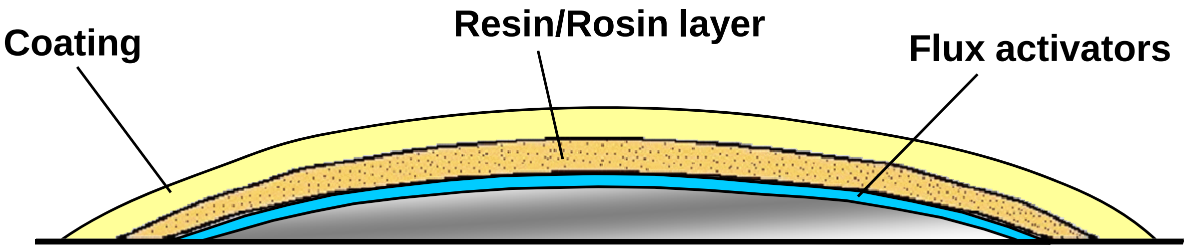
Visualization of creeping current through charge contrast measurement



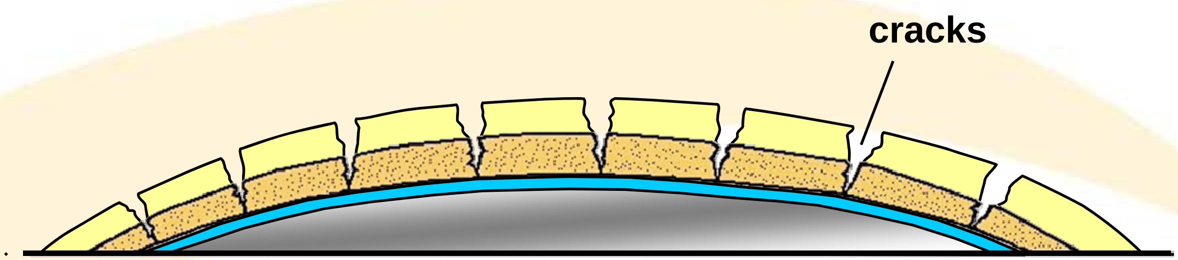
Optically clean

Electrically contaminated

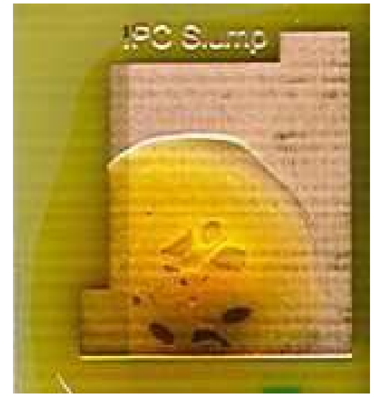
Resin/Rosin Residues



After soldering



After temperature cycles



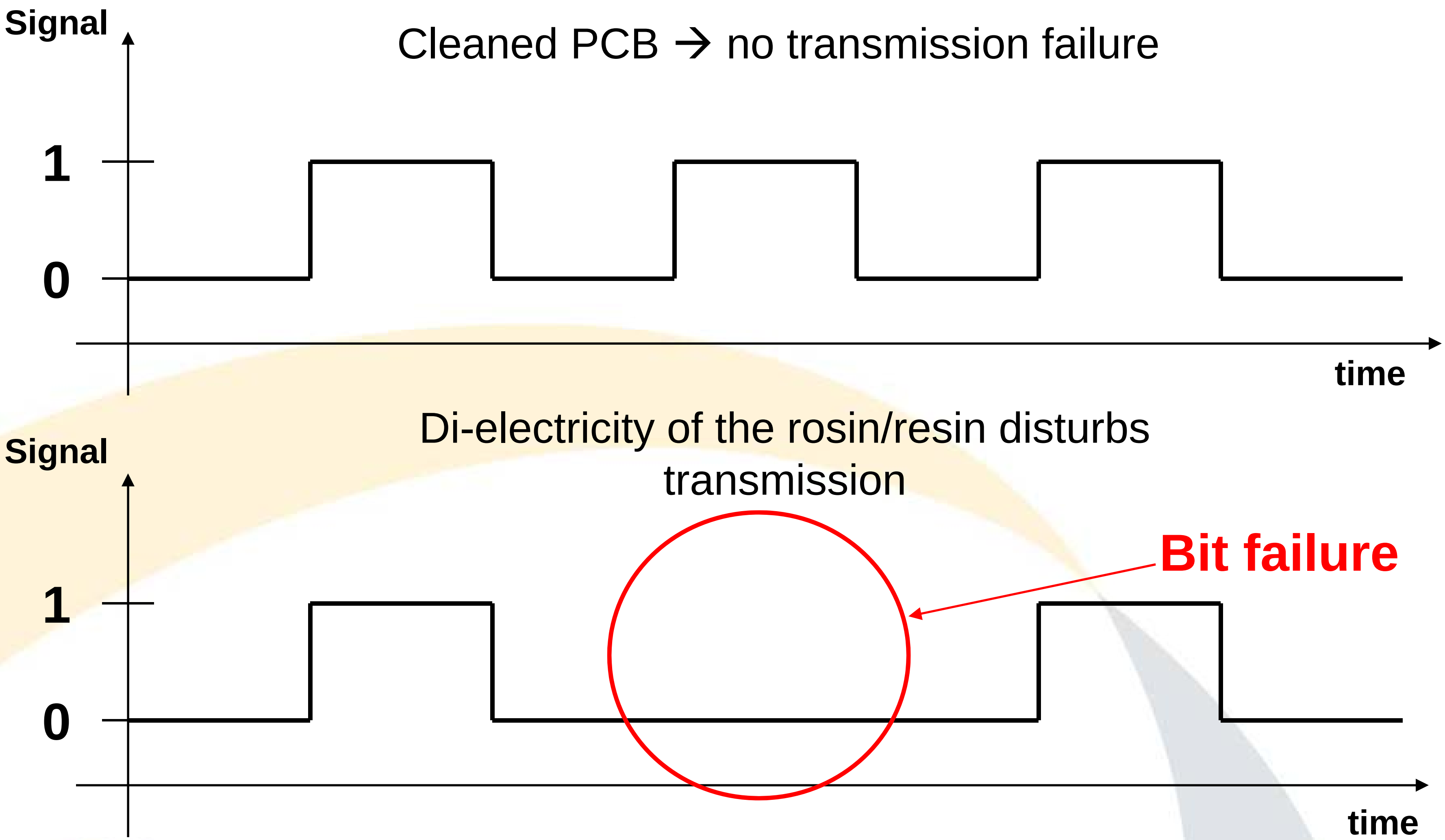
Important: no humidity, only temperature cycles – day/night

