CORROSION RESISTANCE OF ALUMINIUM AGAINST SALT HYDRATES USED FOR LATENT HEAT STORAGE BY USING DIFFERENT COATING MATERIALS

40 YEARS
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1st Corrosion and Materials Degradation Web Conference -CMDWC 2021-

Online, 17-19 May 2021

Bundesministerium für Wirtschaft und Energie

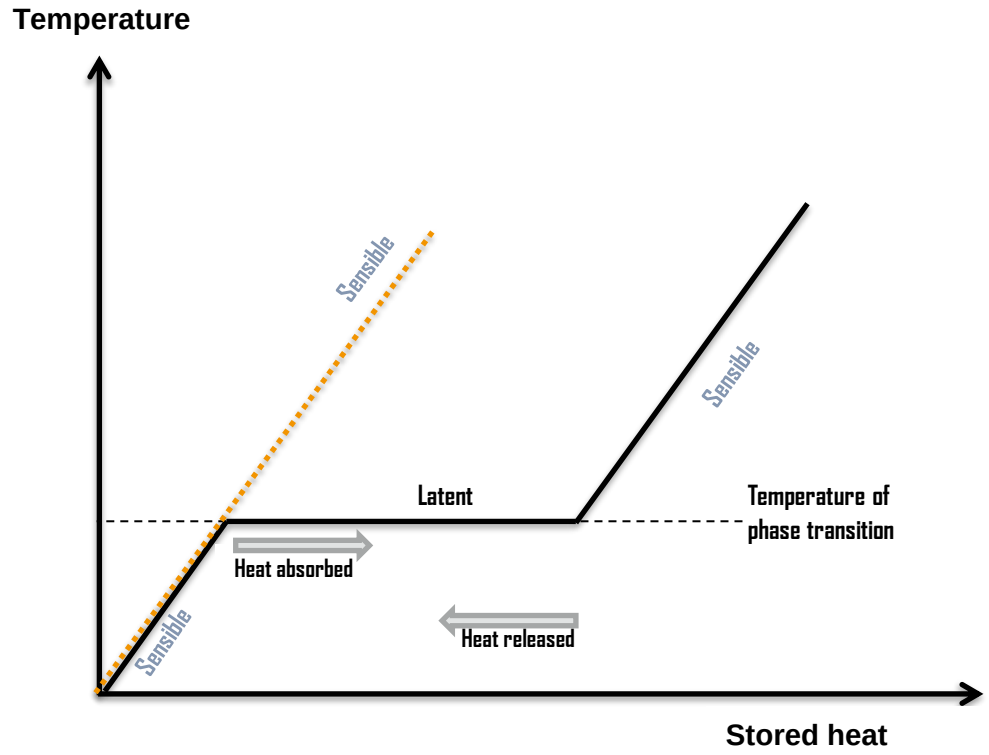
Fraunhofer ISE

AGENDA

- Introduction
  - Thermal Energy Storage (TES)
  - Phase Change Material (PCM)
- Materials and Methods
- Results
- Conclusion

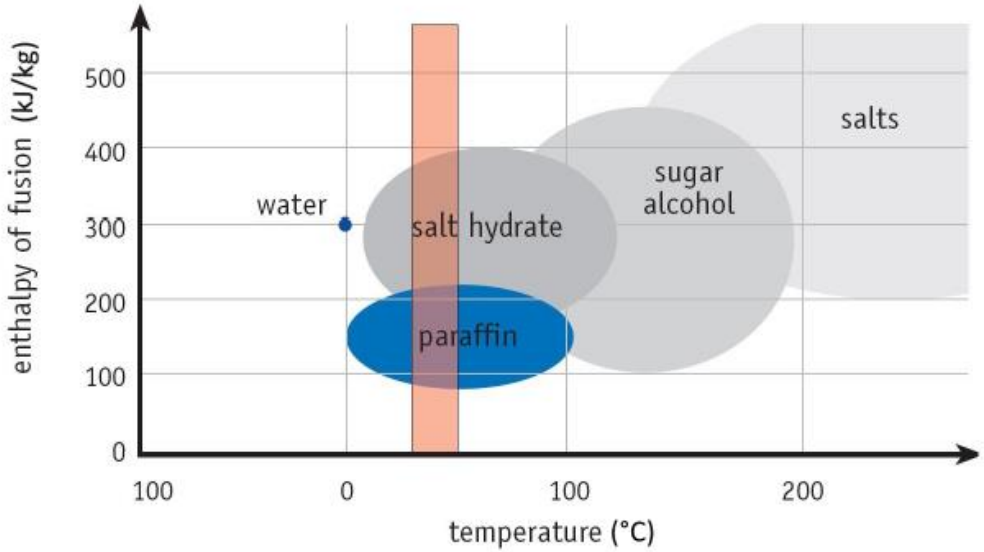
Introduction
Thermal Energy Storage (TES)

