SERMA TECHNOLOGIES

Feedback From 10 years of Failure Analysis on connectors – all electronic sectors

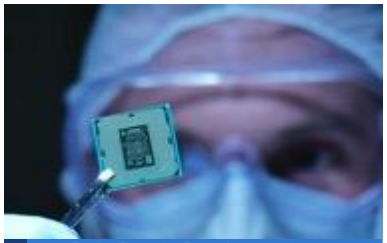
Cédric Favarel

SUMMARY

- Introduction
  - Serma Technologies from Serma Group
  - Failure analysis centre of competence
- Main defects on connectors from field return
  - Package defect
  - Electrochemical migration
  - Wear/Fretting corrosion
  - Pollution/contamination/corrosion
  - Poor electrical contact
  - Whiskers
  - …
- Partial discharge characterization
- Discussion

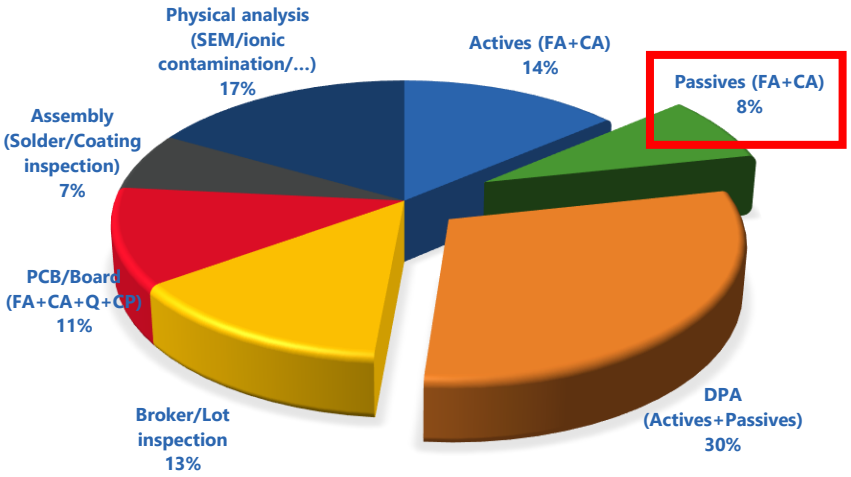
SERMA ELECTRONICS TECHNOLOGIES

SECURE YOUR FUTURE



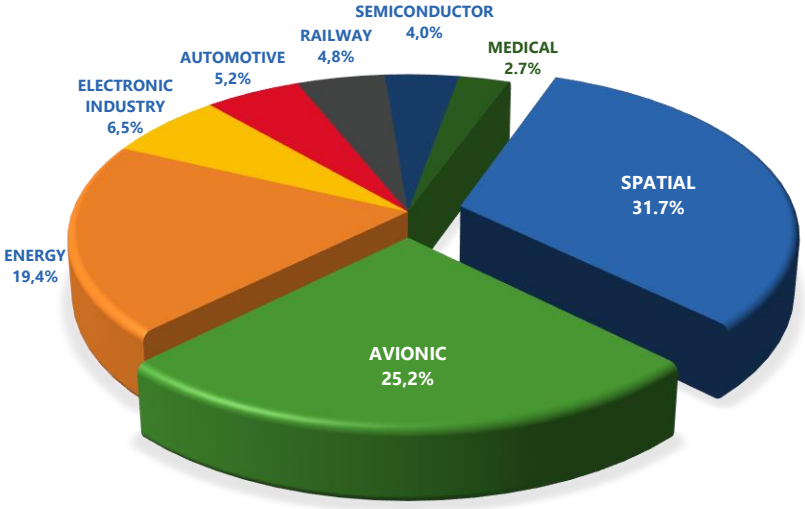
Expertise in Materials - physics and electrochemistry

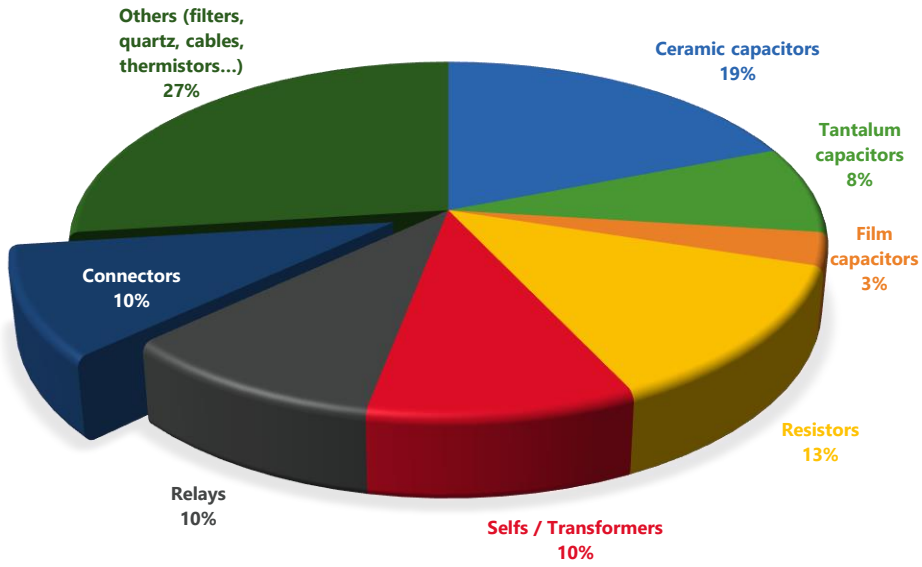
- Failure analysis
- Construction/Risk analysis - DPA
- Batch inspection and counterfeit detection
- Materials & Surface characterization (XPS, SIMS)
- Chips analyses: Si, SiC, GaN, (TEM, AFM)
- Battery