→ Activators cause creeping currents and influence climatic reliability

Climatic Failure Mechanisms

- Electrochemical Migration
- Creeping current
- **Signal distortion on radio frequency circuits**

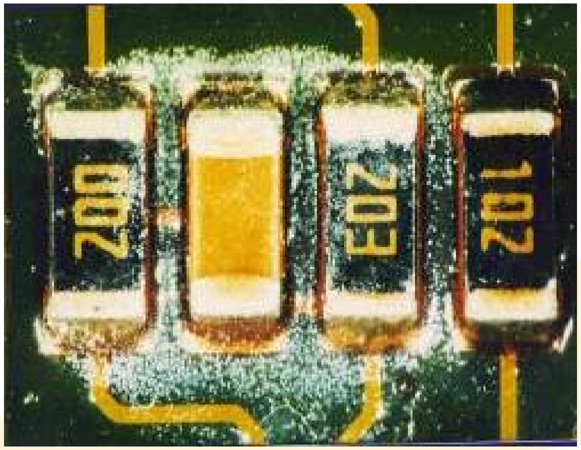
Bit Failures in RF Connections



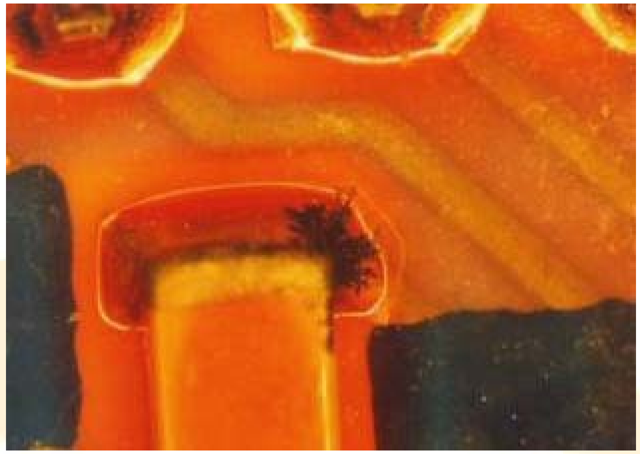
Content

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

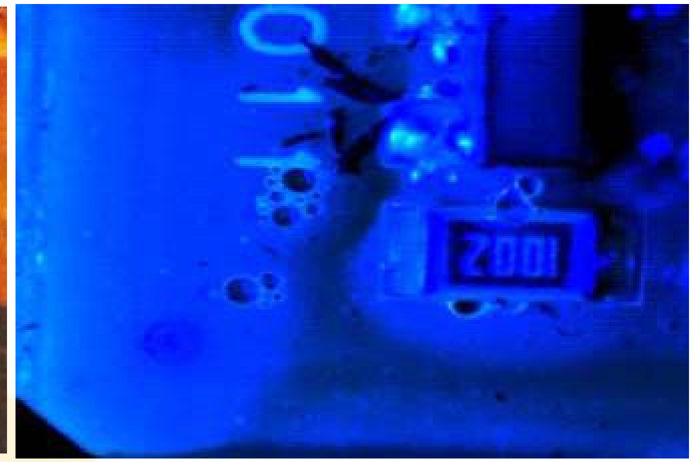
Coating Failures



Delamination



Migration under coating



Pores and delamination

Cleaning before Coating

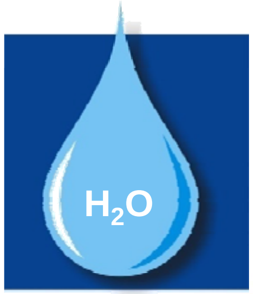
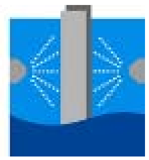
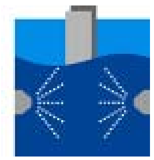
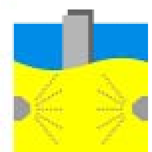
- Influencing factors
- Failure mechanisms
- Coating defects
- Cleaning before coating
- Analytics and test methods

