FEMS EUROMAT 23

In-situ analysis of microscopic corrosion evolution of solar reflectors

J. Wette, F. Sutter, F. Wiesinger,

R. Sánchez-Moreno, A. Fernández-García

Project INTECSOL, PID2021-126664OB-I00, funded by MCIN/AEI/ 10.13039/501100011033 and by the European Regional Development funding.

MINISTERIO DE CIENCIA E INNOVACIÓN

UNIÓN EUROPEA

FONDO EUROPEO DE DESARROLLO REGIONAL

"Una manera de hacer Europa"

AGENCIA ESTATAL DE INVESTIGACIÓN

Ciemat

Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

PSA

PAC

DLR

CST – Concentrating Solar Thermal Technologies

- Sunlight is concentrated by large mirror arrays onto a receiver
- Solar towers, parabolic troughs, Fresnel, parabolic dishes
- Heat is used: Directly, steam, electricity
- Main advantages: direct heat and efficient storage



Noor III Solar Tower in Ourzazate, Morrocco

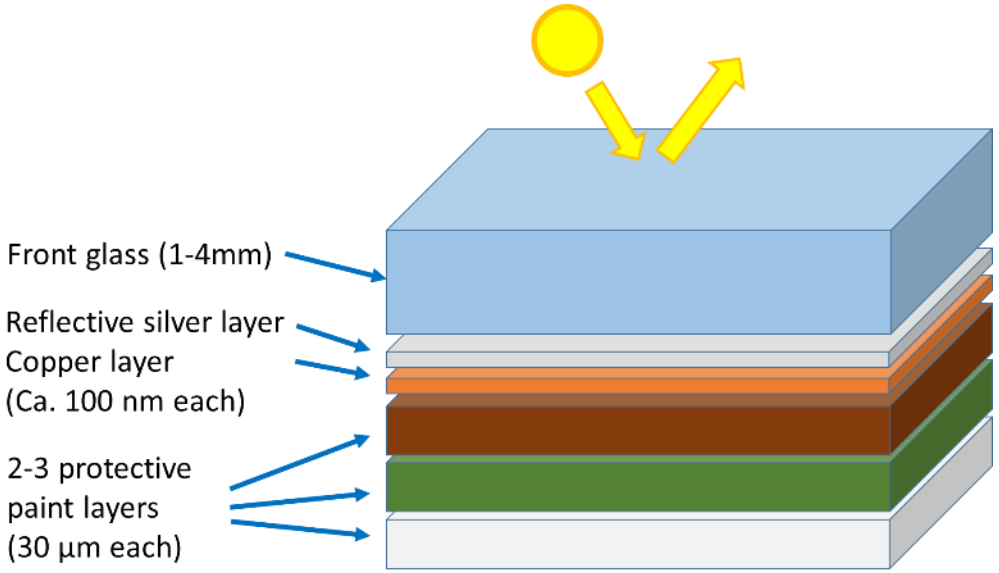


Parabolic Troughs at Ciemat-PSA Almería, Spain

- Over 1 million m^2 of mirrors in extensive projects
- Optical quality, durability exremely important

Solar Mirrors – State of the art

- **Silvered-glass mirrors** are state of the art
  - High specular solar reflectance
  - Excellent durability
- Aluminum sheet or silvered polymer as alternatives





Heliostat with silvered-glass facets at Ciemat-PSA

Mirror degradation

Environmental stresses

- Temperature
- Humidity
- UV-radiation
- Dust
- Chemicals (industrial, NaCl, etc.)





Corroded facet after outdoor exposure [1]

