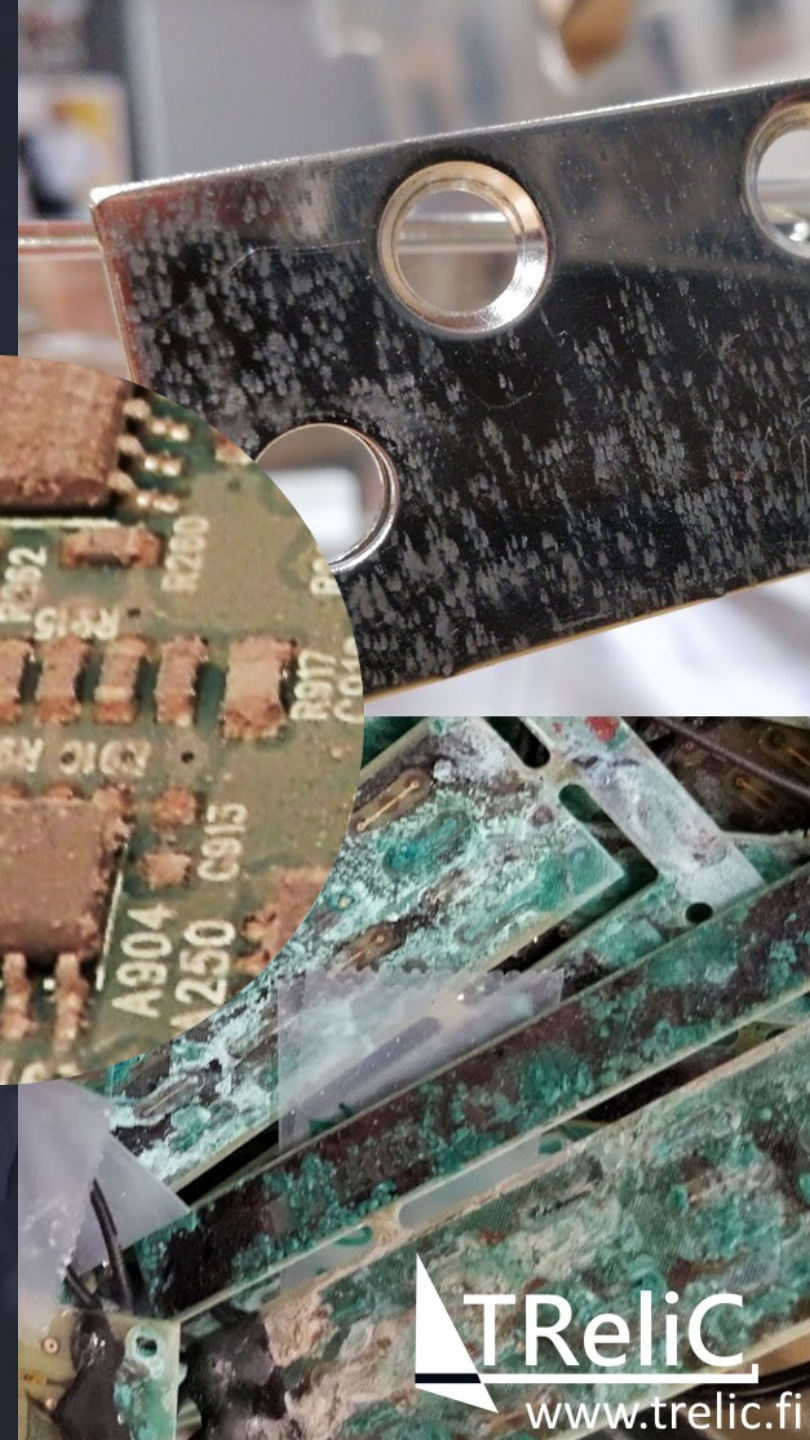
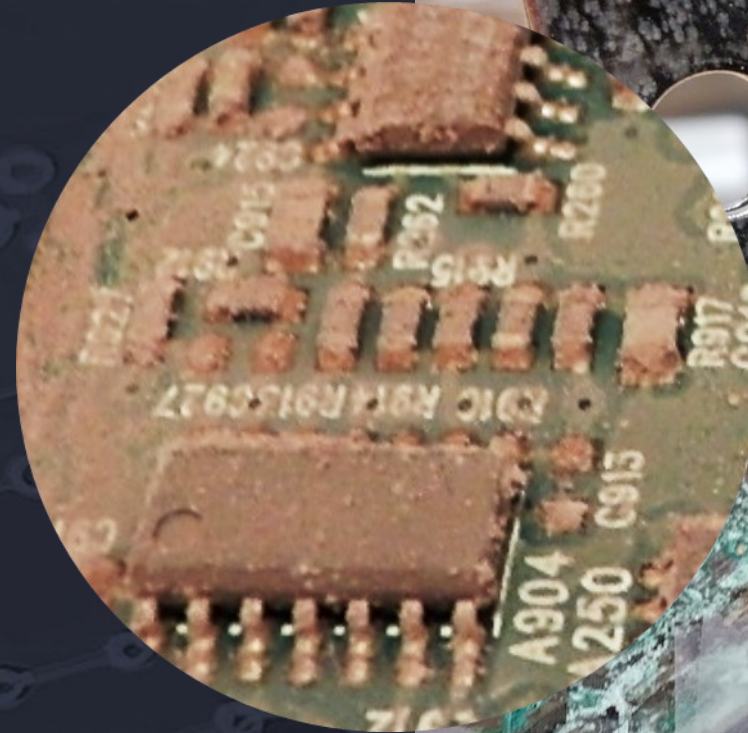


Comparison between mixed flowing gas and flowcells of sulphur corrosion testing

Laura Frisk, CEO, Trelic Oy

Outline

1. Introduction
2. Corrosion testing
 - Mixed flowing gas (MFG) testing
 - Flowers of Sulphur (FoS) testing
3. Analysing corrosive environments
4. Example of MFG and FoS tests
5. Conclusions



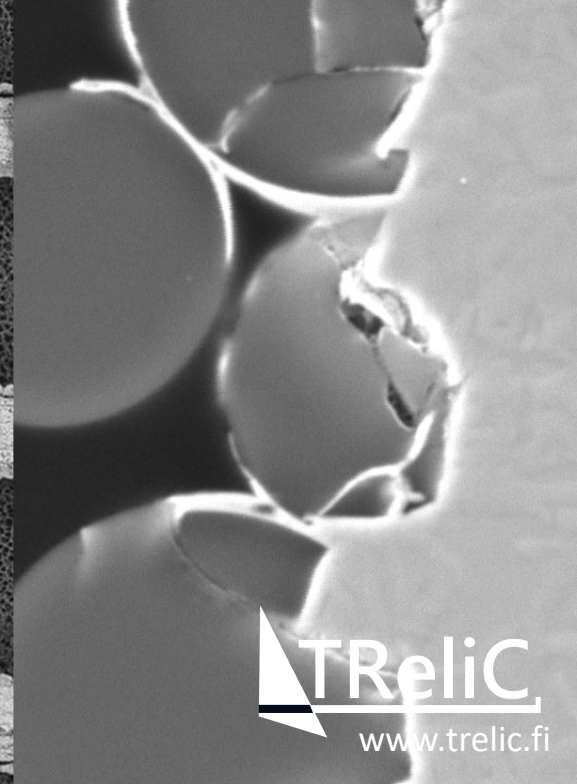
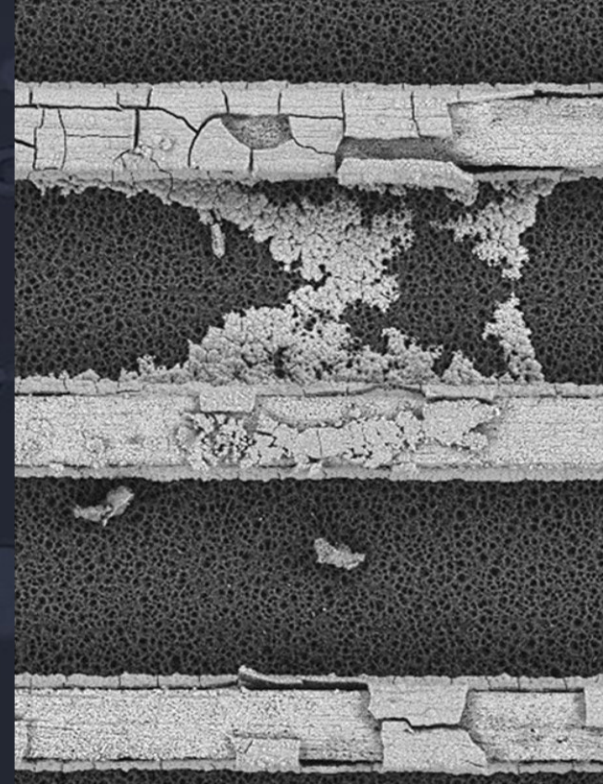
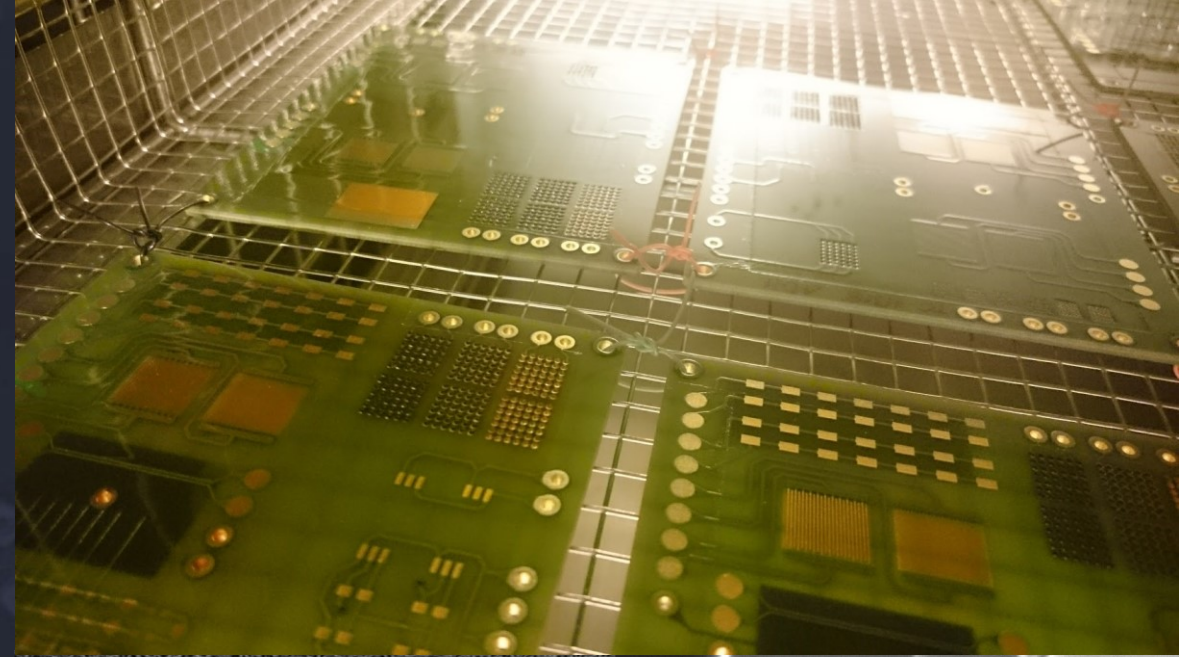
Trelic Ltd