- In order to mismatch the gap between energy supply and energy demand, thermal energy storage (TES) is required
- TES holds thermal energy in form of cold or hot substances for later use
- Thermal energy can be stored both as:
  - Sensible heat: material temperature change as a result of the addition or removal of heat
  - Latent heat: based on the heat absorption and release when the storage medium undergoes a phase change (phase change material)



Introduction
Phase Change Material (PCM)

- Phase change materials are substances with high latent heat, which can store and release large amounts of energy at a certain temperature.
- Salt hydrates are widely used as PCM due to:
  - wide range of melting temperatures
  - high heat storage capacity
  - low price
- However, the main disadvantages of salt hydrates as PCM are:
  - tendency to phase separation
  - hygroscopicity
  - **corrosiveness** → additional coating is required for long term stability.

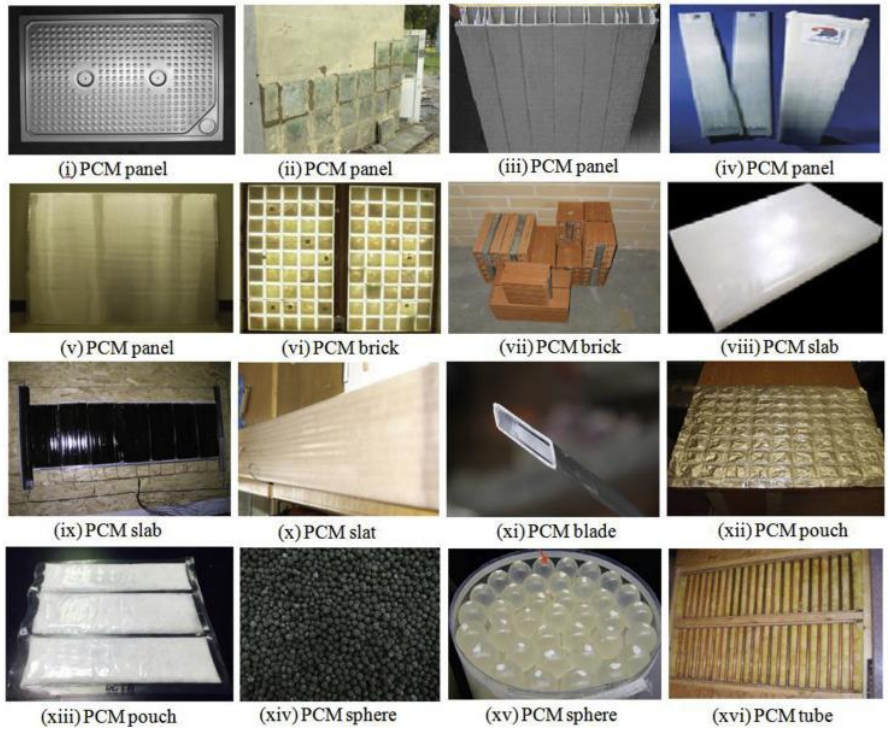


Skovajsa, J.; Koláček, M.; Zálešák, M. Phase Change Material Based Accumulation Panels in Combination with Renewable Energy Sources and Thermoelectric Cooling. Energies 2017, 10, 152. https://doi.org/10.3390/en10020152

Introduction
Phase Change Material (PCM)

- Macroencapsulation (packaging) of PCM provides a self-supporting structure, improves heat transfer and preserves the material composition → Avoid phase separation and high hygroscopicity

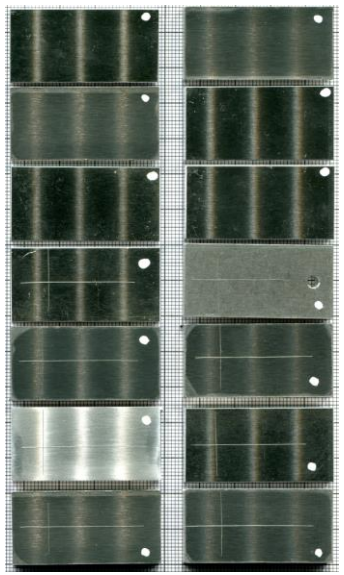
- Corrosion stability of aluminium, as a potential packaging material was investigated in this study.
- In addition, four different coating materials were selected as aluminium protection systems and their compatibility with the chosen salt hydrates were also tested.