Defect mechanisms

- Corrosion (reflective layer)
- Erosion/abrasion
- Paint degradation

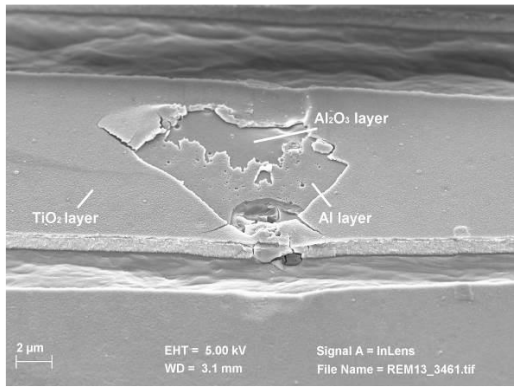
Reflectance loss

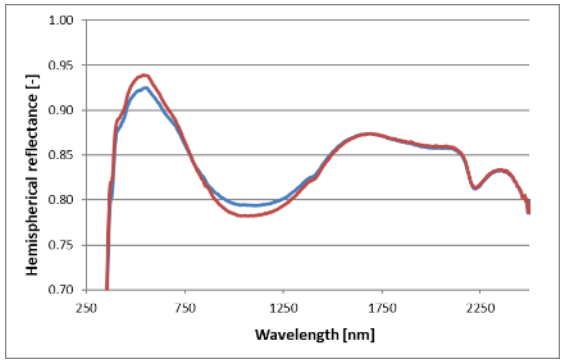
[1] Wette et al.,Advanced Cyclic Accelerated Aging Testing of Solar Reflector Materials, SolarPACES 2018, Casablanca

Mirror Analysis

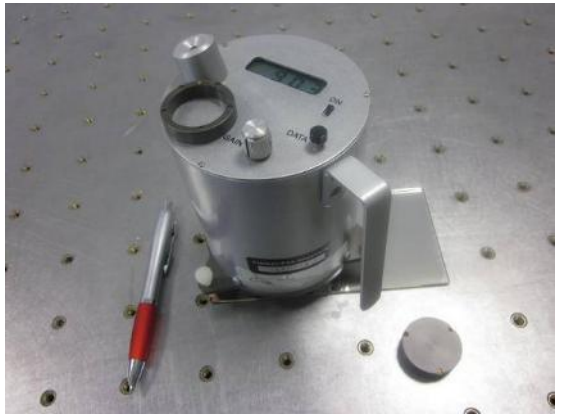
Detailed laboratory analysis

- Spectral reflectance
- Optical, electron microscopy
- Chemical analysis
- Image processing
- …





Devices & Services portable reflectometer



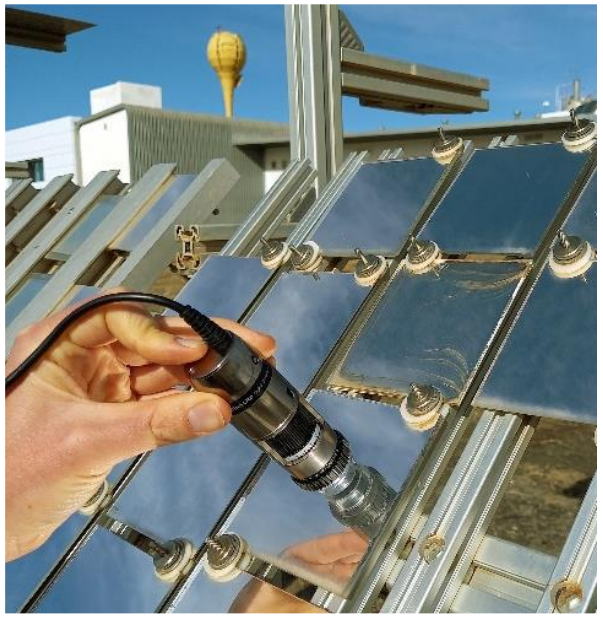
In-field analysis

- Less standardized tools available
- Reflectometer measurements
- Visual inspection
- Camera, drone measurements

Need for advanced field tools

Portable USB Microscope for field measurements

- Flexible, affordable system avoiding the need to collect reflector samples
- Lower optical quality than lab devices
- Preliminary campaign confirmed ability to detect important degradation mechanisms [2]





Surface defects

Corrosion reflective layer



[2] Wette et al., In-field Analysis of Microscopic Degradation of Solar Reflectors, *SolarPACES 2021, On-line*

Campaign: Corrosion Evolution Analysis

Objectives:

- Follow the evolution of corrosion spots for different materials and different exposure sites on field samples
- Evaluate setup (outdoor microscope)
- Gain insights on corrosion dynamics