FAILURE ANALYSIS ON PASSIVE COMPONENTS

- Since 10 years: **> 5000** FA on passive components
  > 50% on spatial and avionic industry sector
  > 500 FA on connectors



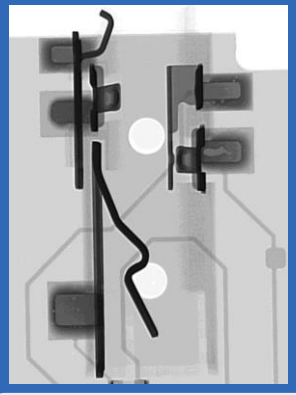


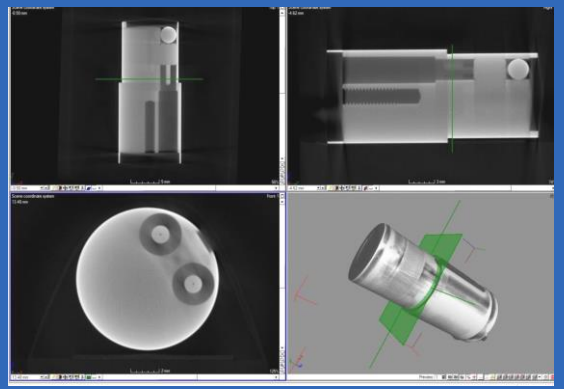
ANALYSIS TECHNIQUES

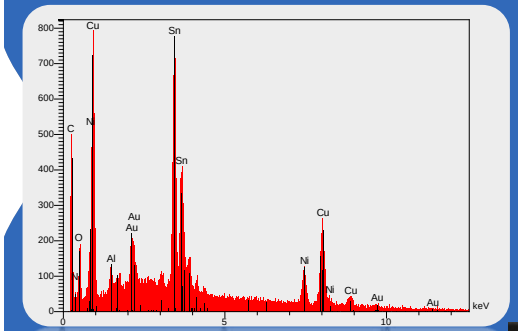
- **Non destructive steps:**
  - Optical inspection
  - X-rays inspection (2D/3D)
  - X-rays fluorescence
  - Scanning Electronic Microscope (SEM) / Material analysis EDX
  - Electrical test

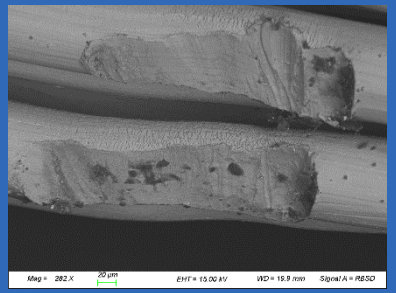
- **Destructive steps:**
  - Cross section
  - Mechanical/chemical opening
  - tensile test/insertion force

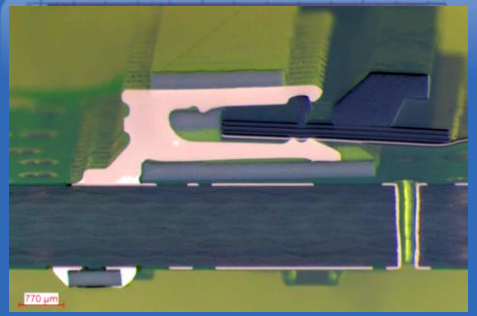
- Other particular analysis can be used: FTIR, Auger, IR Thermography…