**Consultation and experimental work
for reliability analysis and materials**

Specialised in electronics and electrical
engineering

Wide range of services and analysis techniques

In-depth knowledge from academic research
combined with strong background from
industrial projects



Trelic Ltd - Services

Reliability analysis

- Thermal testing
- Humidity testing
- Corrosion testing
- Mechanical testing
- Combinatory testing
- Data logging and analysis of electrical properties

Failure analysis

- Cross-sectioning
- Structural analysis
- SEM, SAM and optical microscopes
- Corrosion analysis

Material analysis

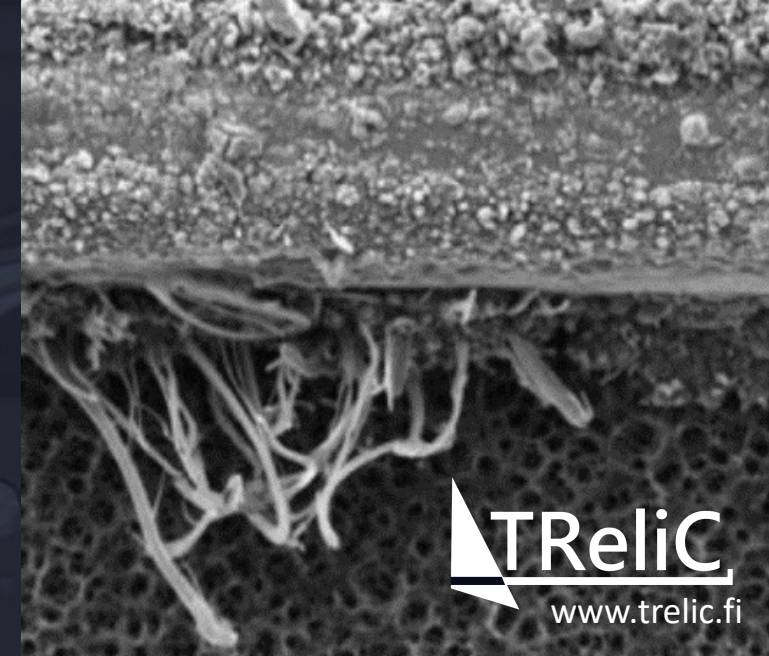
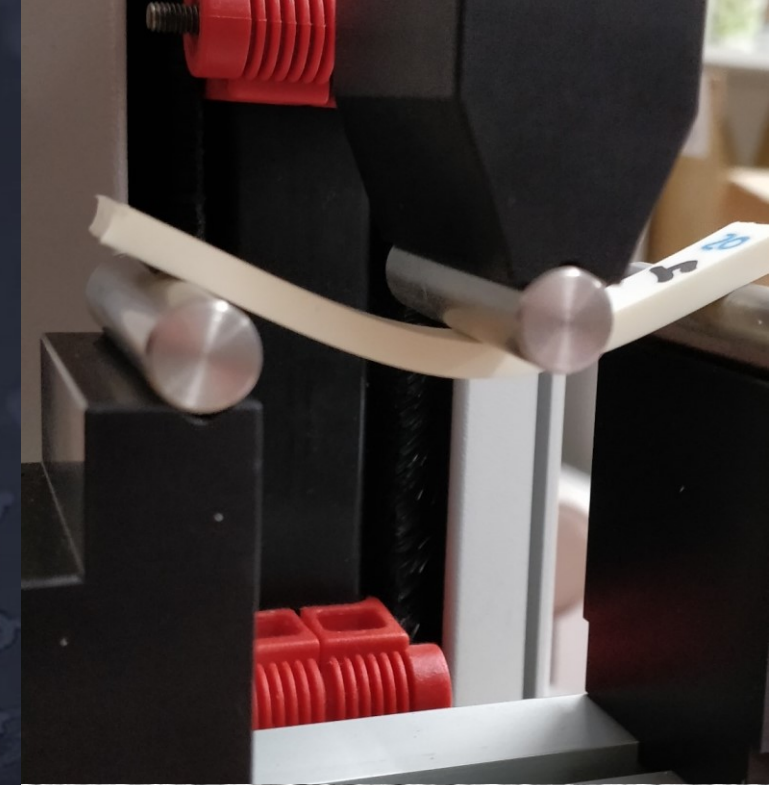
- Mechanical properties
- Thermal properties
- Chemical properties
- Long term behaviour

Electronics assembly

- Interconnections
- Flex and stretch structures
- Small scale manufacturing and prototyping

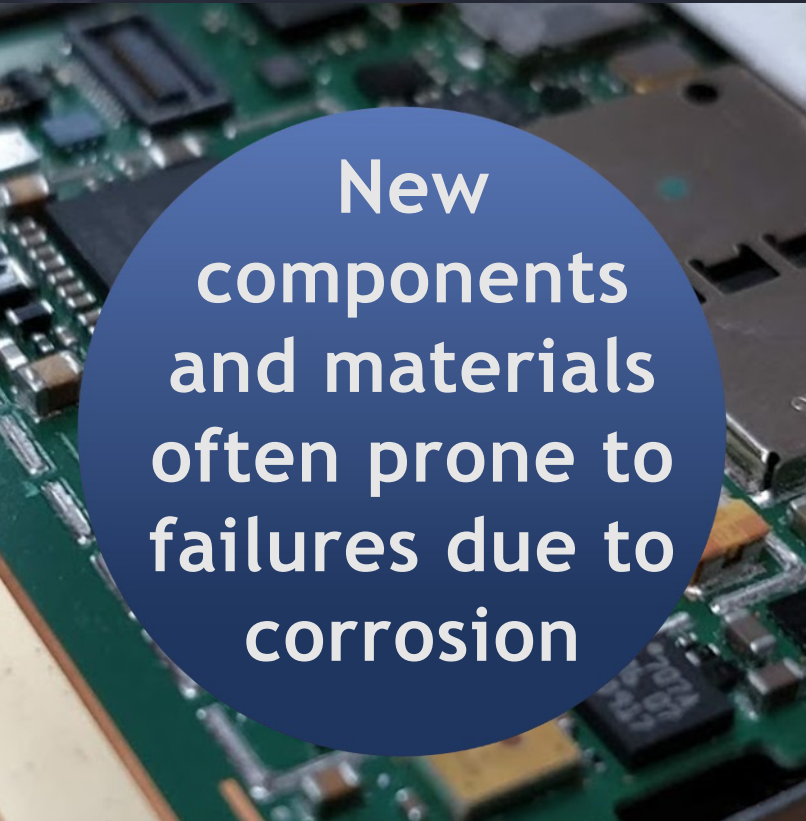
Statistical analysis

- Analysis of test data
- Prediction of use life




Corrosion in electronics

- **Major cause for failures in electronics**
- Becoming more and more critical for reliability



New components and materials often prone to failures due to corrosion



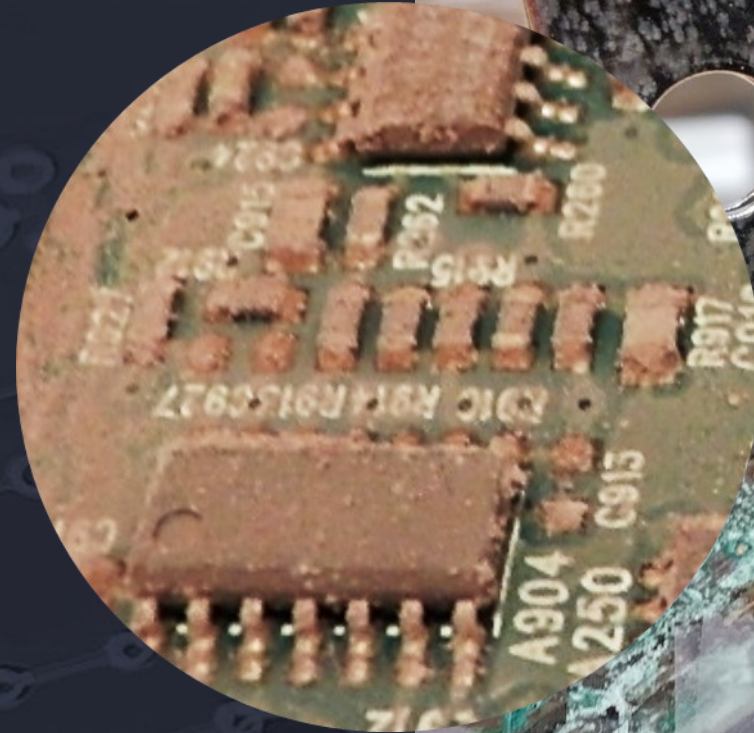
Areas with high level of air pollution, salt and dust