Cleaning before Coating

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

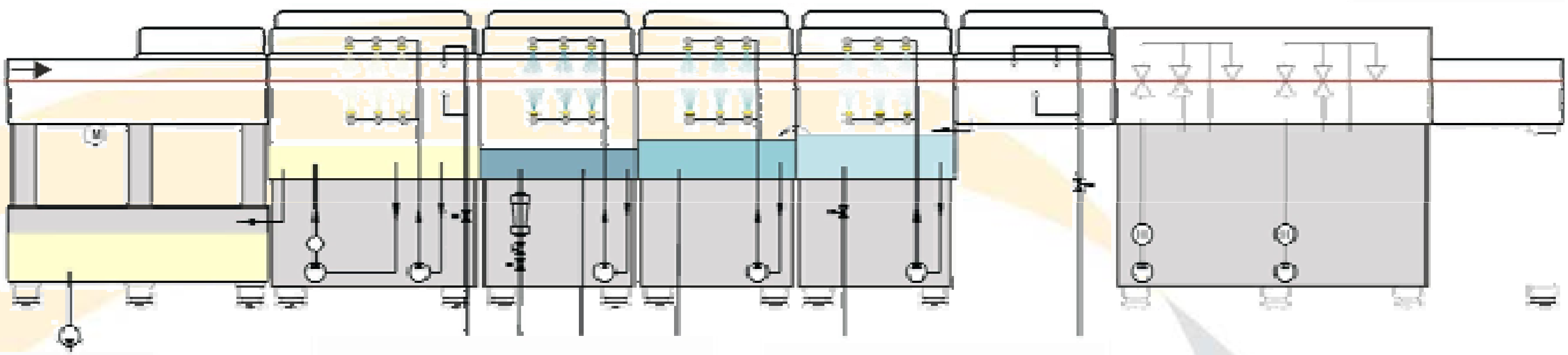
→ Reliable coatings require cleaning

Cleaning before Coating

	Aqueous cleaning	**Spray-In-Air**  **Ultrasonic**  **Spray-Under-Immersion** 
	Semi-aqueous cleaning	**Ultrasonic**  **Spray-Under-Immersion** 

Aqueous Spray-In-Air Inline Process

Process characteristics:
- High or medium throughput
- Spray pressure > 40 psi
- High space requirements