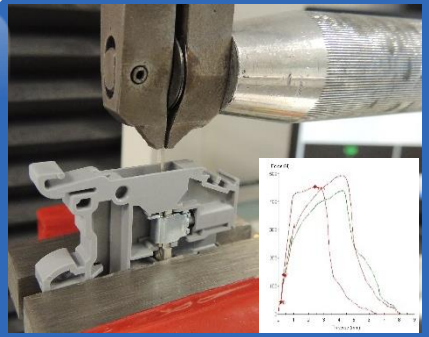




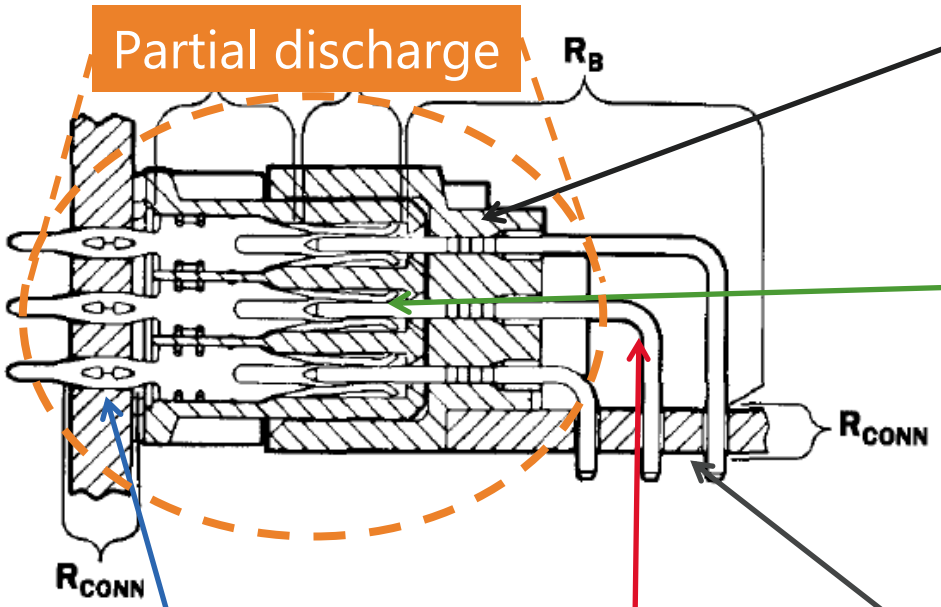








DEFECTS ON CONNECTORS



Package defect

Wear out

Freeting corrosion

Pollution

Poor contact

Press fit / PCB degradation

Tin whiskers

Metallic Migrations

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PACKAGE DEFECT

- The main defects observable on package are related to delamination or cracks:

→ path for humidity/contamination

→ possibility to make species migration under polarized conditions

- **Failure mechanism:**

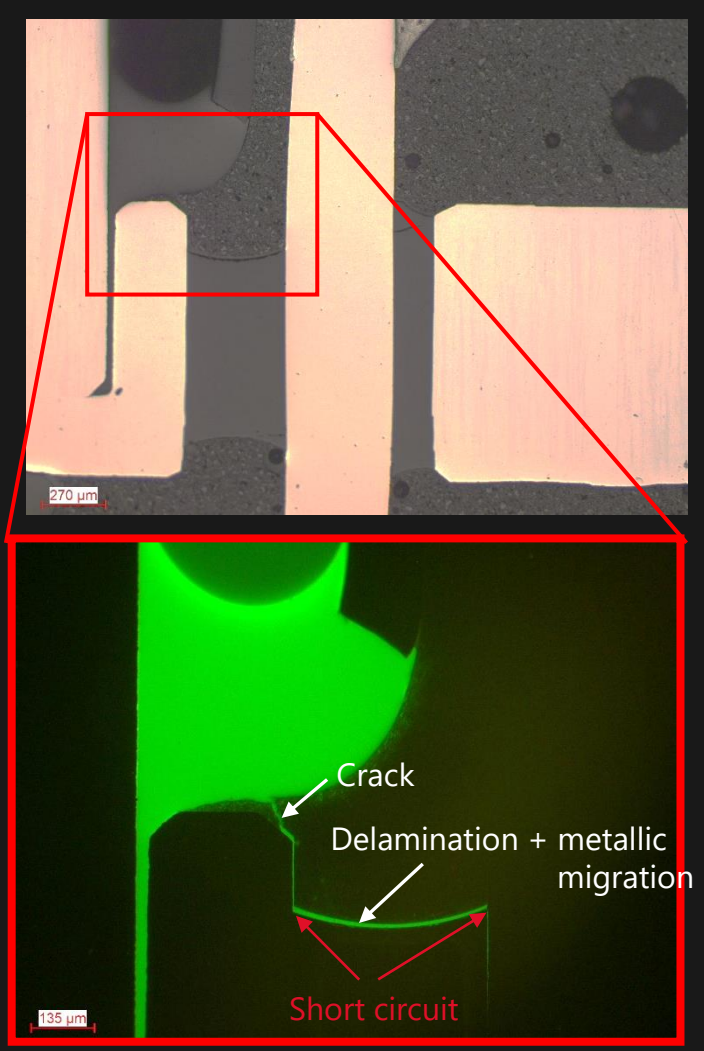
Leakage path, up to short circuit between leads.

- **Main cause:**

Initial parts weakness (design)

Assembly conditions (process)

Environmental stresses (humidity management/ reflow profile/ handling, thermal expansion…)



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ELECTROCHEMICAL MIGRATION (ECM)

- **Failure mechanism:**

Movement of metal ions between metallic conductors to form dendrites → Leading to current leak, insulation breakdown

- **Main cause:** design/environment

Moisture:

Few water is needed (condensation, relative humidity).

- Observed on copper, gold, tin, nickel, lead, palladium, solder.
- Not with metals that form protective oxide films (chromium, aluminum or tungsten)

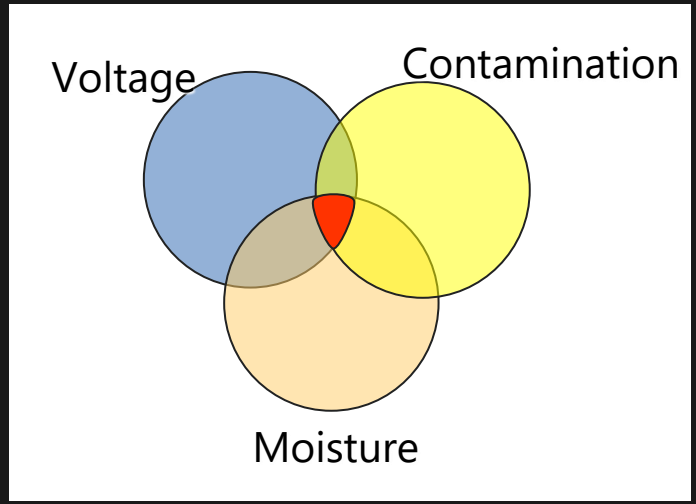
Contamination:

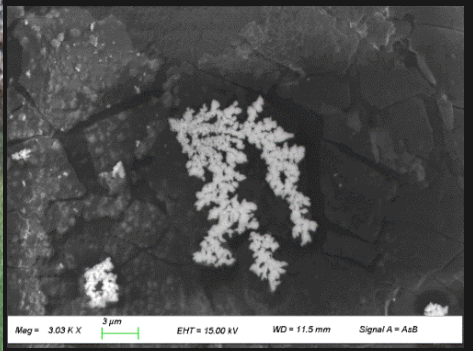
Change the conductivity of the water and attract water on to the insulating surface between the conductors (flux).

Voltage :

Low potential difference needed depending the distance between the conductors.

- Increasing factor: temperature.





WEAR OUT
FRETTING CORROSION

Fretting wear is generated by small-amplitude movement (few µm -100µm) leading to the formation of small debris particles

EDX analysis:
→Wear : no detection of oxygen element
→Freeting corrosion: clear presence of oxygen

► **Failure mechanism:** degradation of mating layer, increase the electrical contact resistance, hot spot, thermal runaway → intermittent or contact loss.

► **Main causes:** Process/environment

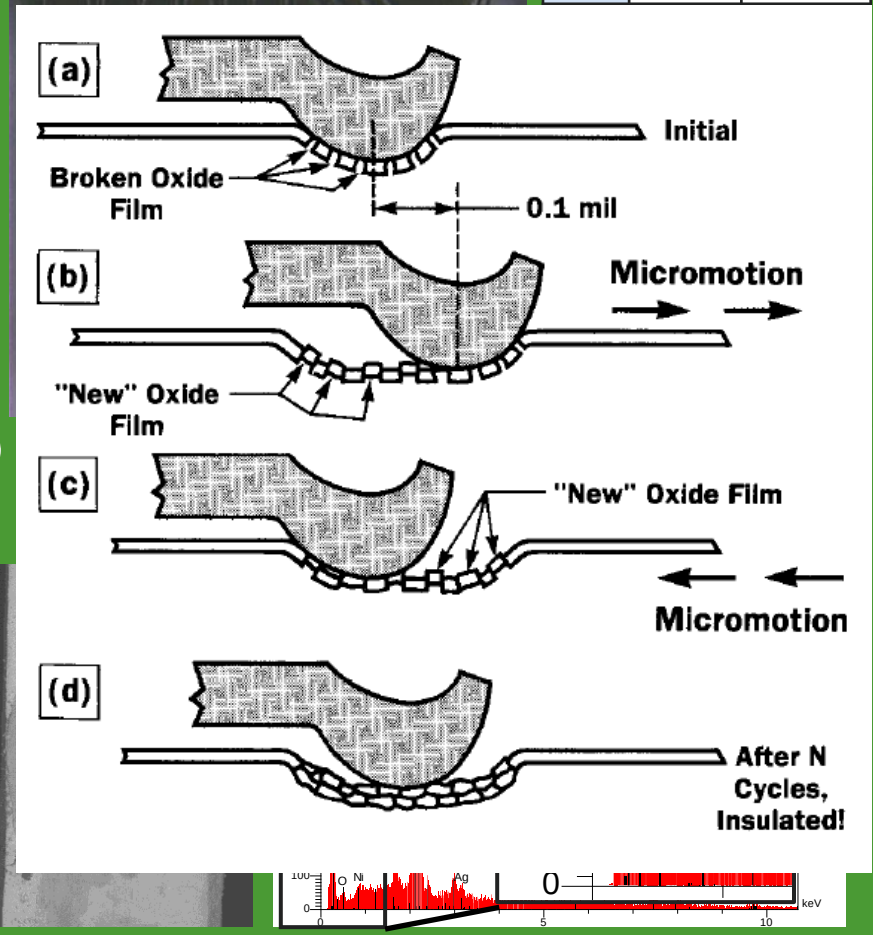
Vibrations and/or changing temperature due to differences in thermal expansion coefficients of the mating materials.

→ Choice of coating is particularly important

Gold coating

- ✓ Less susceptible to fretting degradation
- ✓ resistant to corrosive environment,
- ✓ require the use of underlayer (nickel)
- ✓ Thickness depending the application