New demanding industrial environments

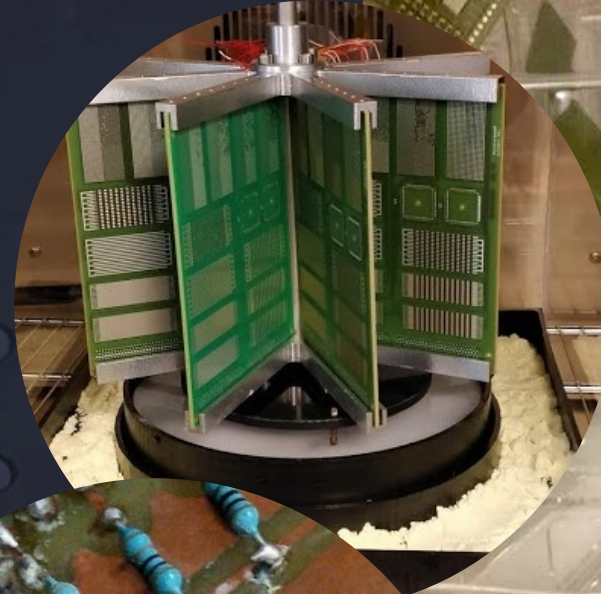
Outline

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2. **Corrosion testing**
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Corrosion testing

- Several test methods in use
- **The relation between test and use conditions is not known**
- Corrosion processes are very complex
 - ✓ Difficult to replicate and model
 - ✓ Lots of different factors cause and accelerate corrosion



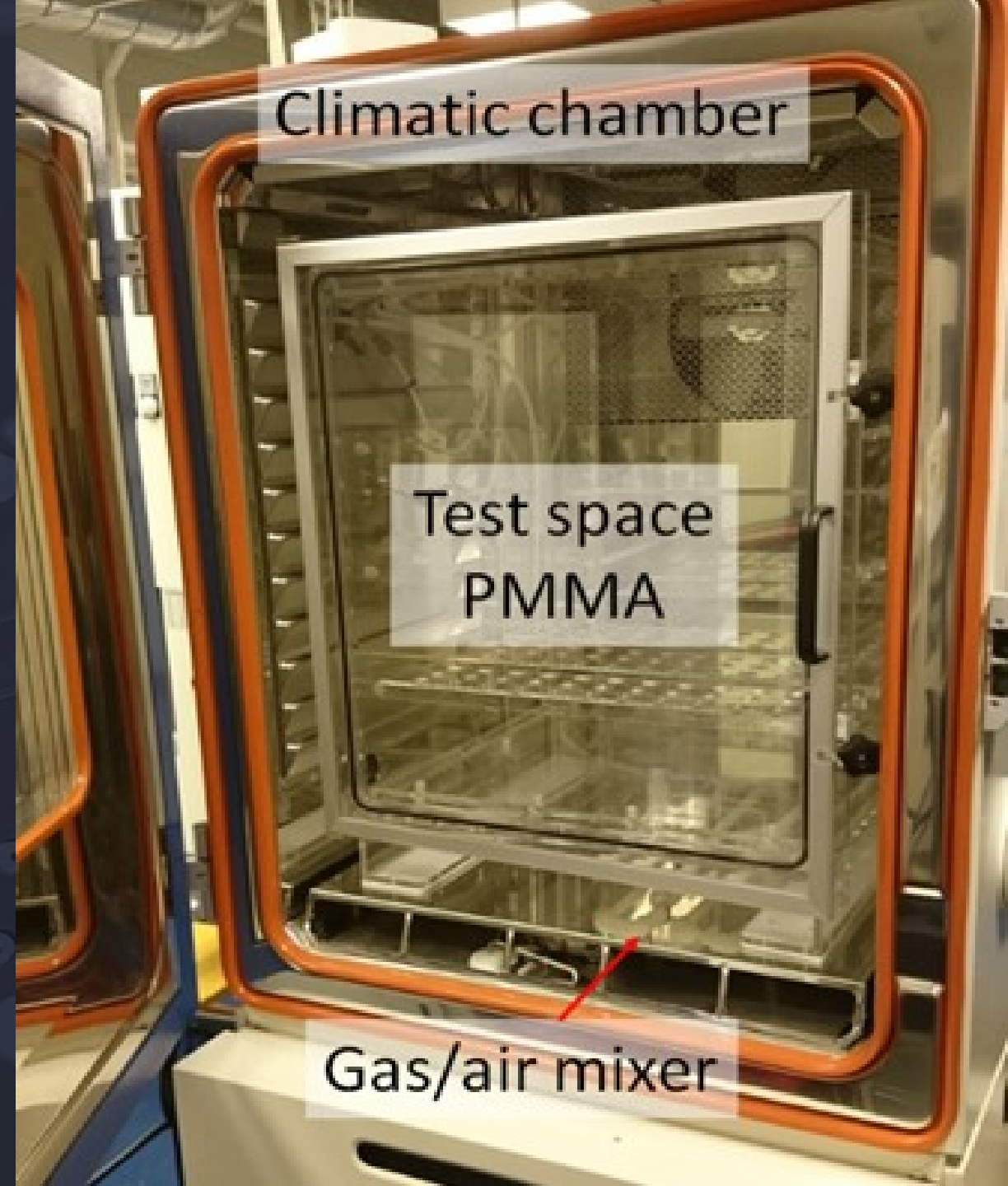
Typical test methods

- **Mixed flowing gas (MFG) testing**
- Salt spray testing
- **Flowers of Sulphur (FoS) testing**
- Dust testing
- Humidity testing
 - Constant temperature and humidity testing
 - Humidity cycling testing
 - Condensing testing
- Combinations of different test methods



Mixed flowing gas (MFG) test

- Several corrosive gases used together
- Can be used with a wide range of different gases
- The environmental conditions within the chamber controlled
 - Relative humidity
 - Temperature



Mixed flowing gas (MFG) test

- Our chamber:

- Maximum gas concentrations

- **Hydrogen sulfide**, H₂S: 25ppm
 - **Sulphur dioxide**, SO₂: 25ppm
 - **Nitrogen dioxide**, NO₂: 25ppm
 - **Chlorine**, Cl₂: 1ppm

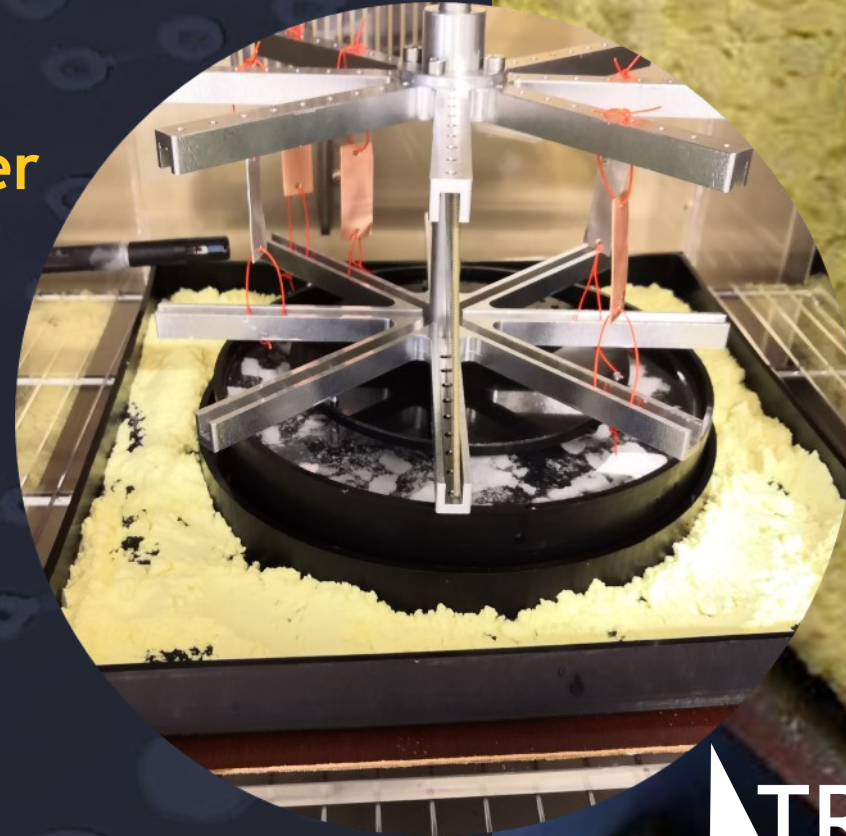
- Temperature range: +15°C - +60°C

- Relative humidity: 10% - 93%

Condition	Class	H ₂ S	Cl ₂	NO ₂	SO ₂	Temp	RH
Telcordia	Outdoor	100ppb	20ppb	200ppb	200ppb	30°C	70%
Battelle	Class 3	100ppb	20ppb	200ppb	-	30°C	75%
	Class 4	200ppb	50ppb	200ppb	-	50°C	75%