- Two exposure sites (low and medium corrosivity, C3/C4, ISO-9223)
- 30 samples
- 5 materials (silvered-glass mirrors)
- New and already exposed samples (3-4 years)

Results
1st Site: Plataforma Solar de Almería, Tabernas

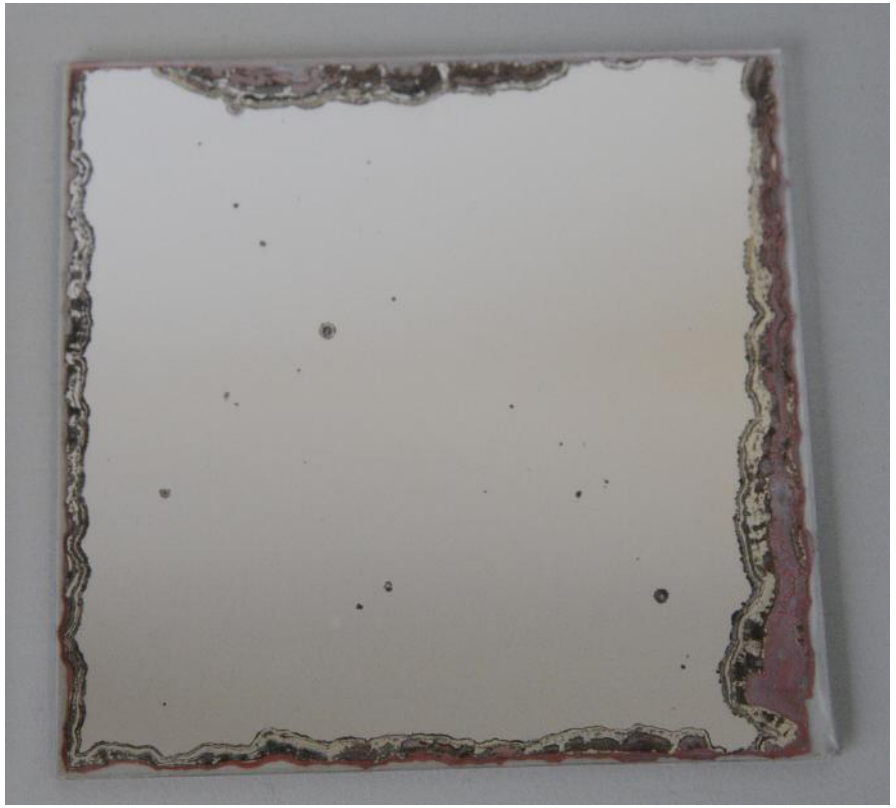
- Dry, semi-desert, corrosivity C3
- 12 samples, 3-4 years of exposure at the beginning of campaign
- 1.5 years between measurements
- Creation of 12 new spots during campaign
- 78 spots evaluated in total
- Evolution of existing spots:
  - Minimal to small growth 28.2%
  - Strong growth 6.4%