	Au (µm)	NiP (µm)
1	0.08	5.29



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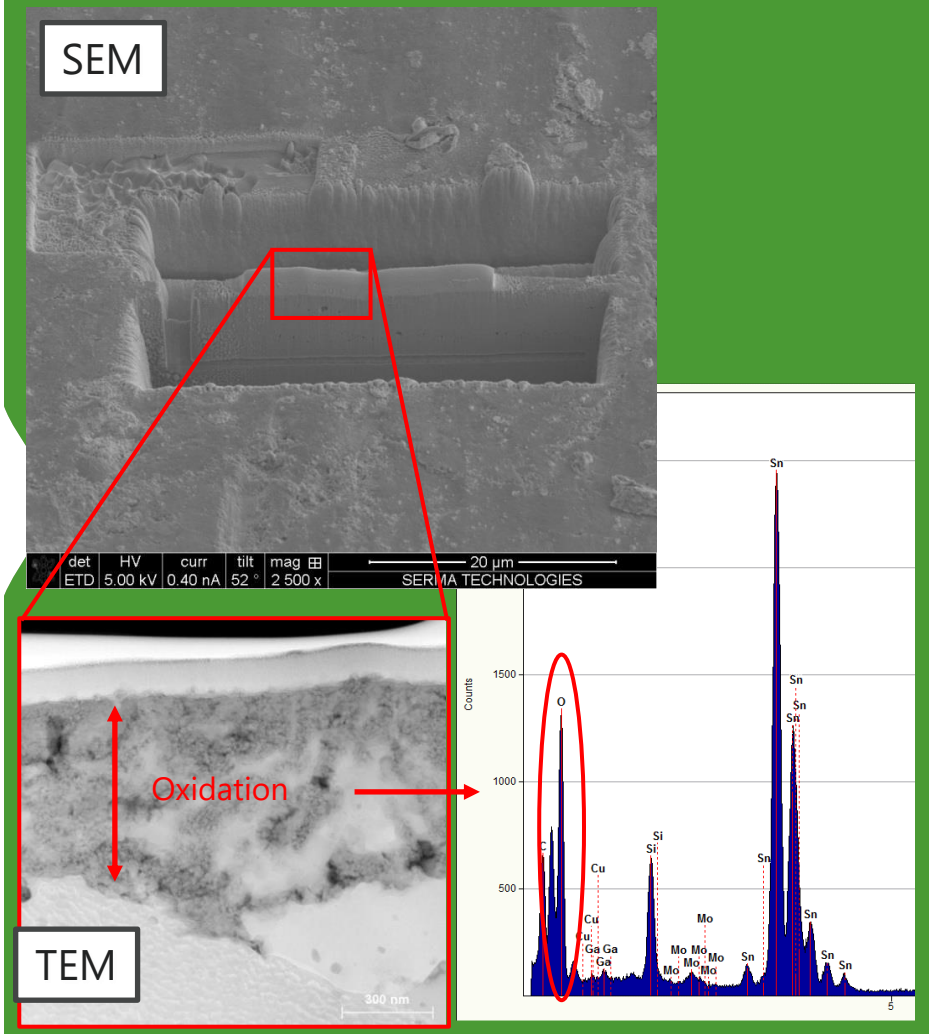


POLLUTION

► **Failure mechanism:**

Pollution make a direct insulating layer leading to an increase of the contact resistance.

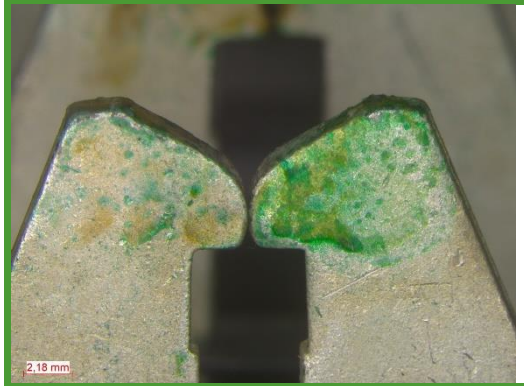
The phenomenon leads to the risk of intermittent or contact loss.

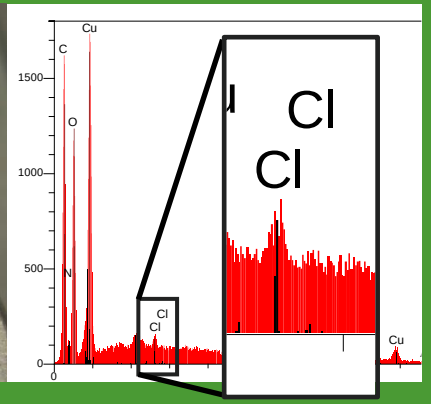
► **Main cause:** environment

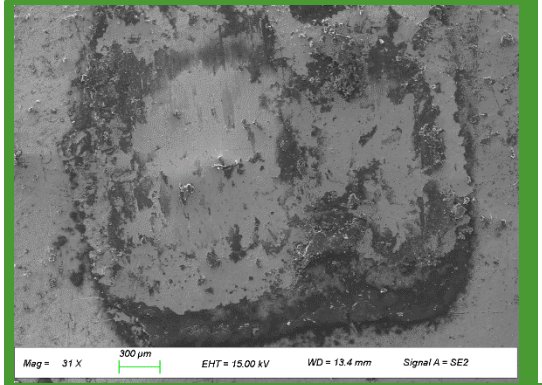
Pollution could mainly come from assembly process, or with external environment

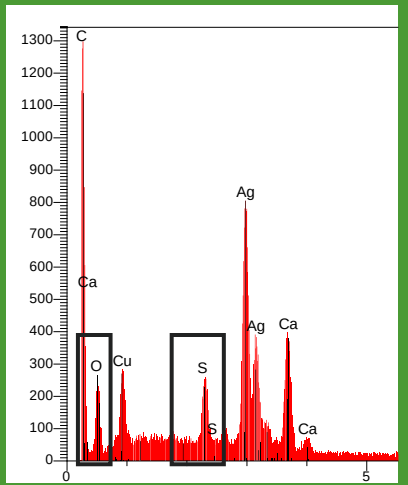
In presence of Cl_2, H_2S, NO_2 and SO_2 complex compound can appears

For example NaCl salts at the interface of contacts is conductive in water and insulating in its crystalline form.