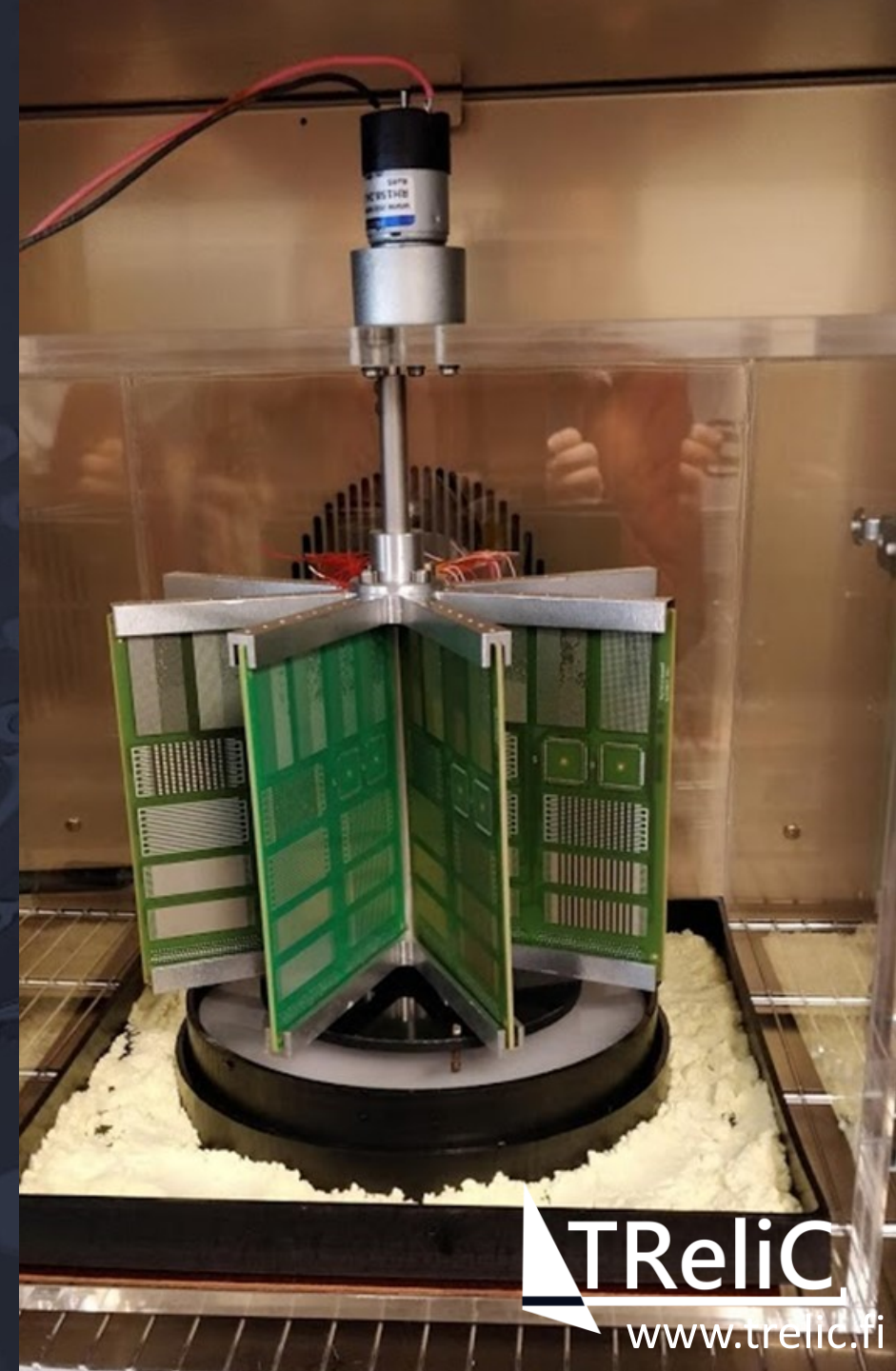
Flowers of sulphur (FoS) testing

- Originally to study coatings on metals
- Lead-free electronics
 - **New versions of FoS tests have been developed to study the corrosion of silver**
- Typically testing done in a desiccator
 - **Powdered sulfur as the sulfur source**
 - Humidity controlled using KNO_3 salt solution
 - At increased temperature



Flowers of sulphur (FoS) testing

- iNemi has designed FoS test optimised for printed circuit boards (PCBs)
- **Includes also chlorine source**
 - **More corrosive environment**
- Uses motor to move the PCBs during testing
 - Even corrosion process
- Recommended test temperature 50°C
- **Can be used with several salt solutions to study different humidity levels**



Comparison between MFG and iNEMI FoS test

▪ iNEMI FoS

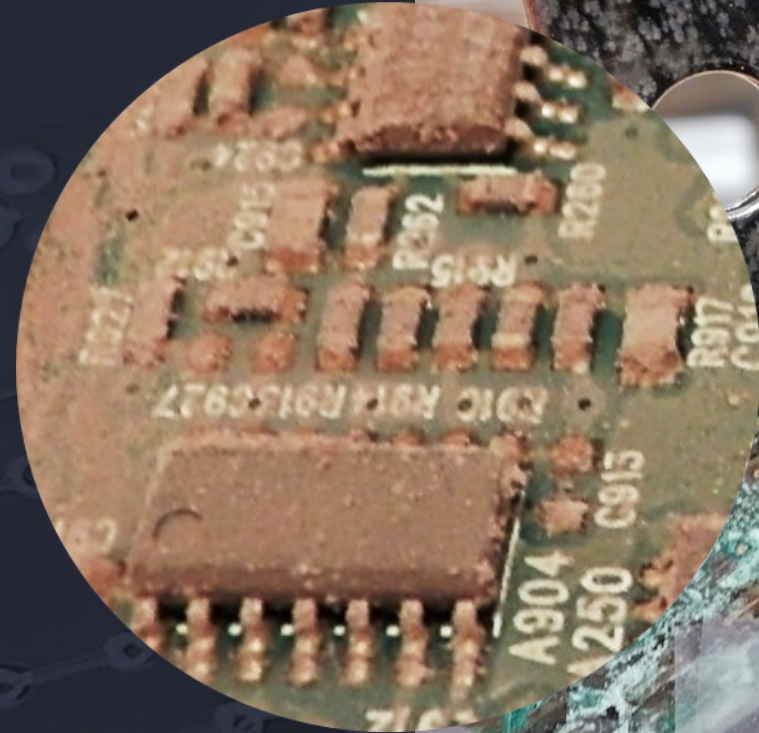
- **Efficient especially for silver**
- Possibility to vary humidity levels using salts
- **Corrosive elements cannot be varied**
- The test chamber has typically limited size and is designed for PCB testing
- Relatively simple test method
 - Testing less expensive

▪ MFG

- Offers lots of versatility
 - **Lots of different test conditions possible**
- Possibility to test large products and whole devices
- **Requires sophisticated test chamber**
- Often expensive

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Analysing corrosive environments

- Analysing corrosive environments is typically difficult
- Several elements affect corrosion
- **It is very difficult to measure all critical elements at the same time**
- Error and variation can cause problems

*Dust,
impurities,
chemicals*

*Nitrogen
compounds, for
example NO_2*

*Salts, for
example NaCl*

Chlorine (Cl_2)

*Sulphur
compounds,
for example
 SO_2 , H_2S*

*High relative
humidity and
temperature*

How to monitor test conditions

- **Sensors to monitor conditions**

- It is difficult to analyse all potential corrosive elements at the same time
- Often expensive and requires sophisticated equipment