2nd Site: Almería city, coastal

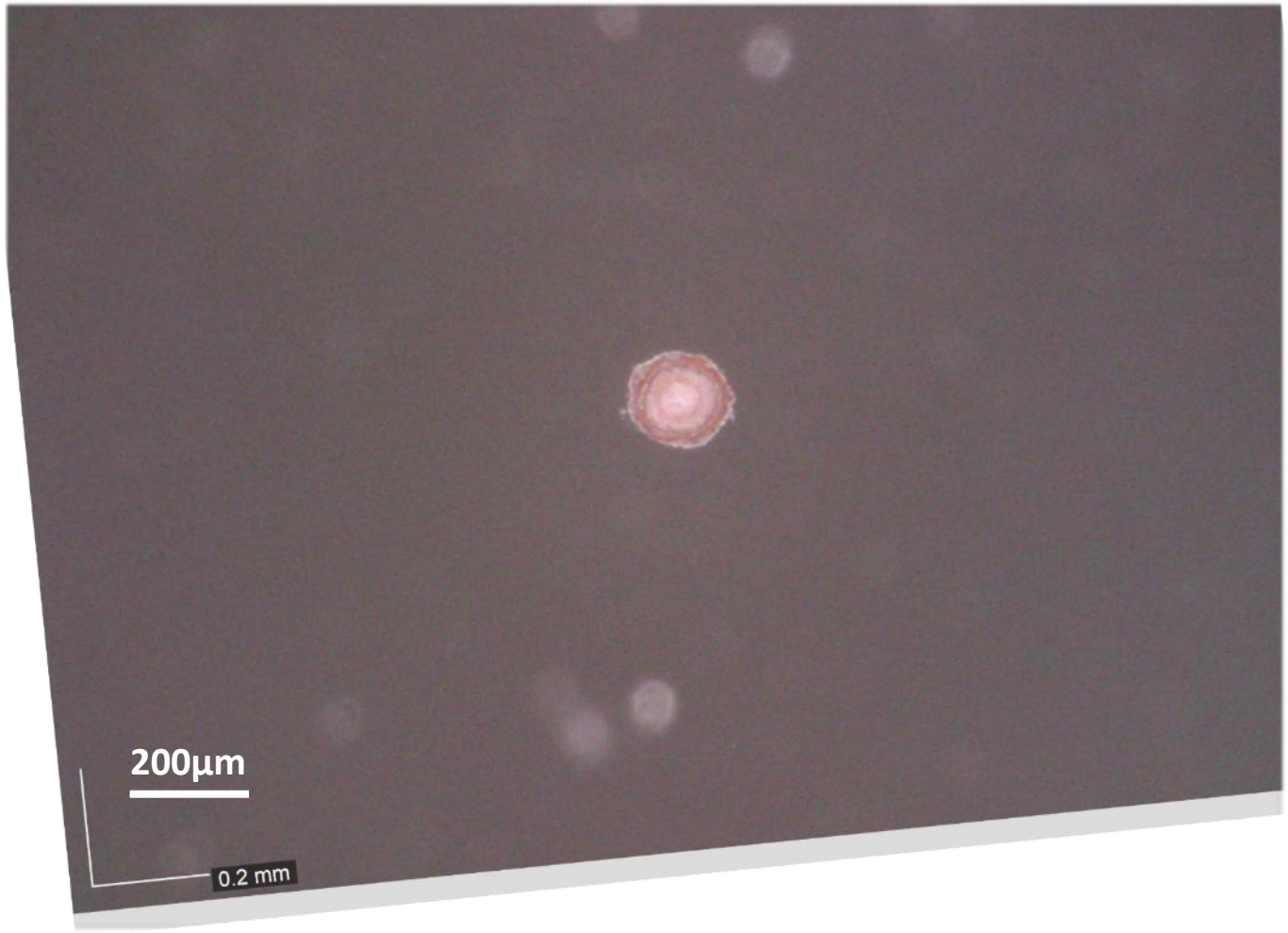
- Ca. 500 m from Mediterranean Sea, higher corrosivity C4
- 13 samples, 3-4 years of exposure at the beginning of campaign
  - 4 newly exposed samples
- 1 years between measurements
- Creation of 7 new spots during campaign,

  31 spots on new samples
- 84 spots evaluated in total
- Evolution of existing spots:
  - Minimal to small growth 6.0%
  - Strong growth 1.2%



