In collaboration with

Study and Comparison of Naturally-Aged and As-Received Silvered-Glass Reflectors

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Background

Silvered-Glass reflectors at the Masdar Institute Solar platform (MISP)

Heliostat field and Beam-Down Tower at the Masdar Institute Solar Platform (MISP)

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Installed July 2009

Corroded facet selected for analysis

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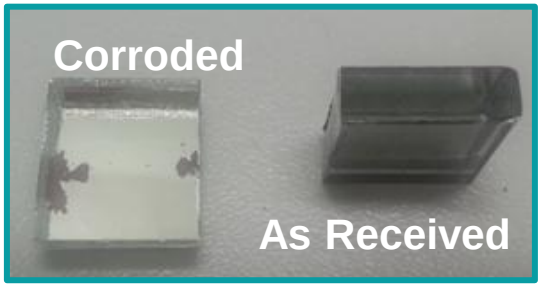
> 10 pp specular reflectance drop after 7 years exposure

Motivation

- Availability of heavily degraded mirrors after 7 years of outdoor exposure and as-received ones from the same original manufacturing batch:

⇒ Possibility of comparison of as-received and outdoor-exposed samples :
Understanding corrosion causes



⇒ Possibility of comparison of samples under accelerated aging and ‘’naturally’’-aged ones:
Allows evaluation of accelerated-aging protocols

* Presentation by Johannes Wette @ 5:50 , same room

Objectives

Understanding the cause of rapid corrosion observed in

back-silvered glass mirrors exposed for 7 years at the MISP, Abu Dhabi

⇒ Characterization of exposed and corroded mirrors, and as-received ones using Scanning Electron Microscopy (SEM) with Energy Dispersive X-ray Spectroscopy (EDS)

⇒ Same analysis performed on as-received samples of a state-of-the-art commercial mirror as a reference for comparison

Back-silvered Glass Mirrors Corrosion Mechanisms

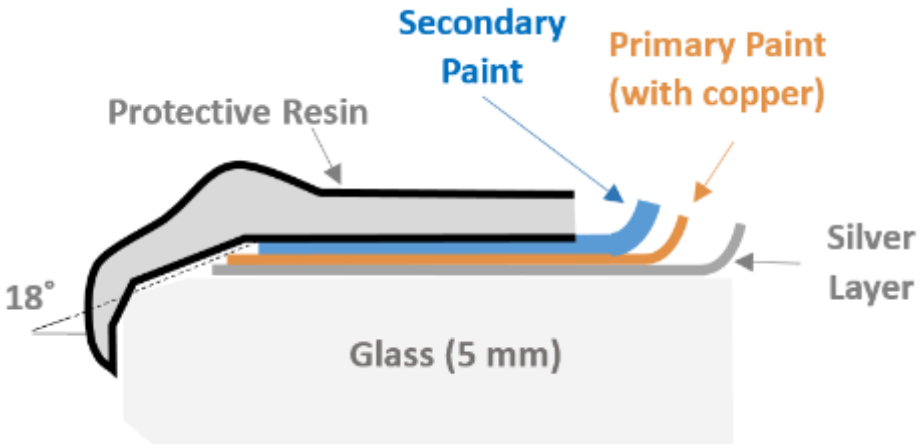
- Silver corrosion (tarnishing) can happen in presence of **salts** (mainly chloride), **ozone** and **sulfur**
- Silver vulnerable to air pollutants: acids, ammonia, hydrogen sulfide
- Corrosion influenced by environmental factors:
  pH, humidity, radiation, wind velocity, temperature
- Main corrosion products: **AgCl , AgS**. Ag_2O and Ag_2SO_4 can also be found

$\Rightarrow$ Backside protective coatings necessary to prevent corrosion:

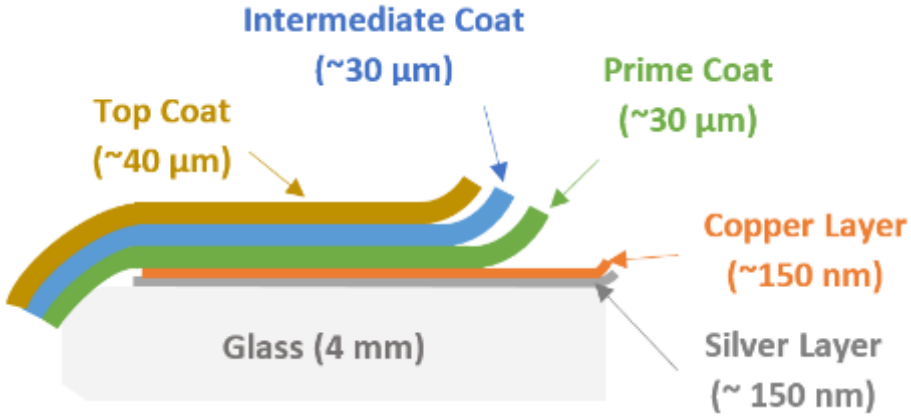
- Diffusion barrier to aggressive ions and humidity
- Protection from UV-radiation
- Protection from erosion

Materials Description

- **Nishio Glass Mirror from MISP:** as-received and exposed, *Nishio_AR* and *Nisho_Exp*
- **Reference mirror:** State-of-the-art commercial back-silvered mirror, *Ref_AR*



Reflector at the MISP by *Nishio Glass Mirror* (Nishio_AR)



Commercial mirror for reference (Ref_AR)

Sample preparation

- Samples of 1 x 1 cm^2 cut and cross-section polished

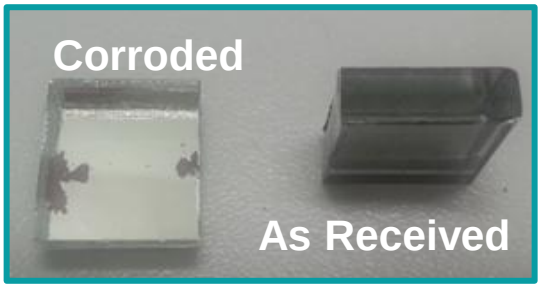
- Polishing in multiple steps with decreasing abrasive sizes on a rotating disc (min 0.25 µm)

- 2 polishing trials:

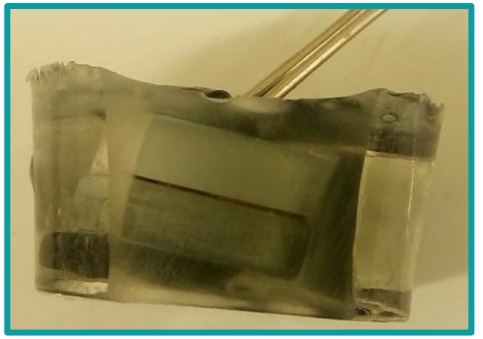
  1- Direct polishing

  => coatings detachment for the Nishio mirror even on the as-received mirror

  2- ‘’Face-to-face’’ preparation with resin embedding



Embedding



Polishing

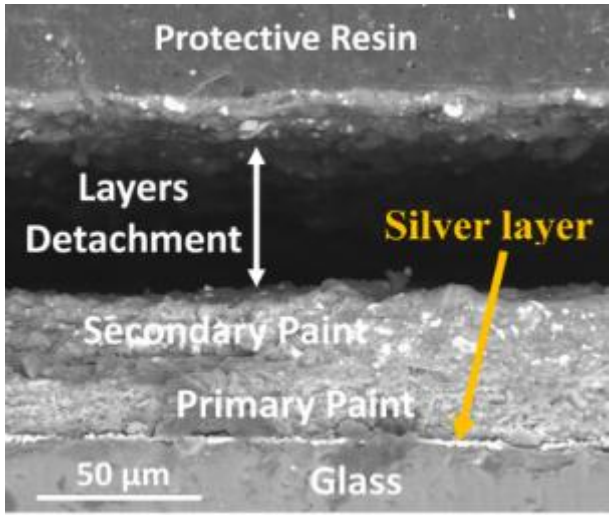
Instrumentation

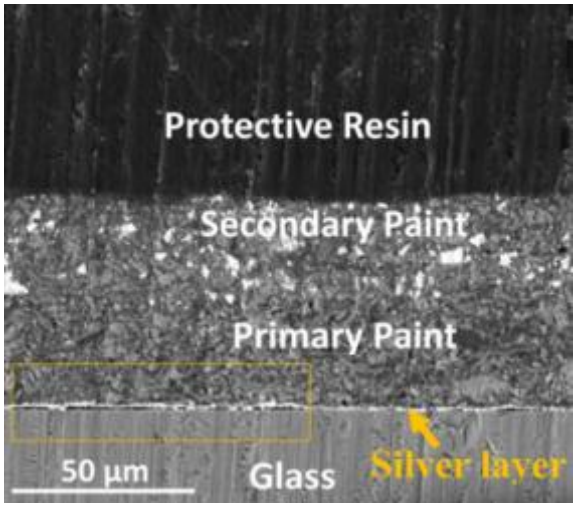
- FEI Quanta 250 SEM in combination with X-ray detector for EDS elemental analysis
- Backscattered Electrons Detector (BSED) used with SEM to provide contrast between different elements (Z contrast)
- Surveyed elements: Silver **Ag**, Copper **Cu**, Chlorine **Cl**, Sulfur **S**, Oxygen **O**

Results – AR samples

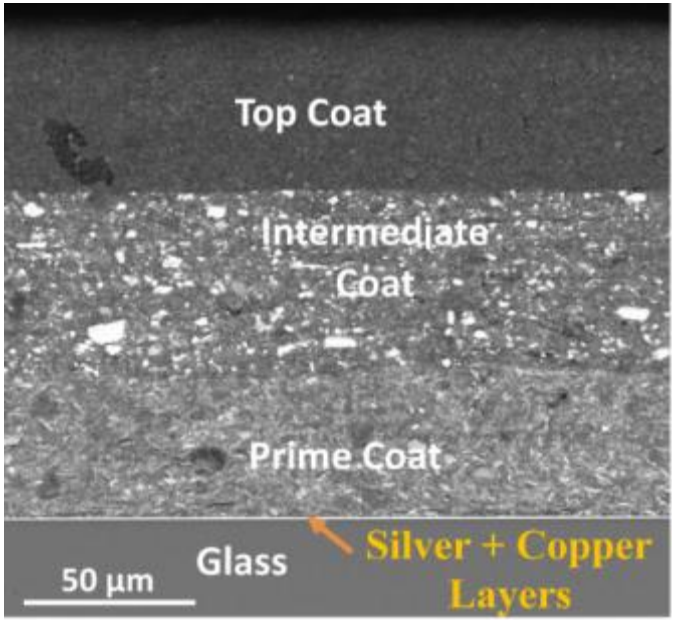
Backside coatings comparison: Nishio and Ref