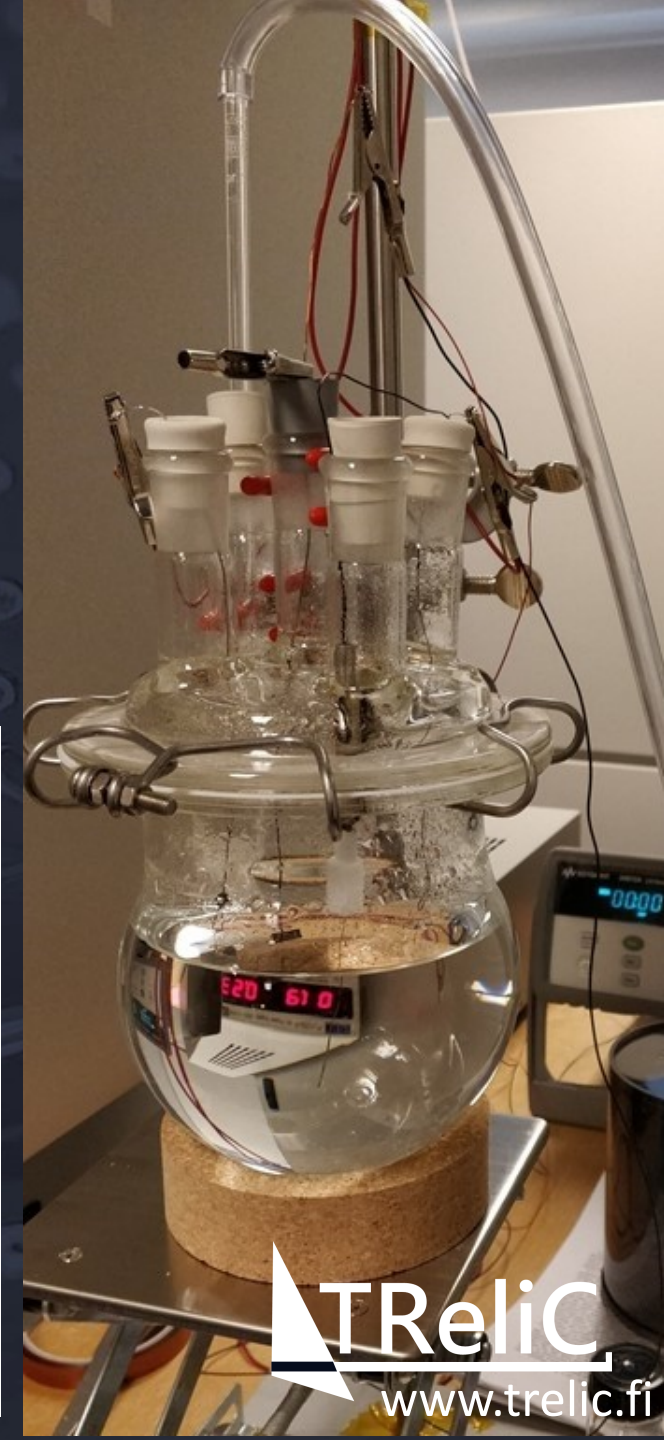
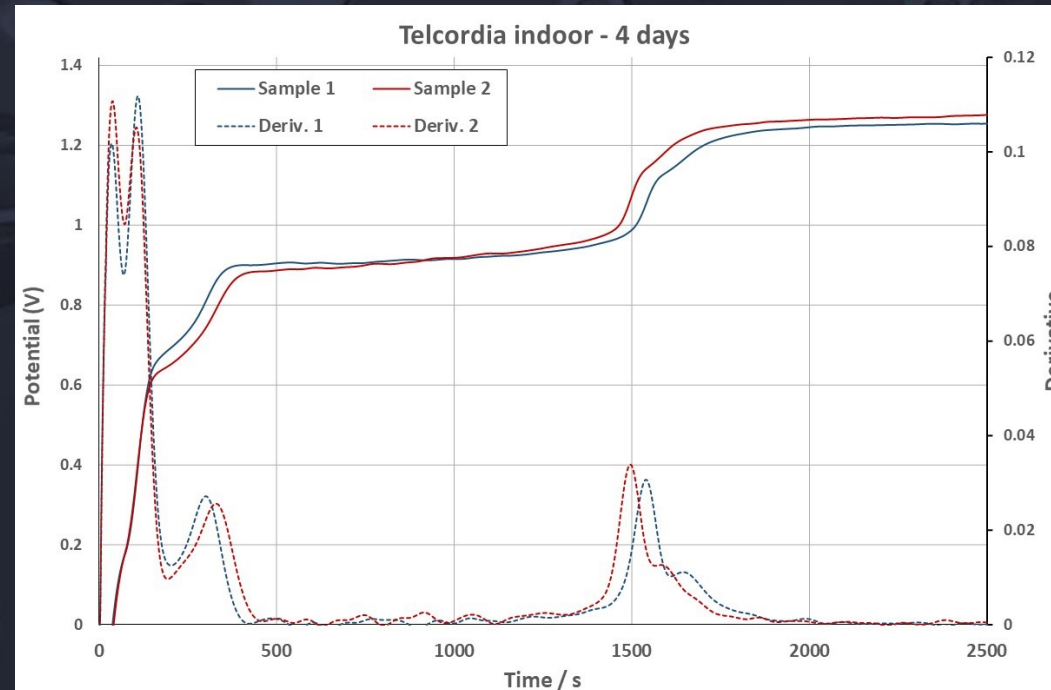
- **Corrosion coupons**

- Typically **copper and silver**
- Gravimetric analysis and coulometric reduction possible
- **Relatively simple measurements**



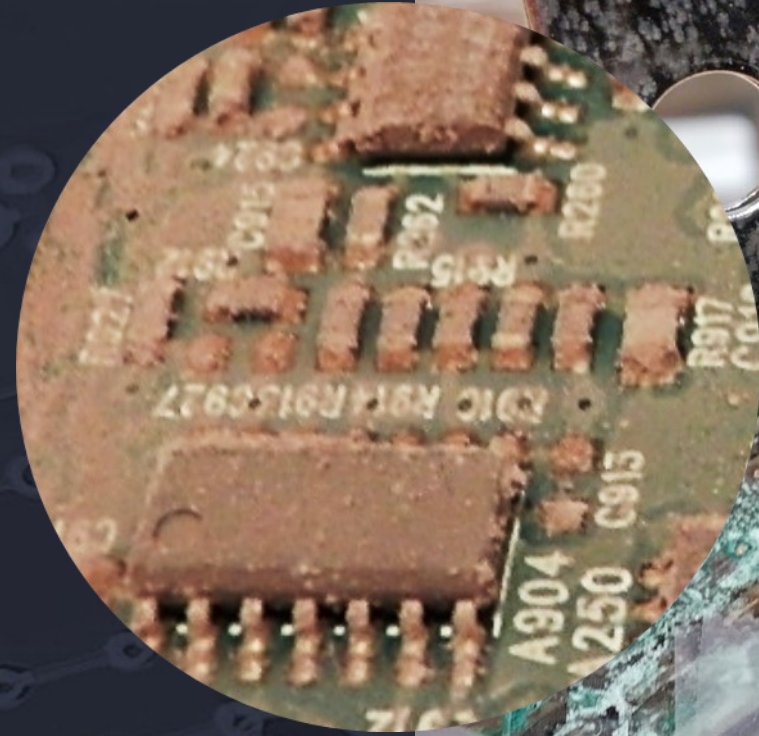
Corrosion coupons

- **Weight gain** can be used to estimate corrosion rate
 - Based on assumption of the main corrosion product
- **Coulometric reduction**
 - Used to recognise corrosion products
 - Calculate corrosion rate



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Example of MFG and FoS tests

■ Test samples

- PCBs with different surface finishes
- Printed silver wires
- Parylene coated samples

■ FoS and MFG tests with high sulphur levels

■ Corrosion rate studied with silver and copper coupons

■ FoS test

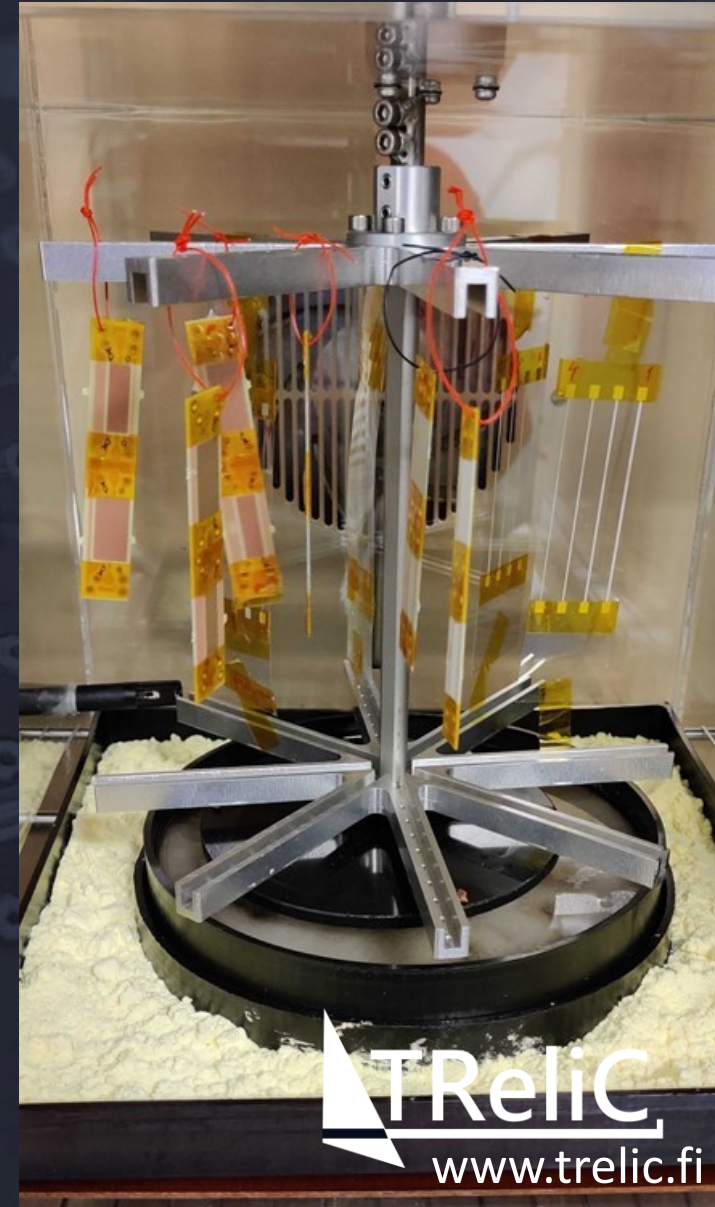
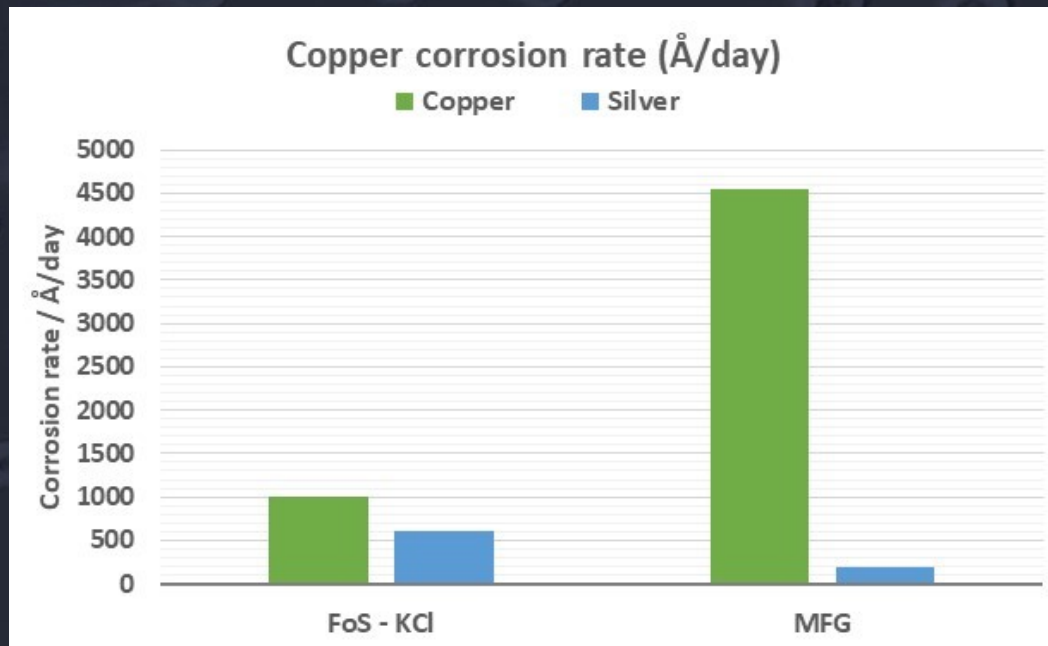
- KCl salt (approximately 80%RH)
- Test temperature 50 °C
- Test duration 5 days