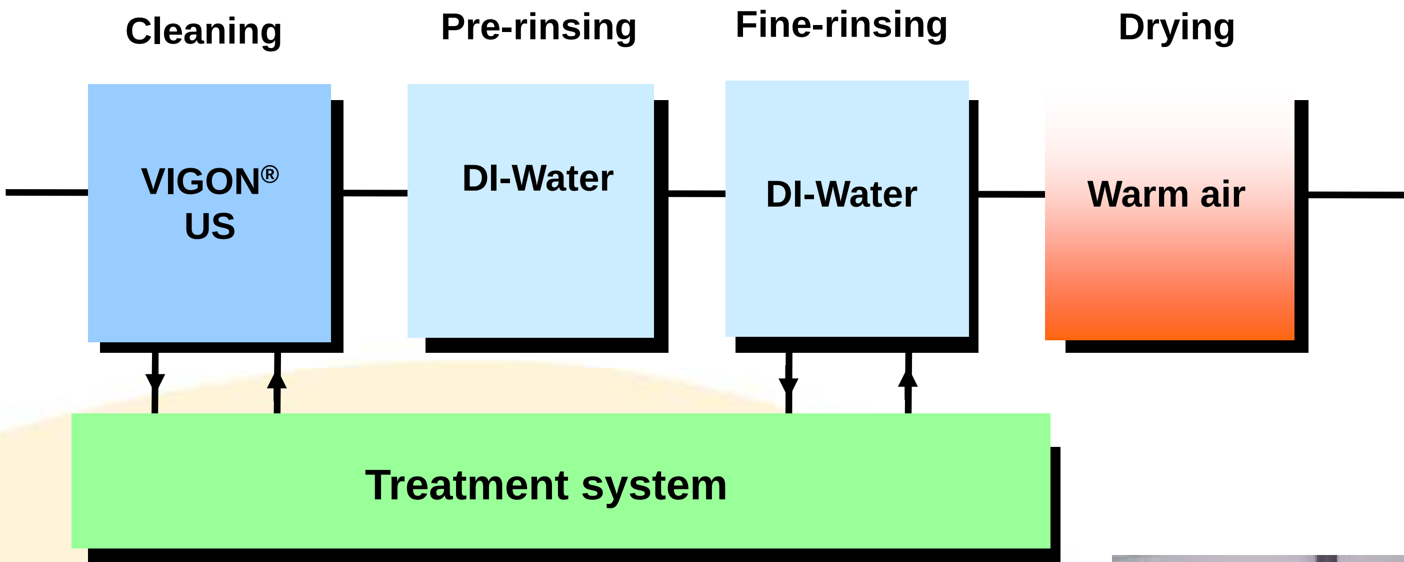


Cleaning

Rinsing

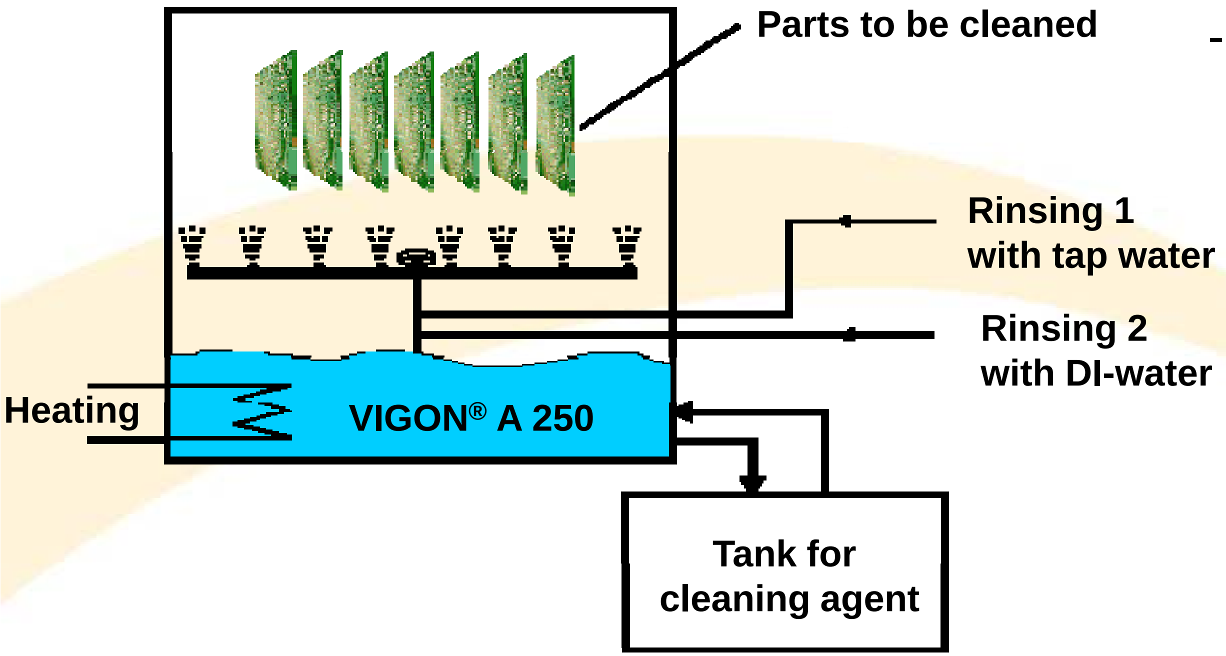
Drying

Water-based Multi Chamber



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

Aqueous Spray-In-Air Batch Process



Process characteristics:

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

Content

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- Failure mechanisms
- Coating defects
- Cleaning before coating
- Analytics and Test methods

Conditions for Reliable Coatings

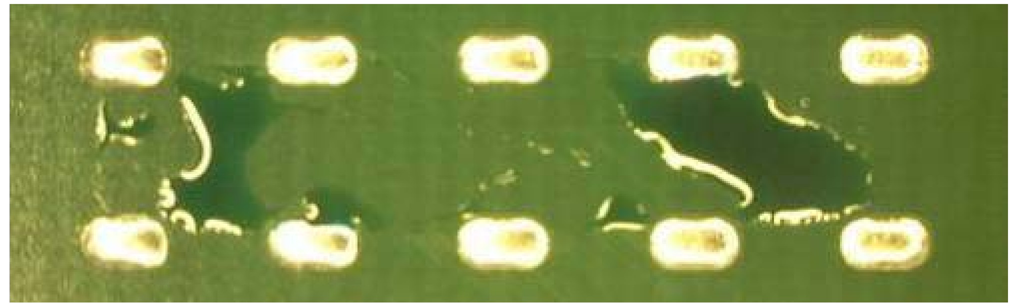
Cleanliness qualification before coating:

Test	Normal value	
Ionic contamination	< 0.4 $\mu g/cm^2$	✓
Surface tension	> 40 mN/m	✓
ZESTRON® Flux Test	Residue-free	✓
ZESTRON® Resin Test	Residue-free	✓
Crosslinking poisons: Sn …	Residue-free	✓