SEM images with BSED => Z contrast





Nishio_AR

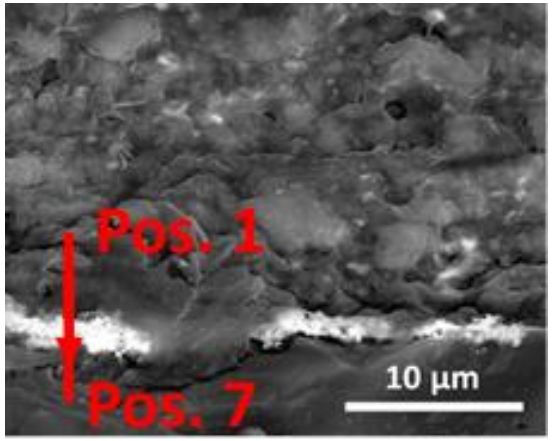


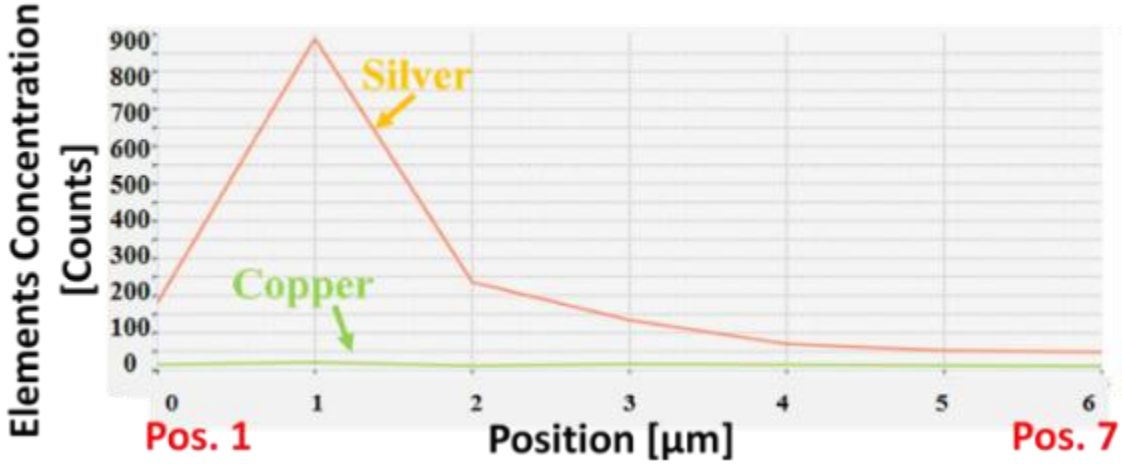
Ref_AR

Results – AR samples

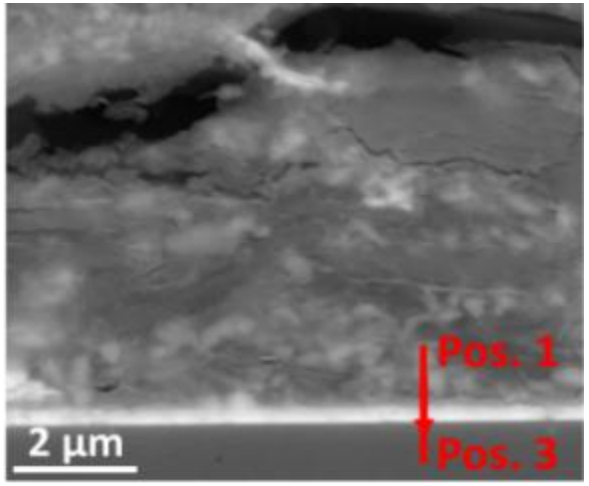
Copper protective layer comparison – EDS line scan