POOR ELECTRICAL CONTACT

- Electrical connection is made through small asperities

- **Failure mechanism:**

Depending the type of coatings, material, shape and mating force:

→ only 1% of the apparent contact area is making contact.

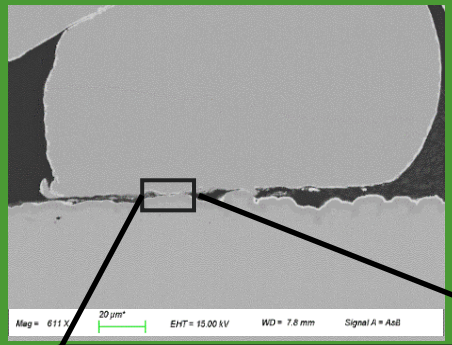
→ phenomenon of constriction resistance/film resistance occurs.

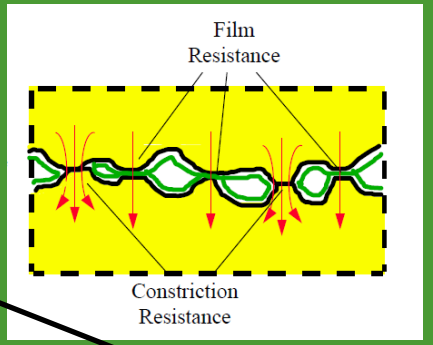
→ Increase the resistance can cause local heating, oxidation, fusion up to open mode.

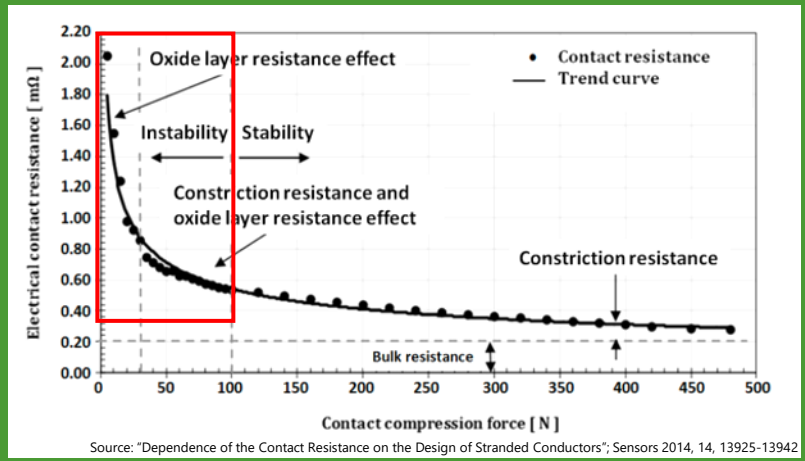
- **Main cause:** design/process

Too low contact force could lead to hot spot risk

- contact resistance is unstable,
- small change in force → large change in resistance.







Source: "Dependence of the Contact Resistance on the Design of Stranded Conductors"; Sensors 2014, 14, 13925-13942

PRESS FIT / PCB DEGRADATION

- **Failure mechanism:**

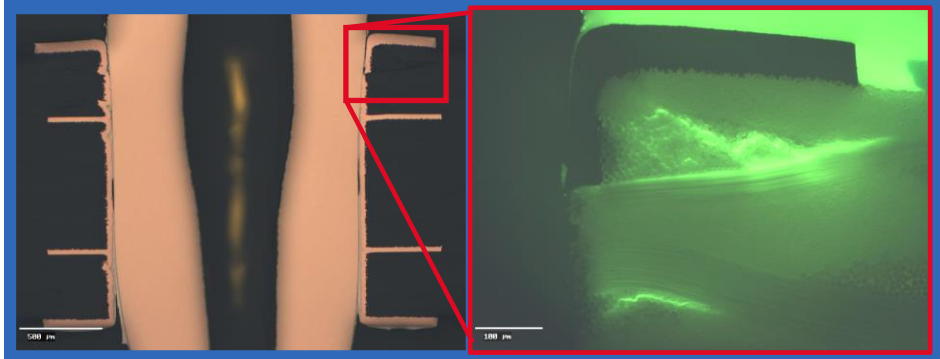
Deformation of the metallized via or internal layer during insertion

- Cracks/deformation of PCB
→ Lead to insulation breakdown/short circuit.

- Rupture of copper track
→ lead to open circuit

- **Main cause:** design/process

Dimensional mismatch pin/via diameter/pressure.



TIN WHISKERS

► **Failure mechanism:**

Whiskers grow across circuit connection up to > 200µm leading to sudden failure and intermittent short circuit.