■ MFG test

- Gases H₂S = 1700ppb; NO₂ = 200ppb; Cl₂ = 20ppb; SO₂ = 200ppb; 40C;
- Test temperature 40 °C, humidity 75%RH
- Test duration 4 days

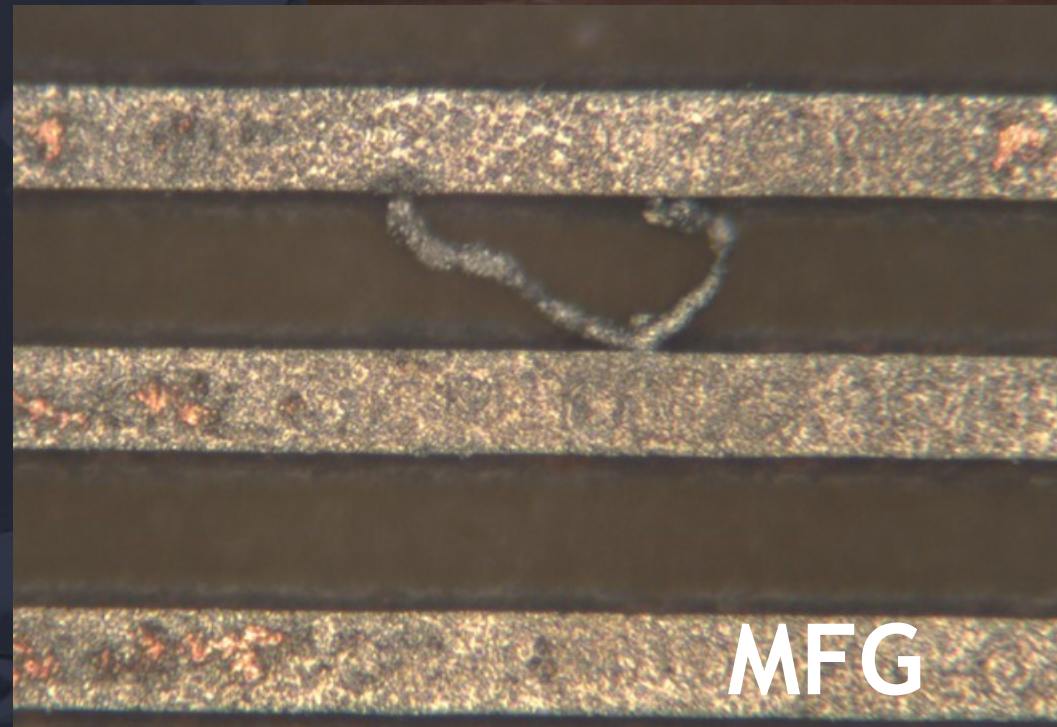
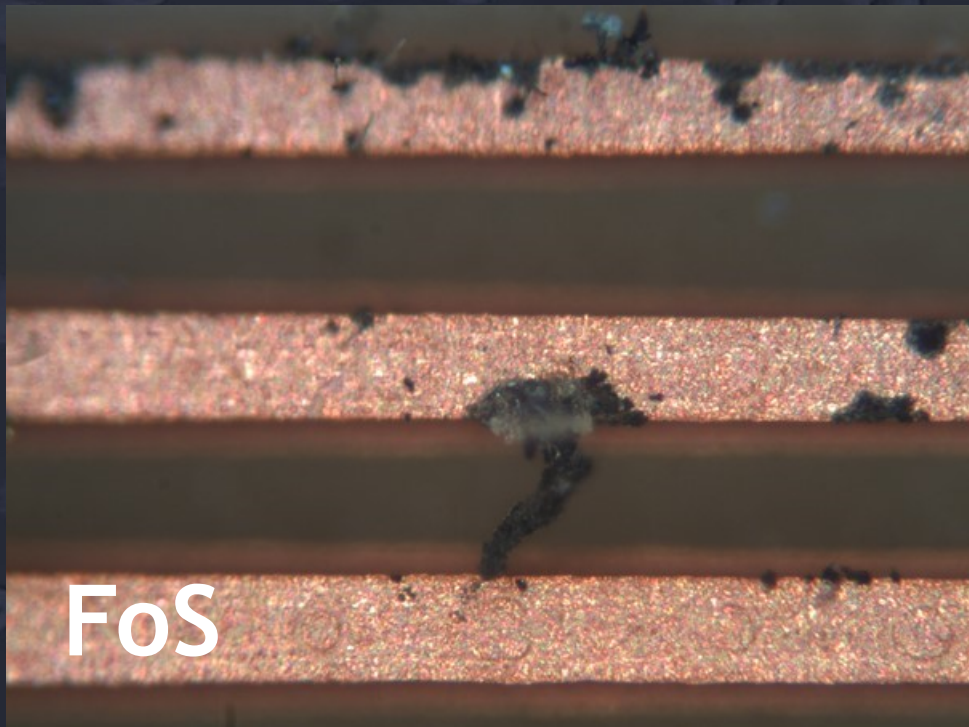
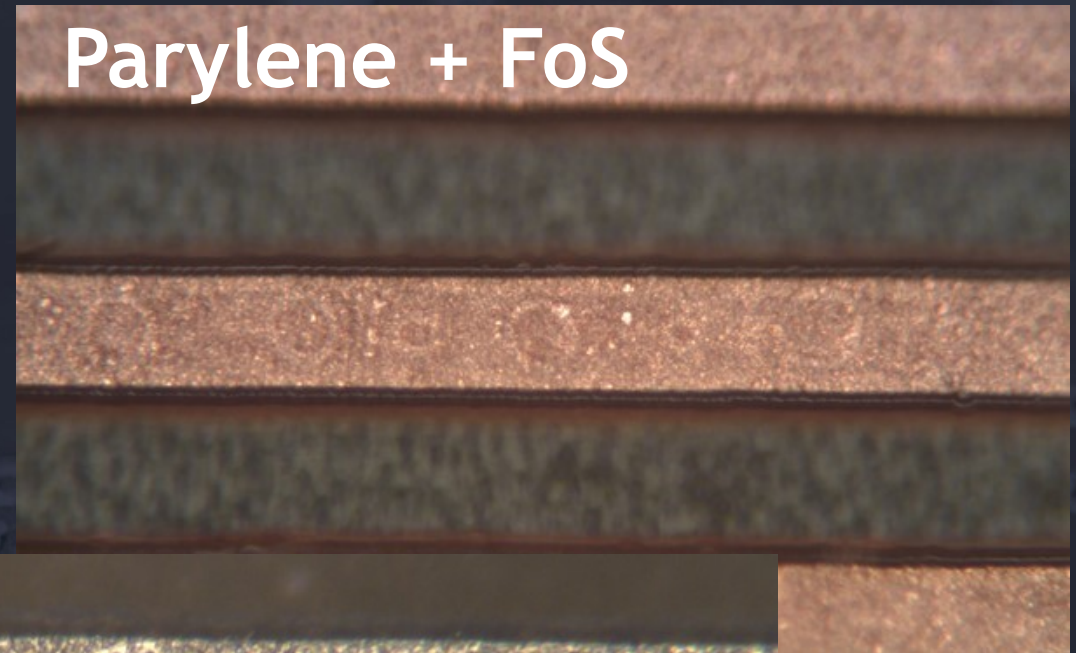
Example of MFG and FoS tests

- Corrosion of silver greater in FoS
- Corrosion of copper and ENIG greater in MFG