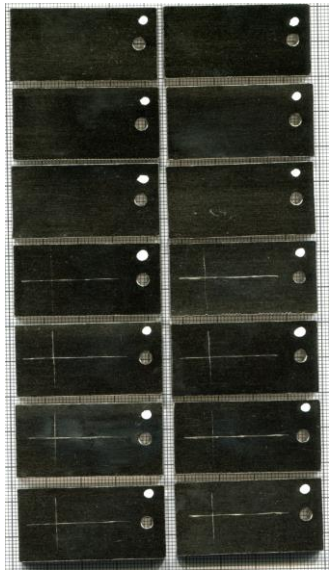
Zhengxuan Liu, Zhun (Jerry) Yu, Tingting Yang, Di Qin, Shuisheng Li, Guoqiang Zhang, Fariborz Haghighat, Mahmood Mastani Joybari. 2018. A review on macro-encapsulated phase change material for building envelope applications, Building and Environment

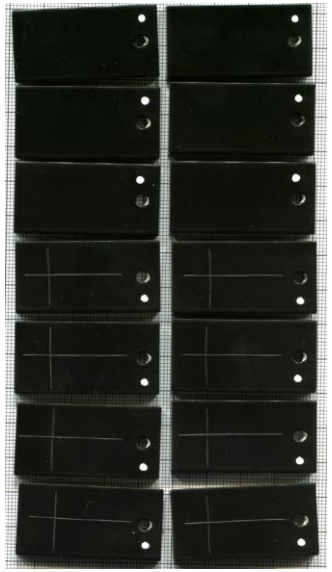
Materials and Methods
Materials

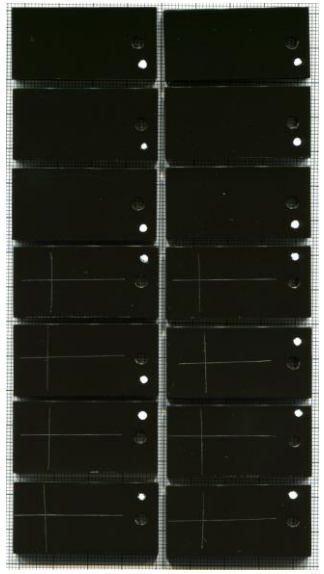
- Both salt hydrates were obtained from Rubitherm and used without further treatment.
  - SP24E ($CaCl_2$, NH_4Cl, KCl and $MgCl_2$)
  - SP50 ($NaNO_3$ and $C_2H_3NaO_2$)
- Al coupons and four different Al coupons-coatings were tested. Dimensions: 40 x 20 x 3 mm


Untreated


Anodized


Electroless Ni-P


Powder coating


Cathodic dip-paint lacquering (KTL)

Materials and Methods

Methodology

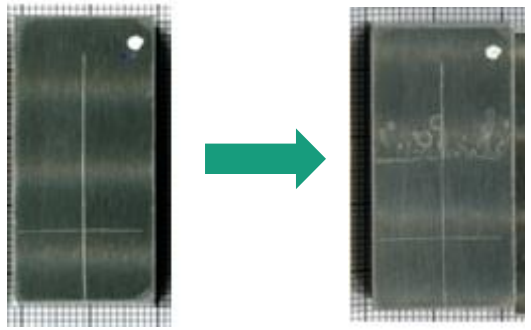
- Methodology adapted from ASTM G1-03 “Standard Practice for Preparing, Cleaning and Evaluating Corrosion Test Specimens”
- Sample preparation
  - Initial cleaning, optical and gravimetric analysis
  - Some coupons were scratched: loss of coating and/or blistering?