► **Main cause:** design/environment

Mechanism not fully understood…

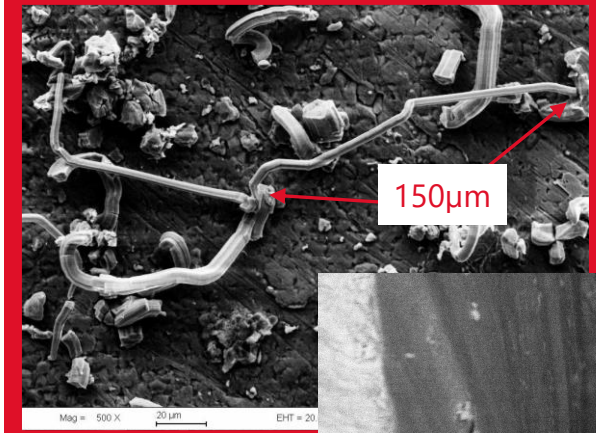
Main energy for growth may comes from microstrains or from externally applied pressure.

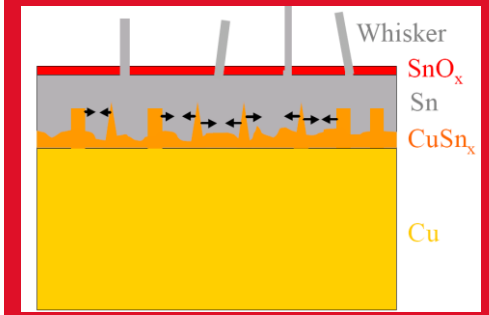
Avoid or control whiskers apparition:

→ Tin alloy with a minimum of 3% of Lead

(Specification : ESCC No 25500 / MIL-STD 1580)

→ « reflow »: tin heated to a T°C above tin melting point





PARTIAL DISCHARGE CHARACTERIZATION

► **Objective:**

Detect insulation defect

Diagnostic tools increasingly used in R&D lab and industry

► **Definition:**

Localized electrical discharge that does not completely pass through an insulator (device remains functional).

Discharge limited because:

→ the local electric field is not sufficient to cause its total propagation

→ the propagation is blocked by an insulator whose breakdown field is higher

► **Failure mechanism:**

Time dependant failure.

Partial discharges lead to a degradation of materials under the action of constraints (thermal, chemical, mechanical) over time.

When the insulating material is too damaged, a complete electric arc occurs → component failure.

→ Partial discharge threshold tend to decrease under low pressure environment

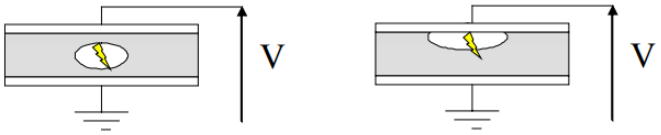
Main defect:

► **Internal discharges**

Inside the insulator:

→ bubble, particle…

→ dielectric strength locally reduced

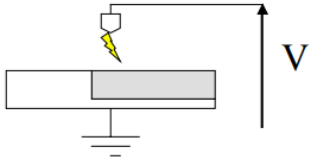


► **Corona effect**

Appears at the corners of materials under an electric field:

→ point effect

→ ionization of the surrounding air near its corners

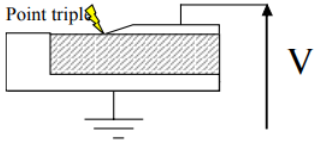


► **Surface discharge**

Generated at the "triple" point metal/insulator/air :

→ drop of water, pollution, dust…, present on the surface of the insulator.

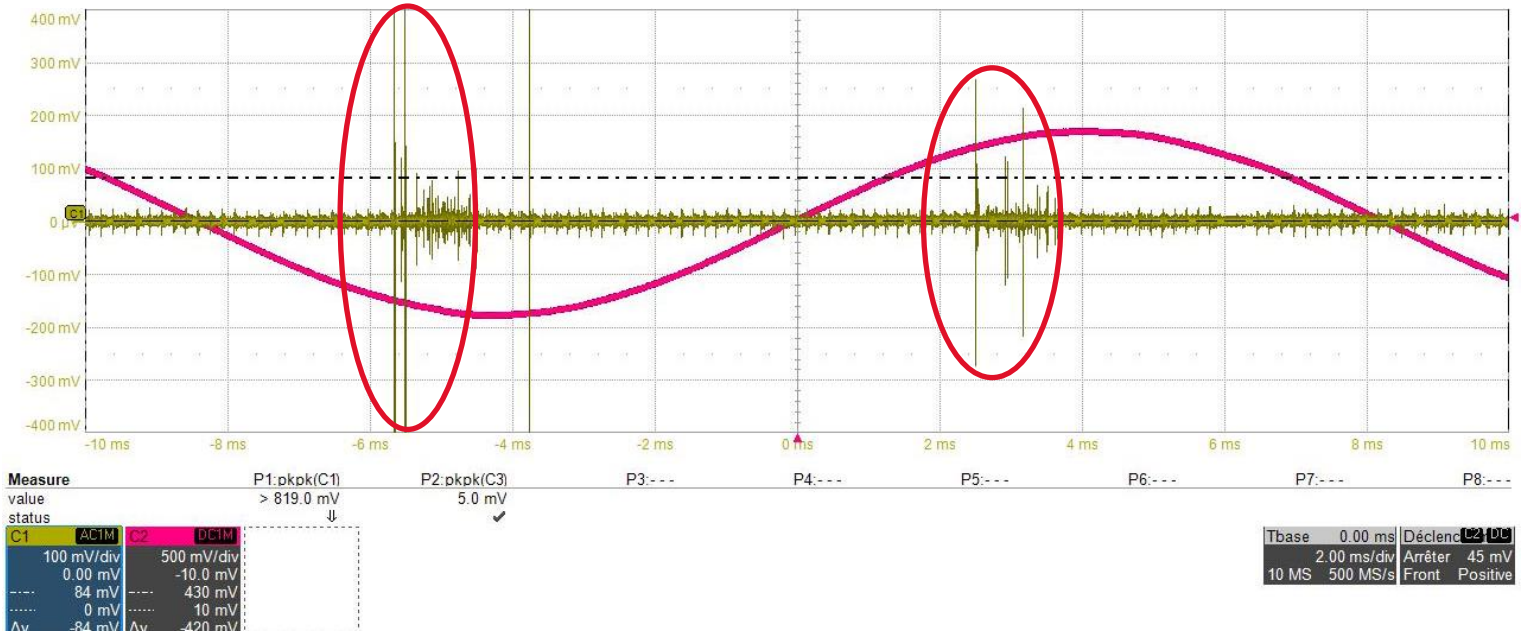
Early problems of insulation degradation often linked to the presence of water