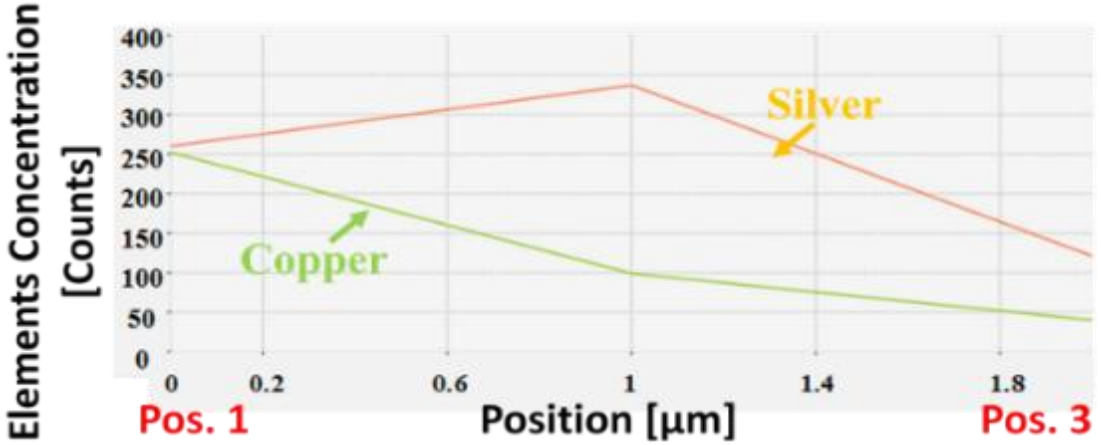
Nishio_AR





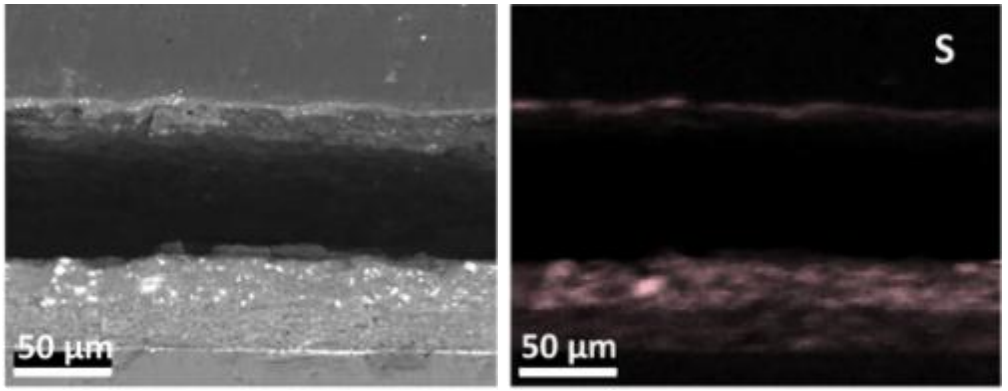
Ref_AR



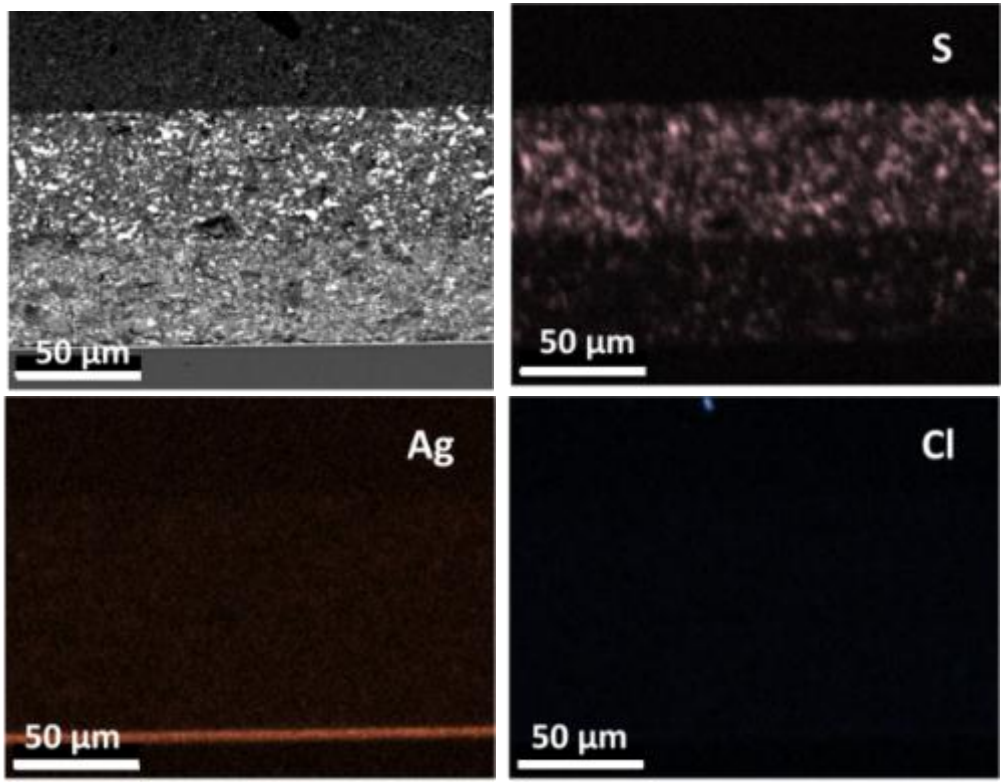


Results – AR samples

Initial Presence of contaminants – EDS mapping



Nishio_AR



Ref_AR

Results – Exposed samples

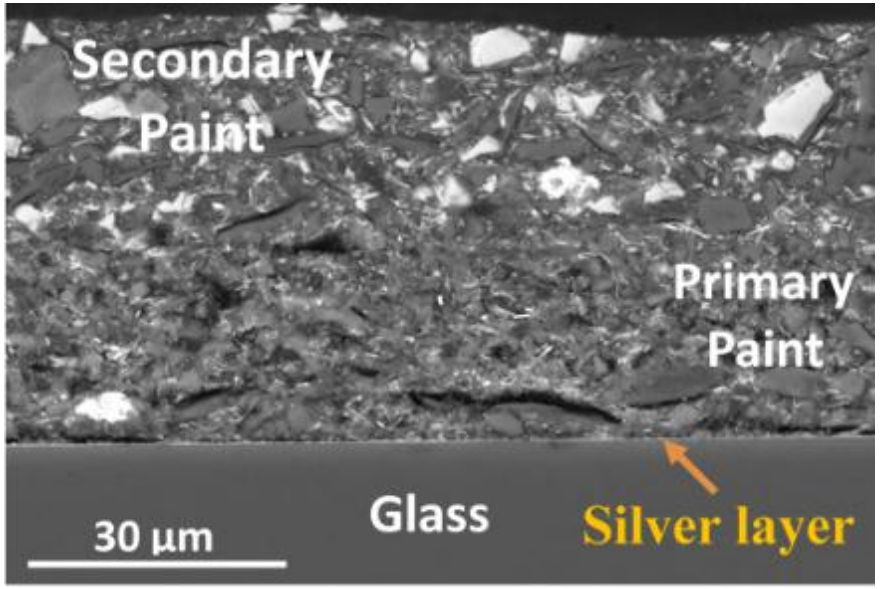
Visual inspection of newly exposed mirror (6 months)