Example minimal growth

- PSA
- 36 months

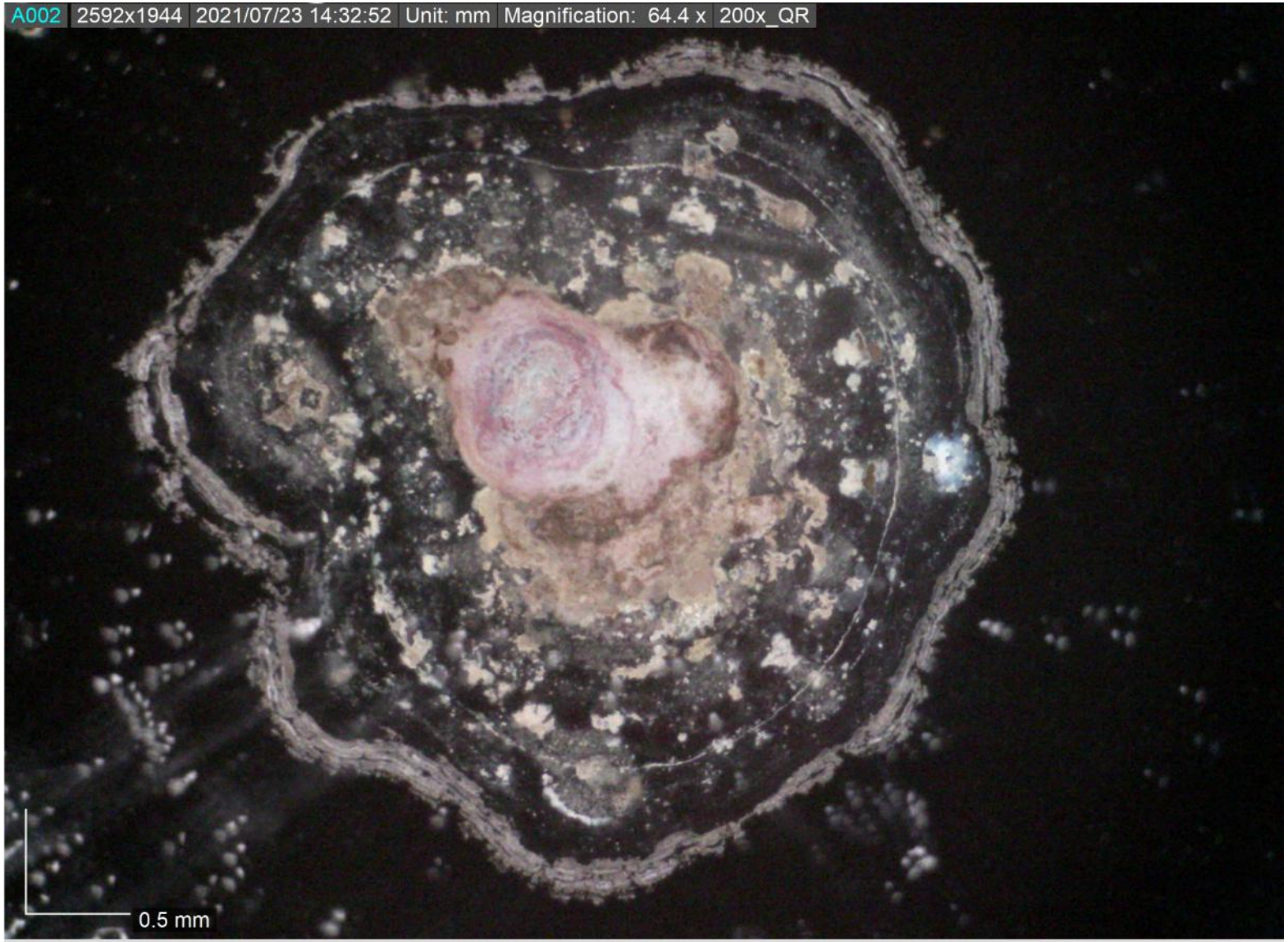


Example minimal growth

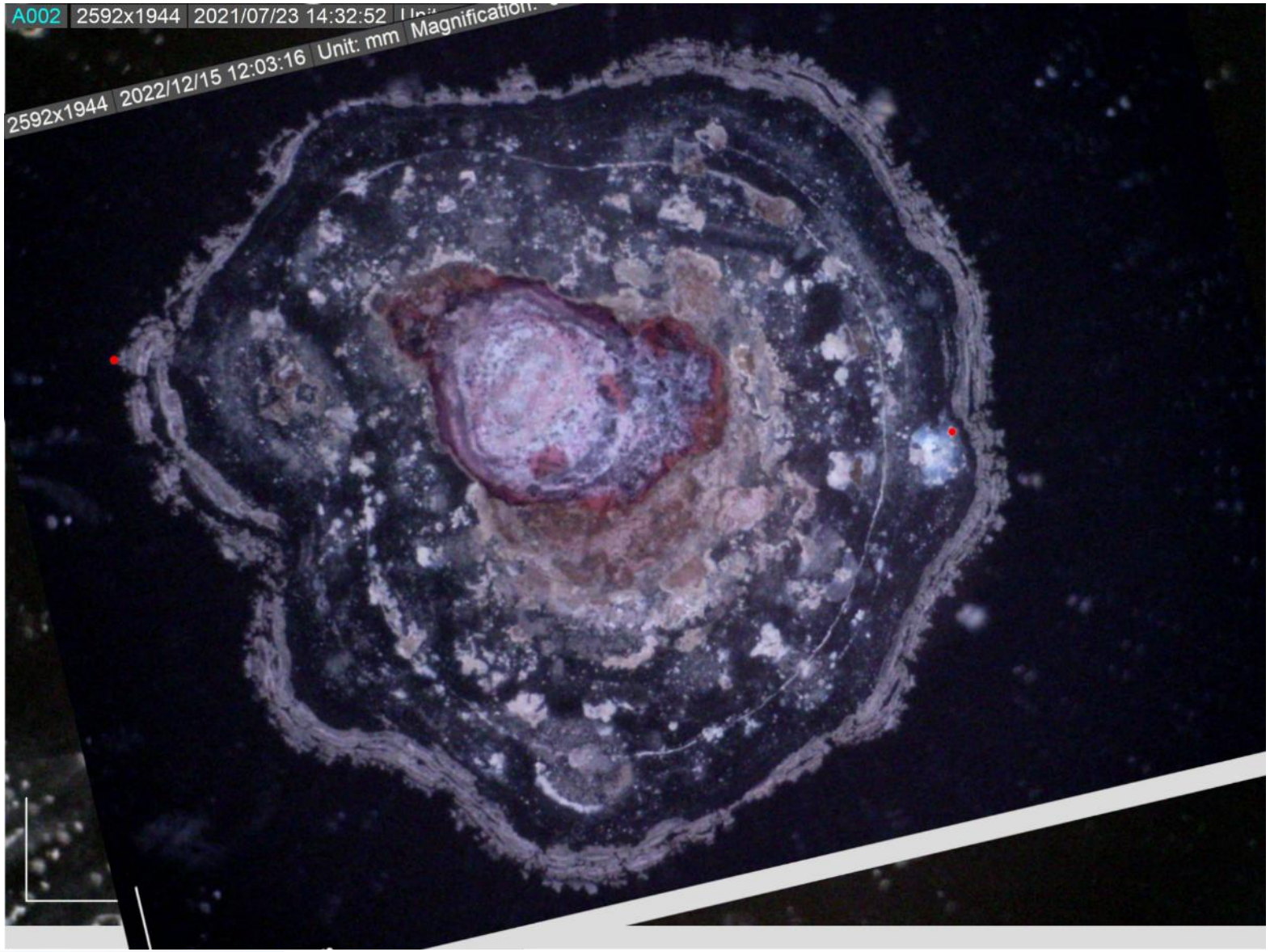
- PSA
- 55 months



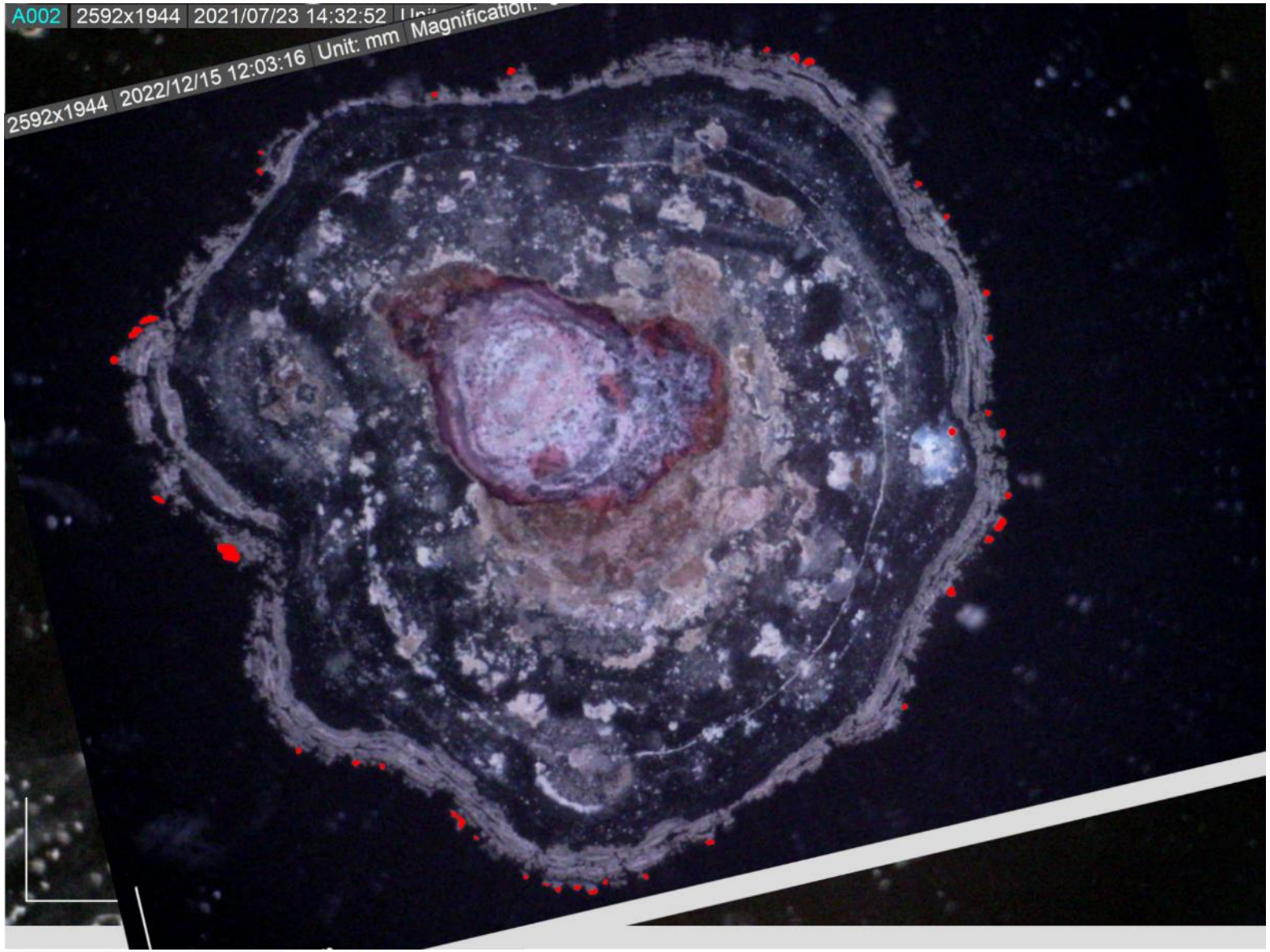
- 36 months


A002 2592x1944 2021/07/23 14:32:52 Unit: mm Magnification: 64.4 x 200x_QR
0.5 mm

- 55 months


A002 2592x1944 2021/07/23 14:32:52
2592x1944 2022/12/15 12:03:16 Unit: mm Magnification:

- 55 months


A002 2592x1944 2021/07/23 14:32:52
2592x1944 2022/12/15 12:03:16 Unit: mm Magnification:

Example considerable growth



- 48months

- 67 months



Conclusions

- **Microscope system successfully implemented for in-field corrosion analysis**
- Corrosion growth not continuous, quick development of spots until stabilization
- Site and material influence the corrosion dynamics (creation & growth of spots)
- “Saturation” reached sooner at high corrosivity site?

Future work/Next steps

- Add measurements, longer period
  - Long term behavior, re-start of growth, creation of spots
- Optimize measurement procedure
  - Automation of image analysis, standardization of image parameters
- Add materials?
- Add sites?
- Deeper analysis
  - Material influence
  - Quantification of growth rate? Modeling
  - Influence of environmental parameters
  - Combination with image analysis, larger areas covered
- Utilize system for further campaigns/tasks

FEMS EUROMAT 23

Thank you for your attention!
Any questions?

Contact: Johannes Wette

johannes.wette@psa.es

INTECSOL

This work is part of the I+D+i Project INTECSOL, PID2021-126664OB-I00, funded by MCIN/AEI/ 10.13039/501100011033 and by the European Regional Development funding.

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

PSA Ciemat

PAC Ciemat DLR

DLR