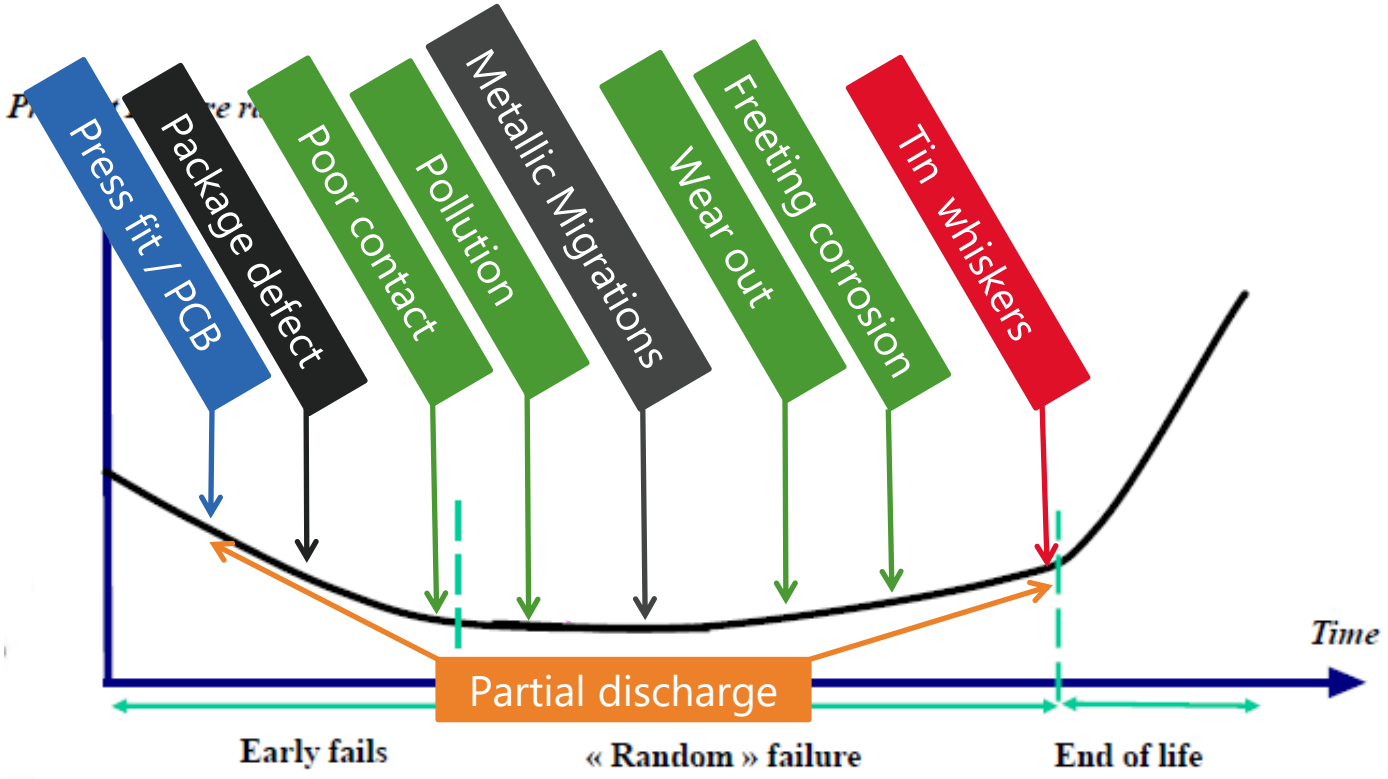
→ **Non destructive test particularly interesting during preliminary inspection process for FA**

- Depending on the position and the level of discharge observed

  → Possibility to localize and identify the first hypothesis of defect



DEFECT APPARITION IN CONNECTOR LIFE



THANK YOU FOR YOUR ATTENTION

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Table of acronyms and abbreviations

- SEM: Scanning Electron Microscopy
- TEM: Transmission Electron Microscopy
- EDX/EDS: Energy dispersive X-ray Spectrometry
- FA: Failure Analysis
- CA: Construction Analysis
- DPA: Destructive Physical Analysis
- FTIR: Fourier-Transform Infrared Spectroscopy
- PCB: Printed Circuit Board
- ECM: Electro Chemical migration