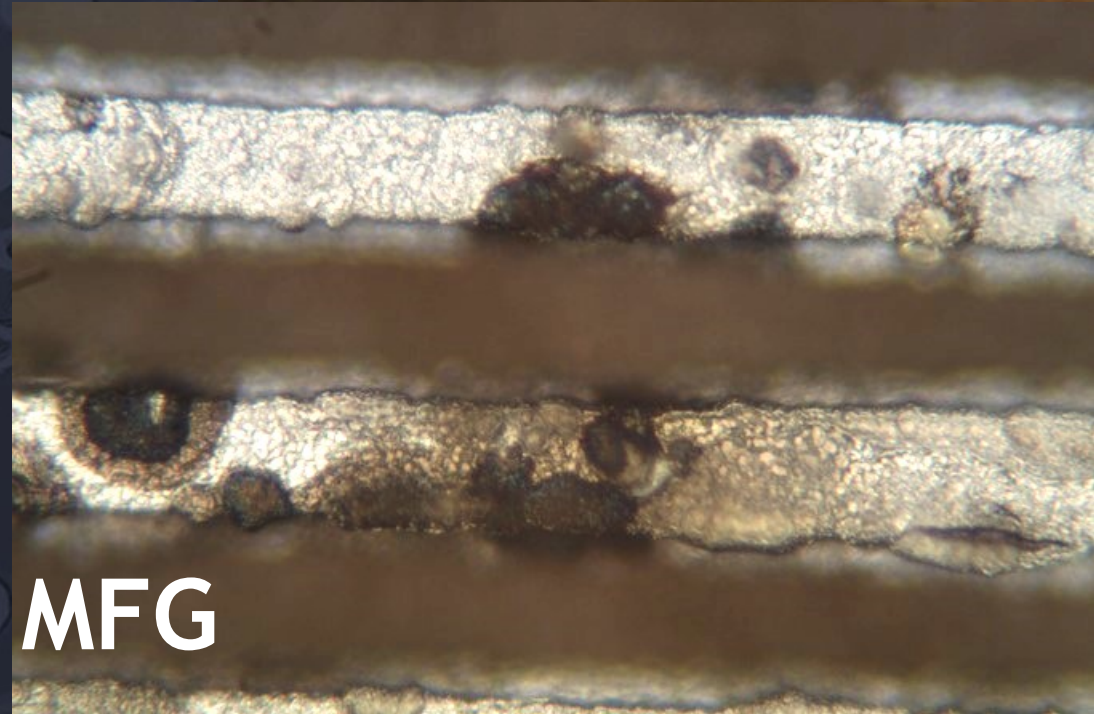
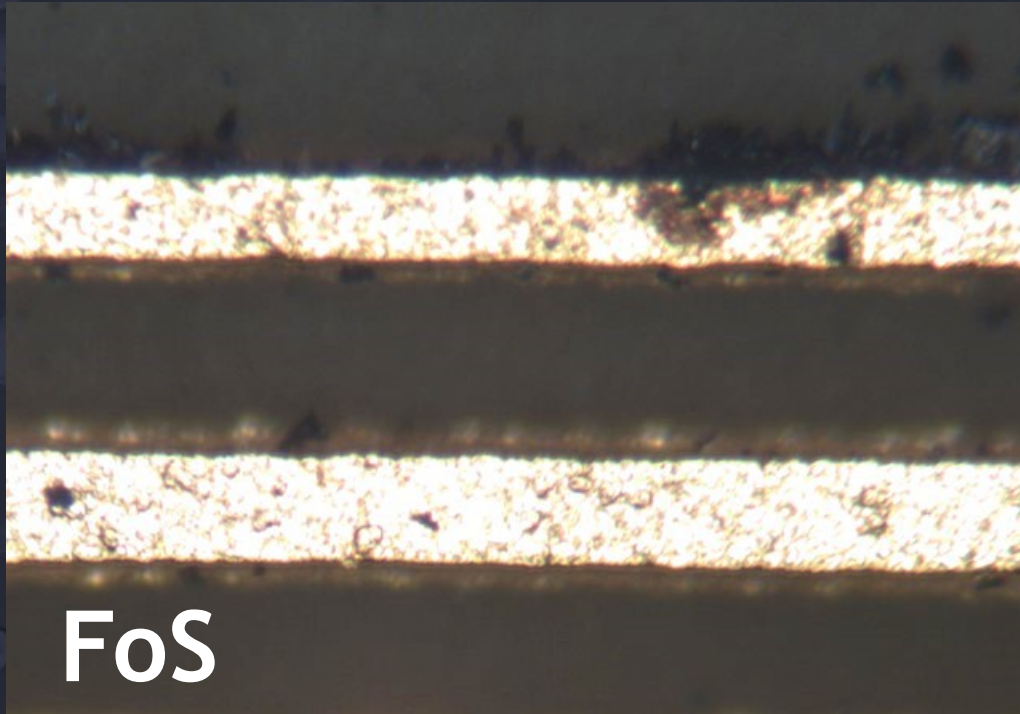
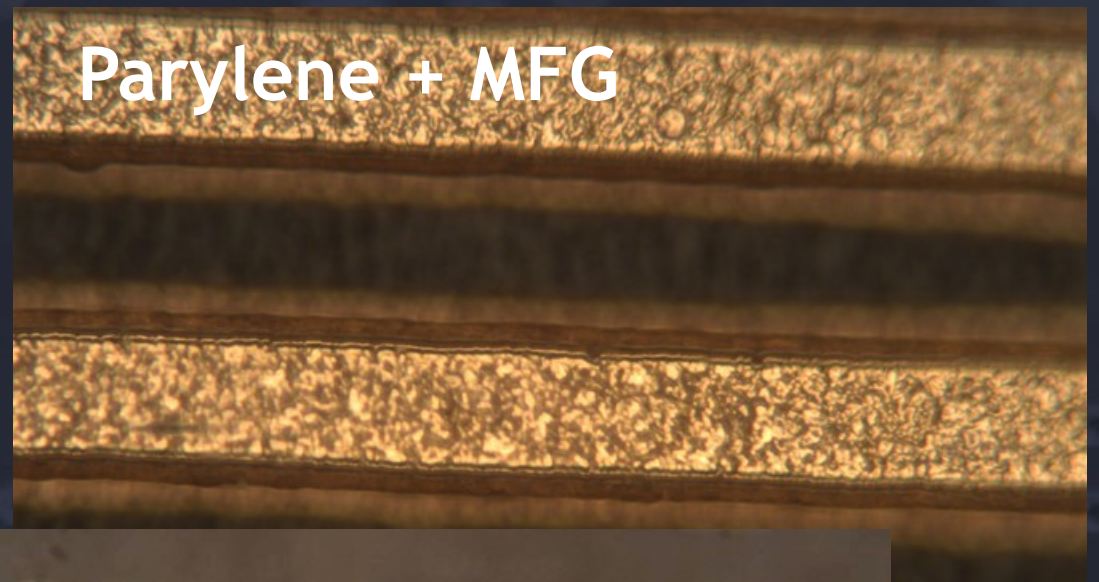
MFG vs FoS