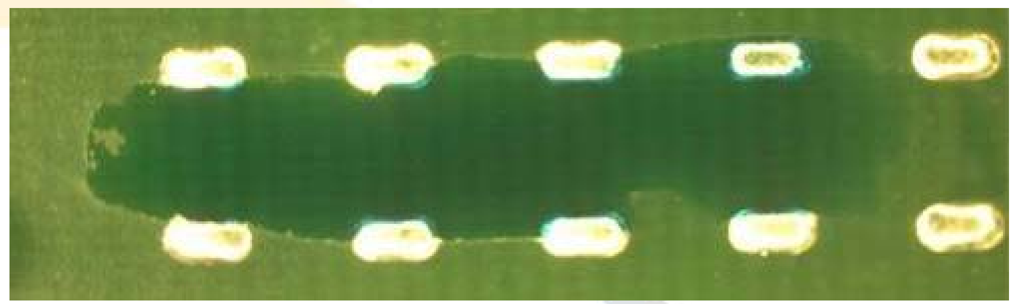
Test method – Ionic Contamination

Measurement with contaminometer

Wettability and Surface Cleanliness



Bad wettability = contaminated surface



Good wettability = clean surface

Test method – Ink Test

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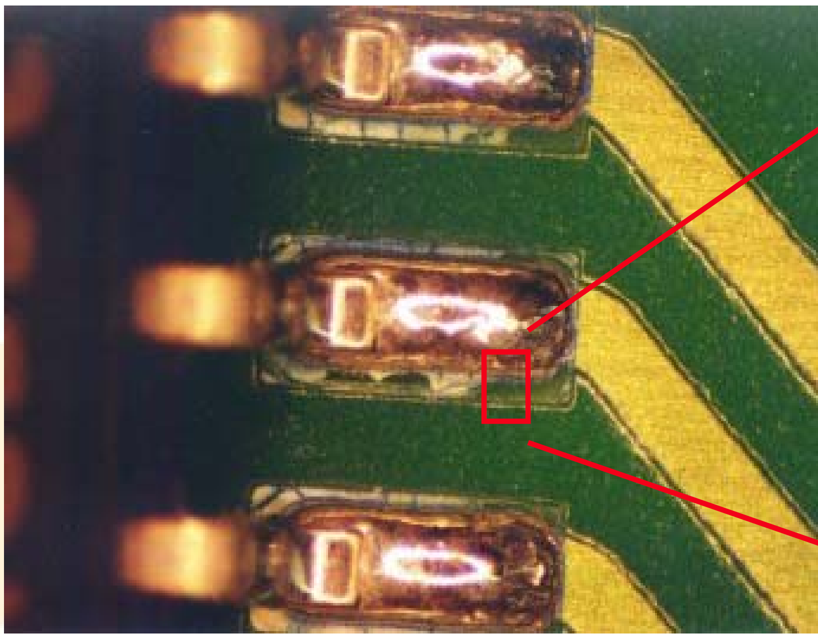
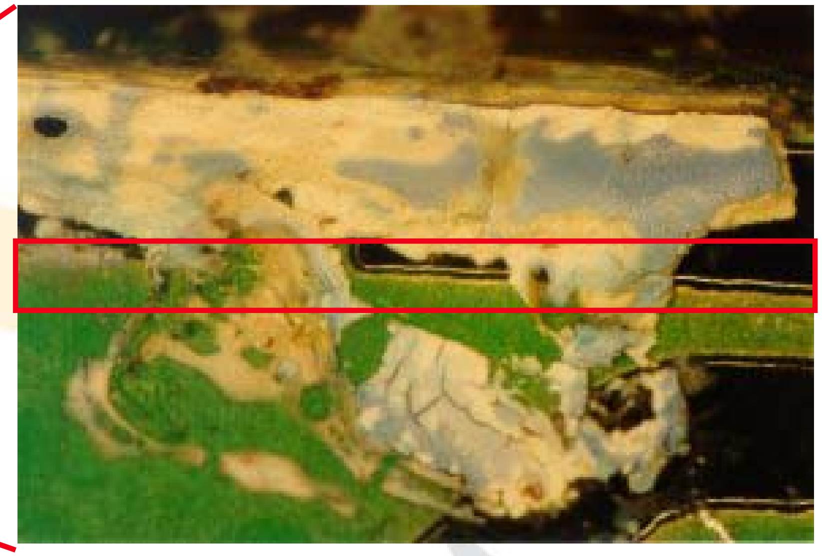
Results after ZESTRON® Flux Test