Backside protective resin detachment at the edges

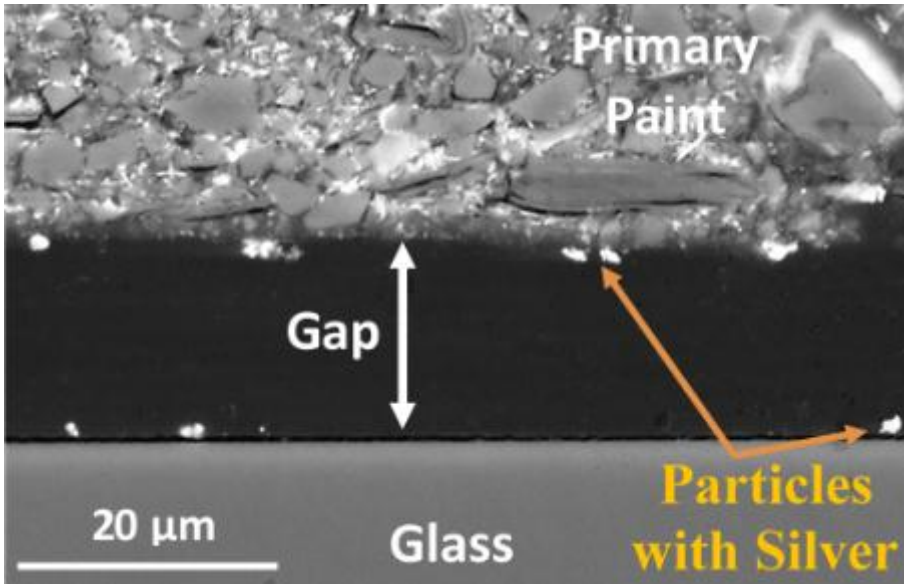
Edge corrosion of the silver layer

Results – Exposed samples

Comparison of Nishio_Exp and with Nishio_AR



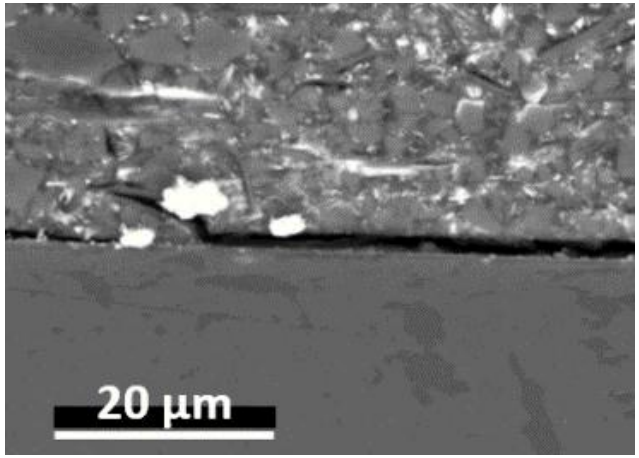
Nishio_AR

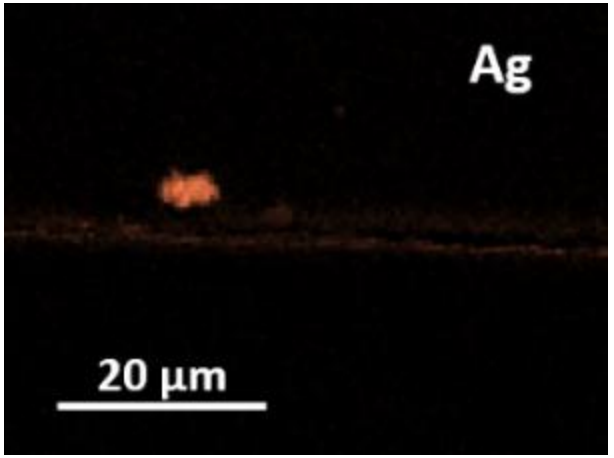


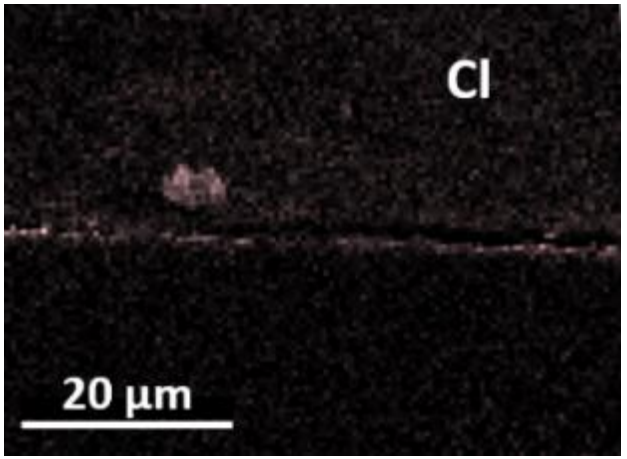
Nishio_Exp

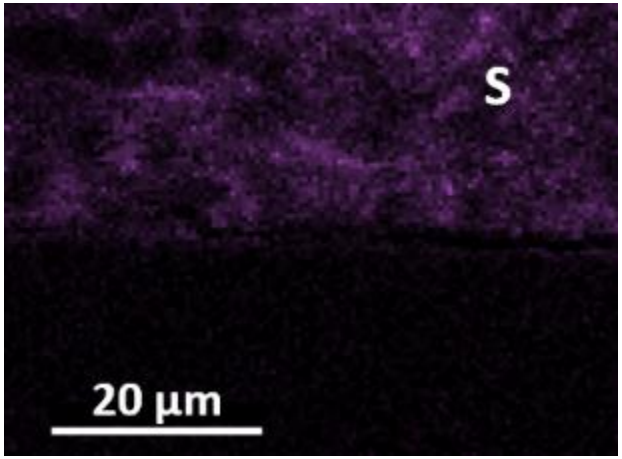
Results – Exposed samples

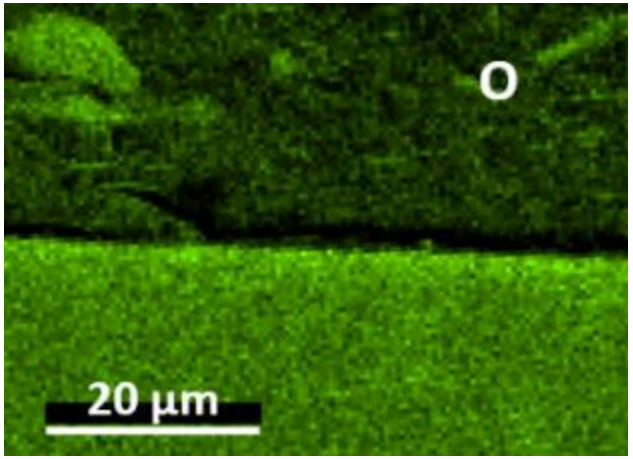
Analysis of Nishio_Exp – EDS mapping











Conclusions and future work

Analysis of corroded and as-received samples

5 main possible causes of the rapid corrosion identified:

1) weak adhesion and manufacturing defects in reflecting layers
2) weak protective top coating, especially against UV
3) absence of copper layer
4) high initial presence of corrosive contaminant, chlorine, remaining from the manufacturing process
5) low mechanical stability of top coating especially at the edges.

Future work:

- Evaluation of corrosivity of the exposure site: standard tests ISO 9223-9226
- Further combined accelerated aging tests

Acknowledgments

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Thank You

Questions?

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