- OSP



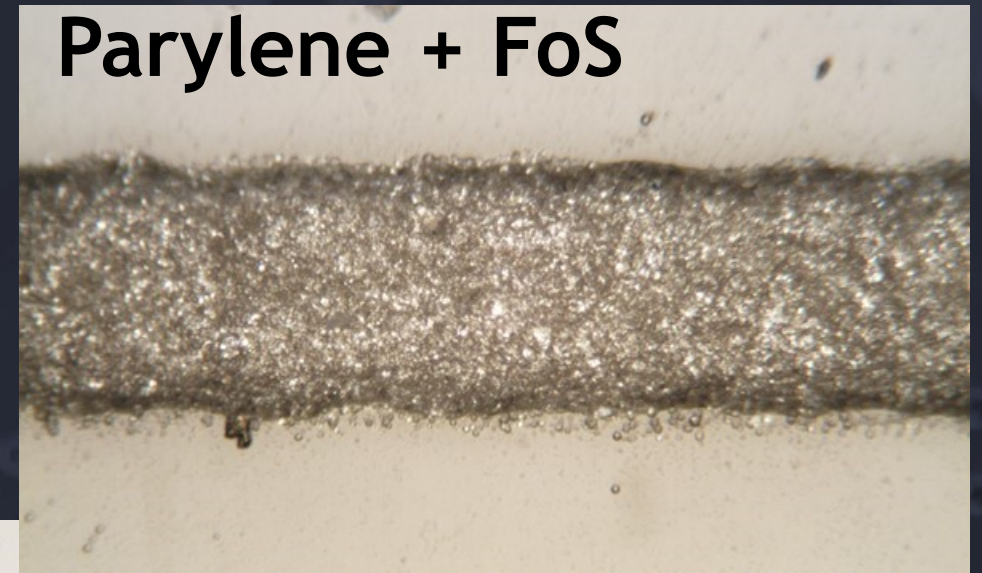
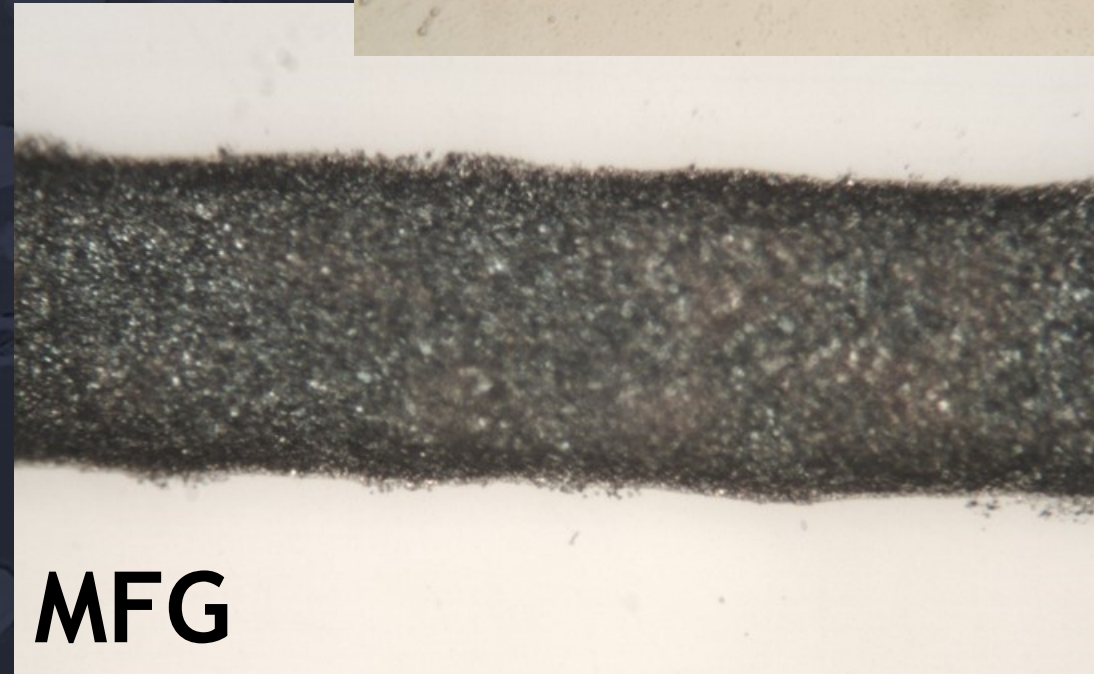
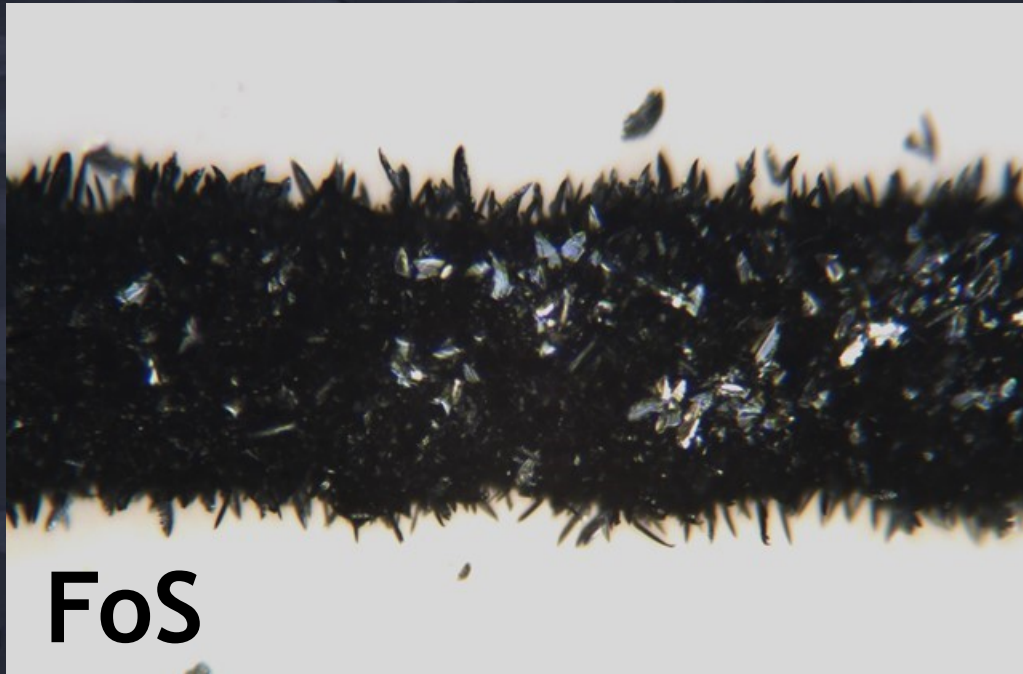
MFG vs FoS

- ENIG



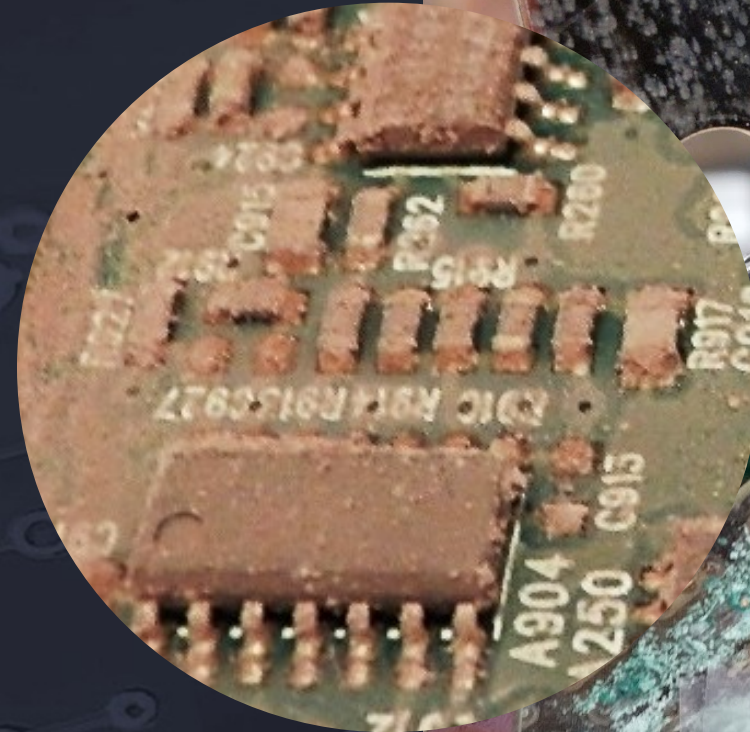
MFG vs FoS

- Printed silver wire



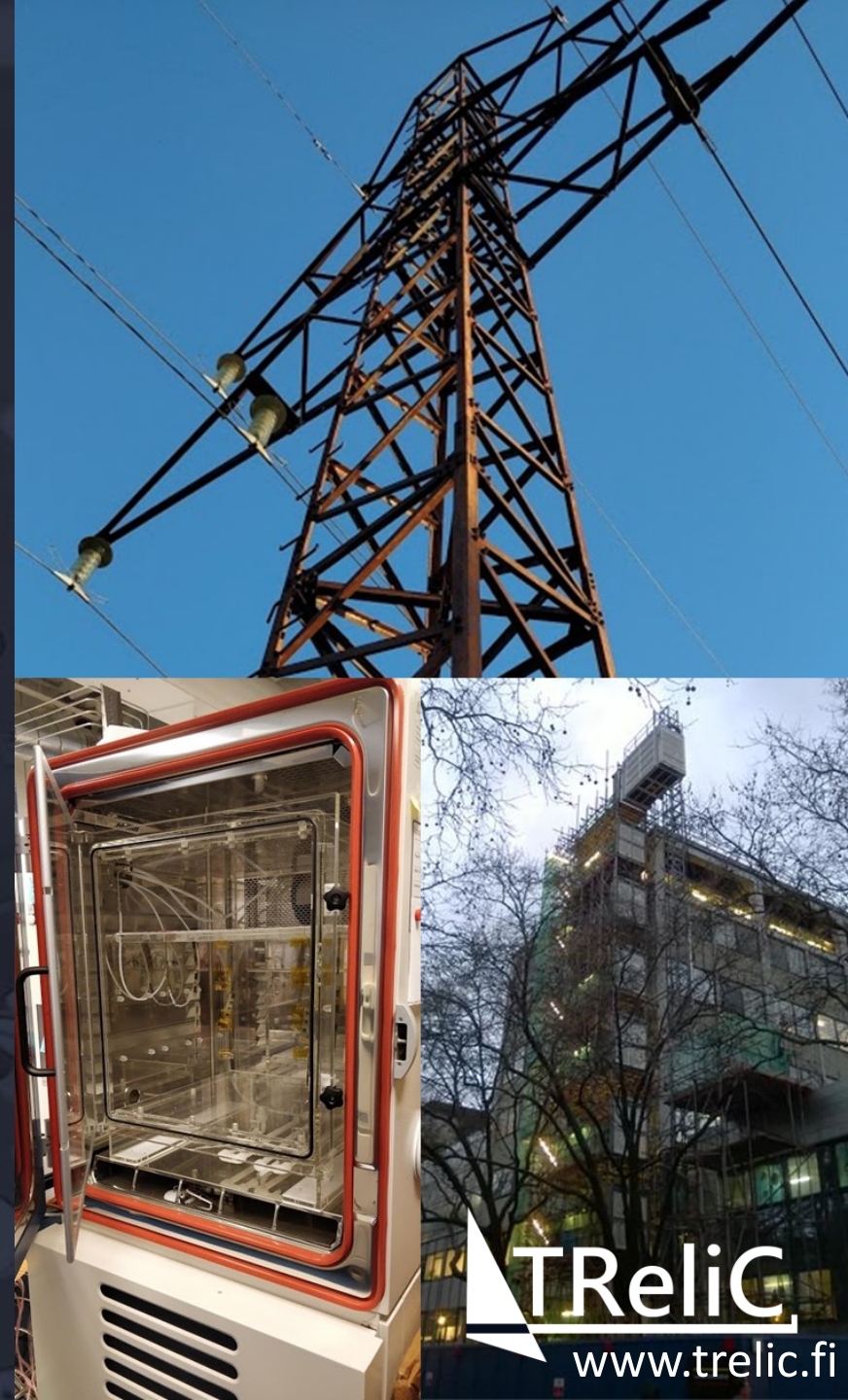
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Conclusions

- Studying corrosion behaviour is critical in electronics
- Both MFG and FoS offer good tests
- **MFG offers more versatility**, but requires sophisticated test chamber and is more expensive
- **FoS offers simple test method but has limited size and corrosive conditions**
- Measuring corrosion rate is very important due to variation in the tests
 - **Corrosion coupons** offer simple solution



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