No encapsulation of organic activators in the rosin layer

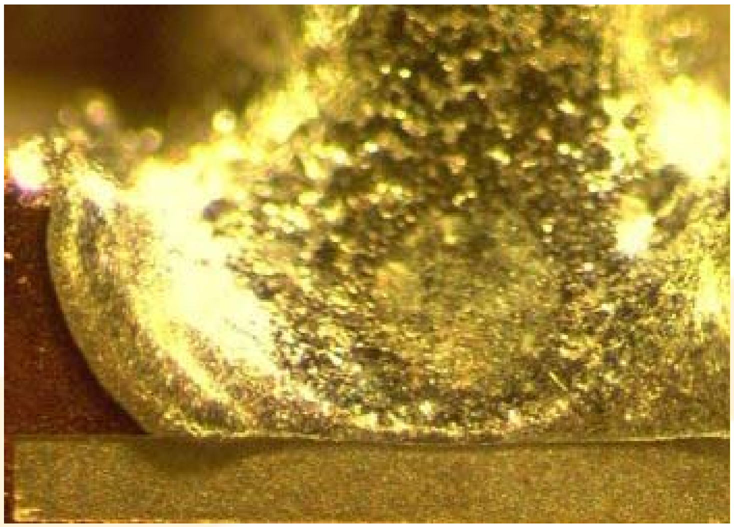




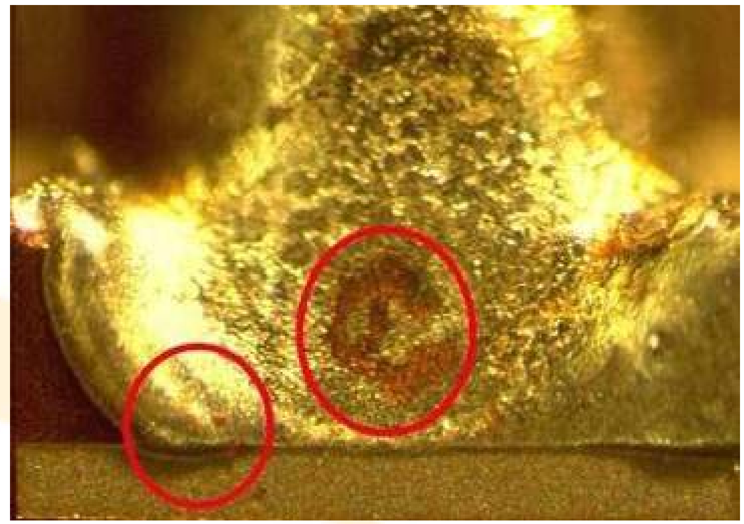
Rosin residues are not discolorating

Results after ZESTRON® Resin Test

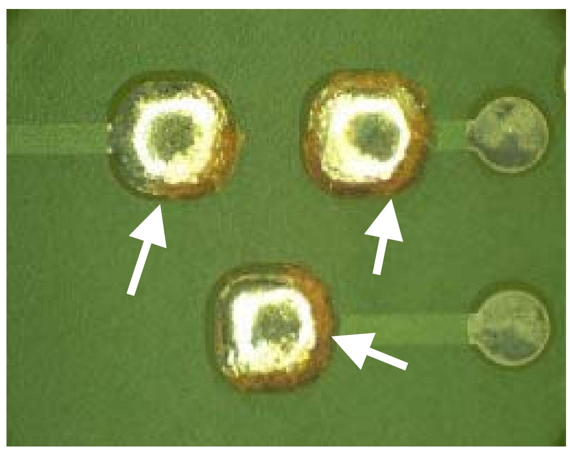
Discoloration of resin residues



Before

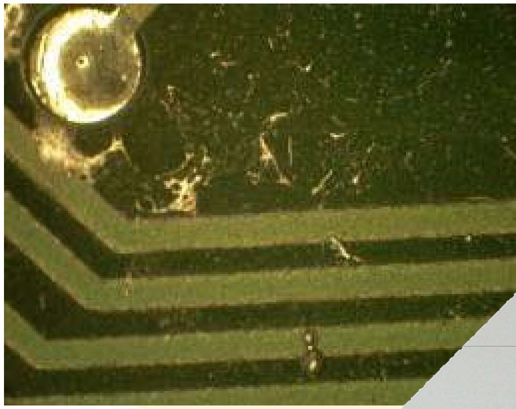


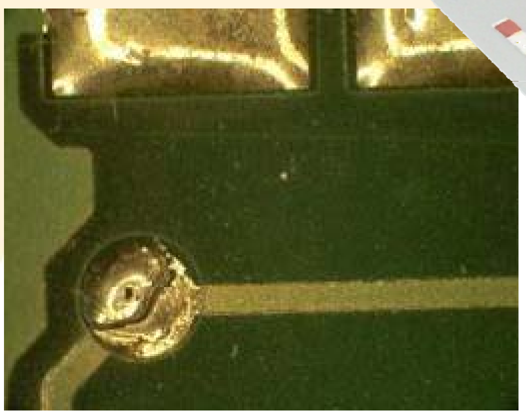
After



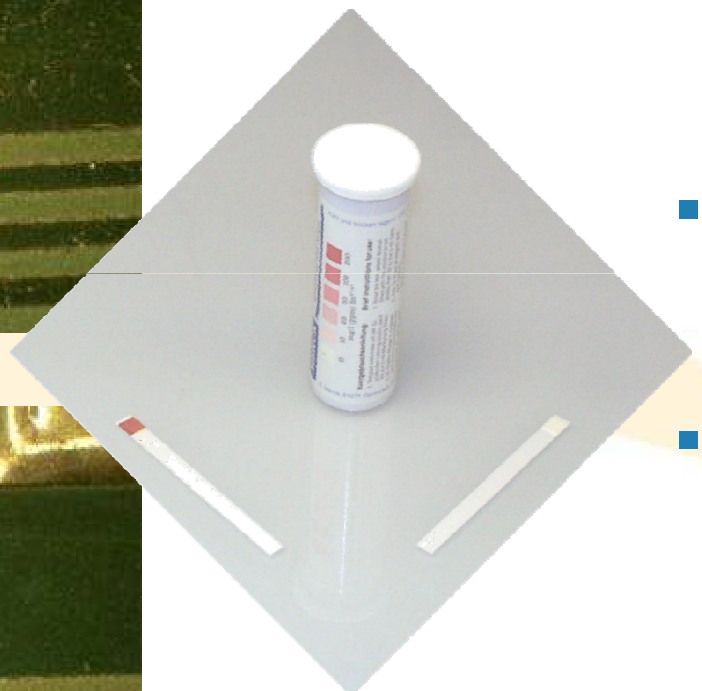
Test Method – Tin Test

Tin Test positive





Tin Test negative



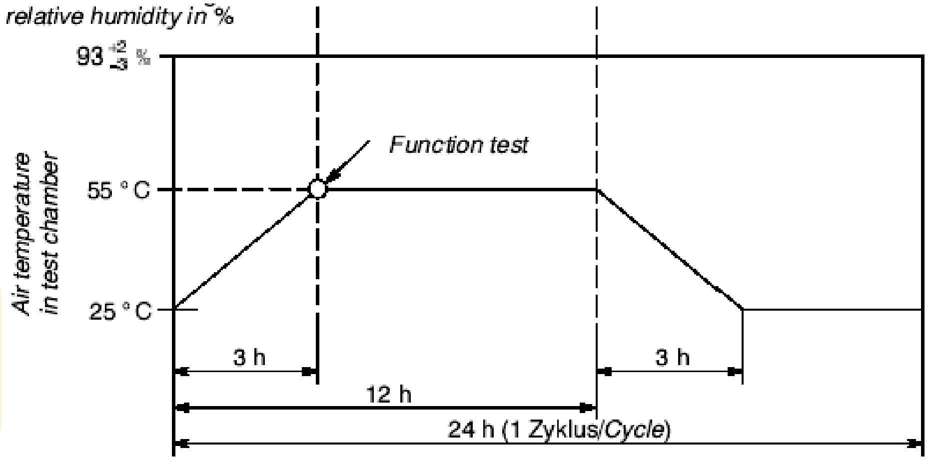
- Detection of tin components
- Based on color reaction

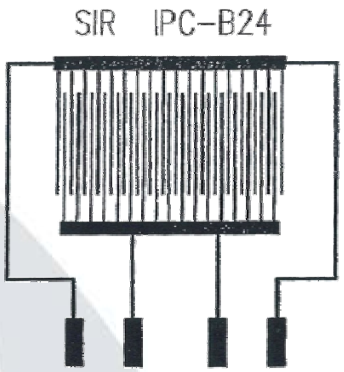
Coating Tests

Coating:

Test	
Climatic Reliability Test	
Coating Reliability Test	

Climatic Reliability Test

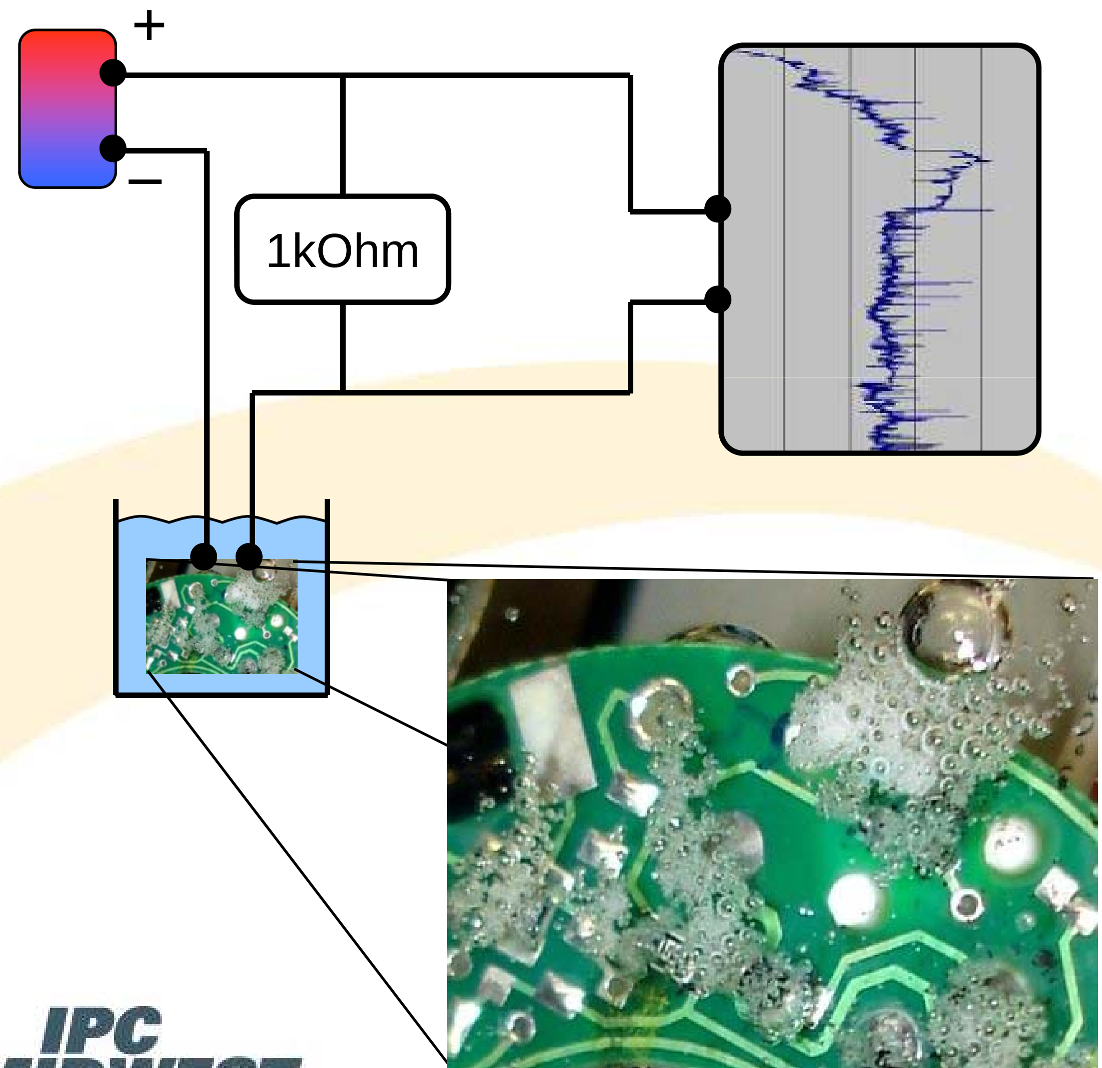




Test according to IEC 68-2
40ºC, 93% RH, 21 days

Simulates climatic conditions under influence of temperature

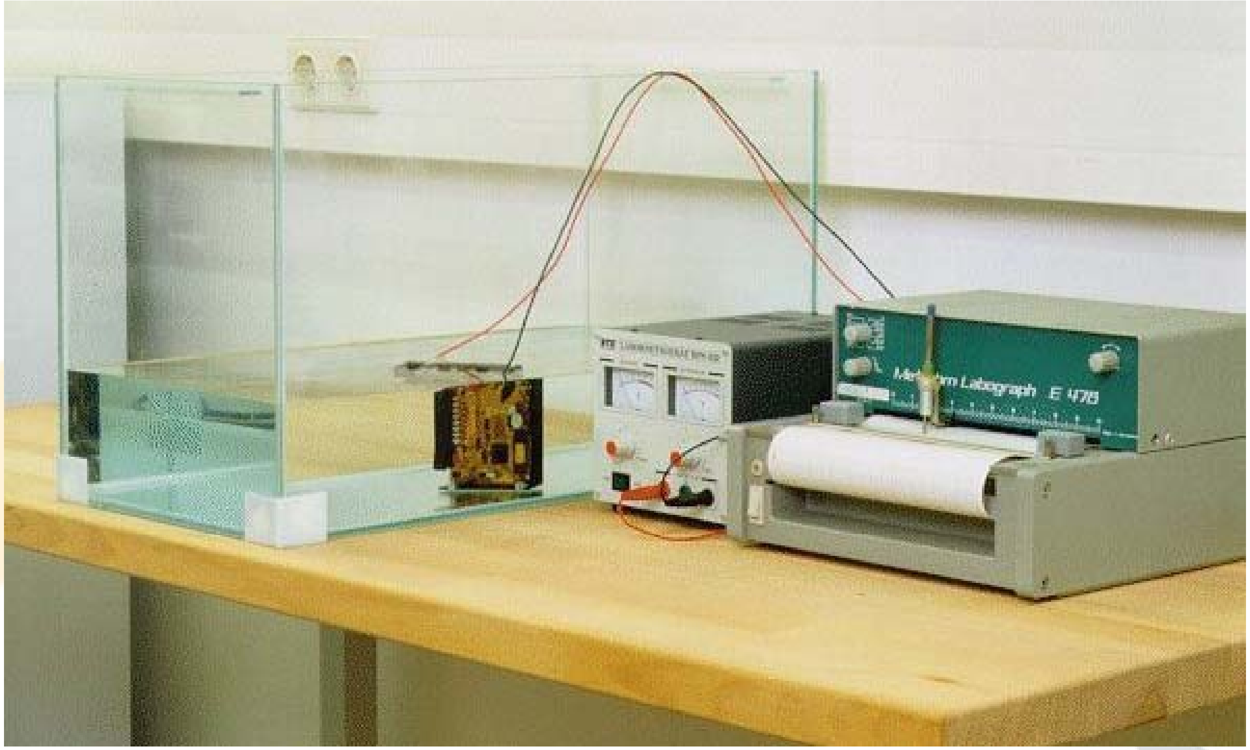
Coating Reliability Test



Coating Reliability Test (CoRe Test)

Gas Development at weak points

Coating Reliability Test

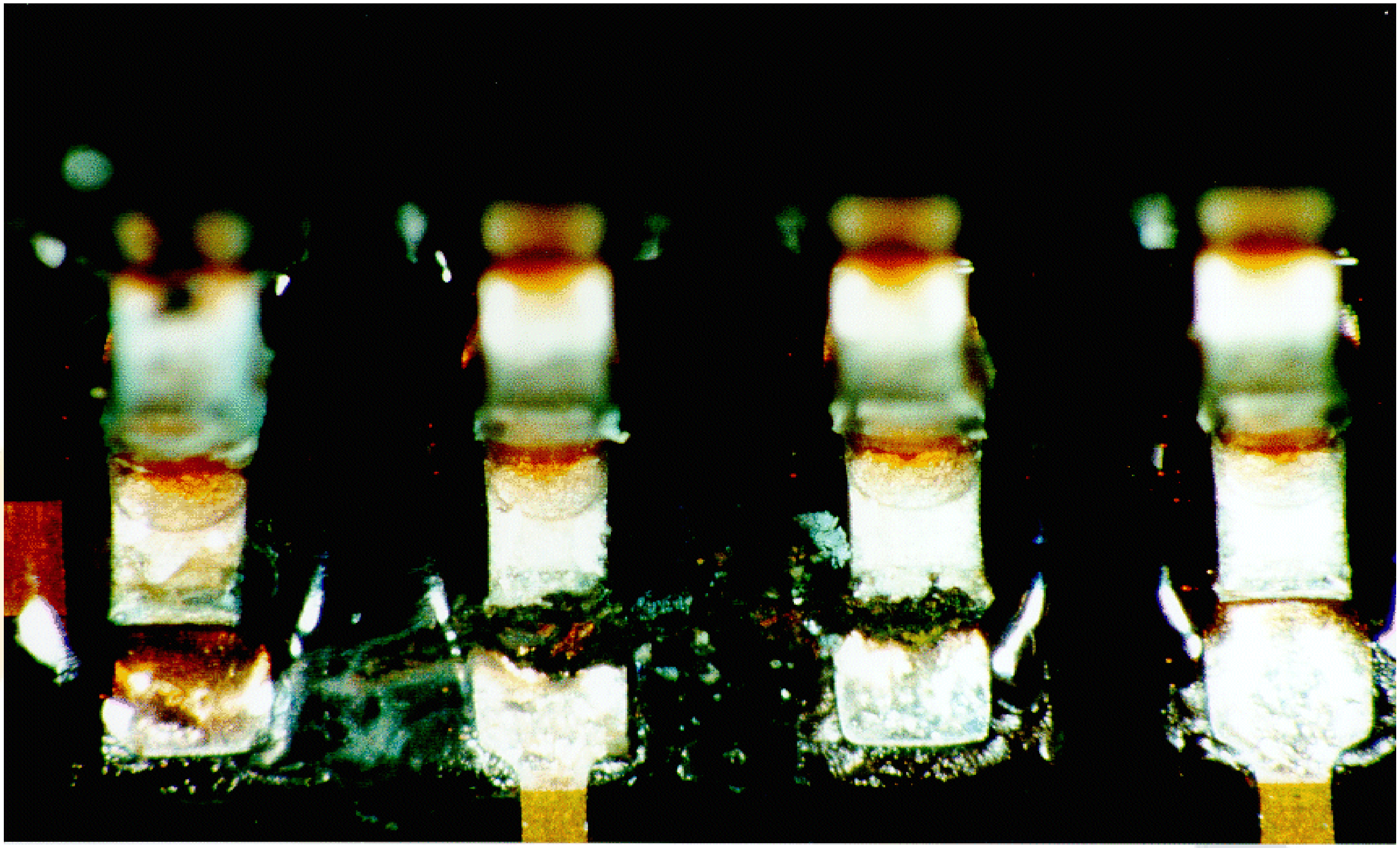


Coating Reliability Test

Test implementation:

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

Coating Reliability Test



Electrochemical migration based on delamination of protective coating

Coating Reliability Test

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

Coating Reliability Test

Answers to the following questions:

- Is climatic reliability endangered by remaining contamination?
- Is coating against humidity necessary?
- Is existing coating reliable against humidity?

Advantages of Coating Reliability Test

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

Conclusion

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