- Immersion test
  - Samples immersed in PCM in closed glass bottles and kept above their phase change temperatures: SP24E at 40 °C and SP50 at 60 °C

Materials and Methods

Methodology

- Sample cleaning-up and analysis
  - Coupons removed from the glass bottles after different periods of time → distillated water, abrasive paper and air dry
  - Optical and gravimetric analysis and pH measurement



- Corrosion rate calculation
  - With data collected in the last step

$$C_R = \frac{\Delta m}{A \cdot \Delta t}$$

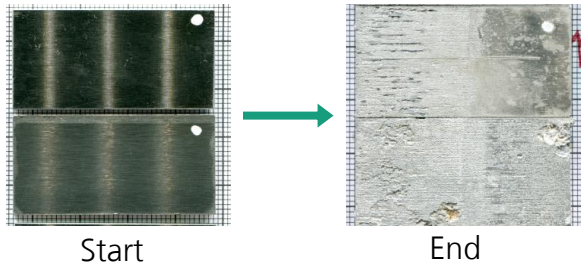
- Values of C_R were evaluated according to the guide for corrosion weight loss used in the industry

Rate	Comment
>1000 mg/cm^2 yr	Completely destroyed within days
100–999 mg/cm^2 yr	Not recommended for service greater than a month
50–100 mg/cm^2 yr	Not recommended for service greater than one year
10–49 mg/cm^2 yr	Caution recommended, based on the specific application
0.3–9.9 mg/cm^2 yr	Recommended for long-term service
<0.2 mg/cm^2 yr	Recommended for long-term service, no corrosion, other than as a result of surface cleaning, was evidenced.

Sastri, Ghali, & Elboujdaini (2007) Introduction and Principles of Corrosion. Introduction and Principles of Corrosion, pp. 1-108

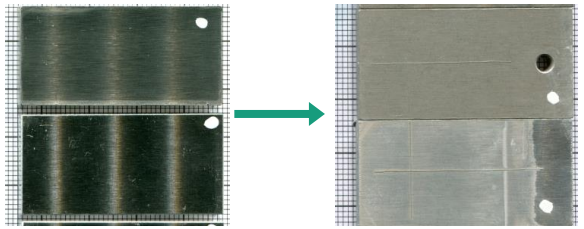
Results
Untreated Aluminium

- SP24E
  - First corrosion traces were observed after 7 days
  - Pitting corrosion (narrow-deep and wide-shallow pits) was found after 79 days.
  - Gray coloration and bubbles formation in glass bottles



Start End

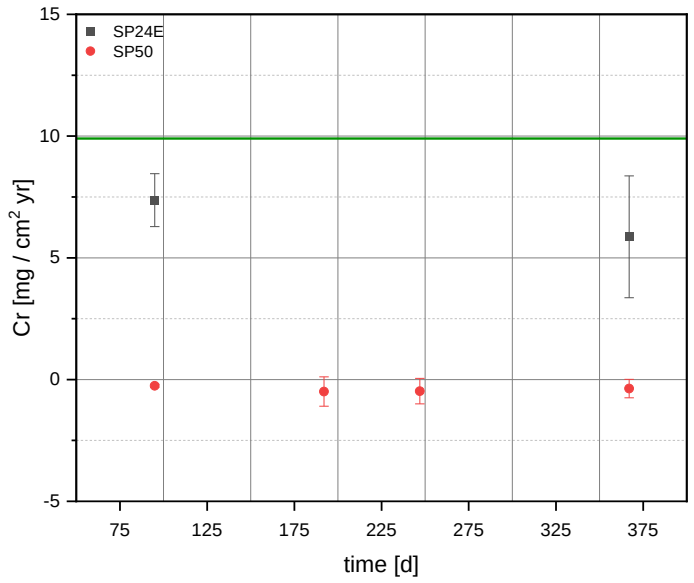
- SP50
  - No traces of corrosion were observed
  - No changes in color, pH or consistency of PCM in the glass bottles were registered.

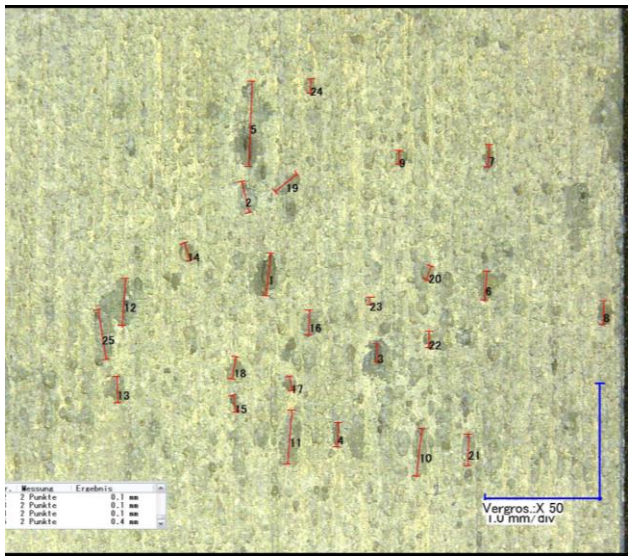


Start End

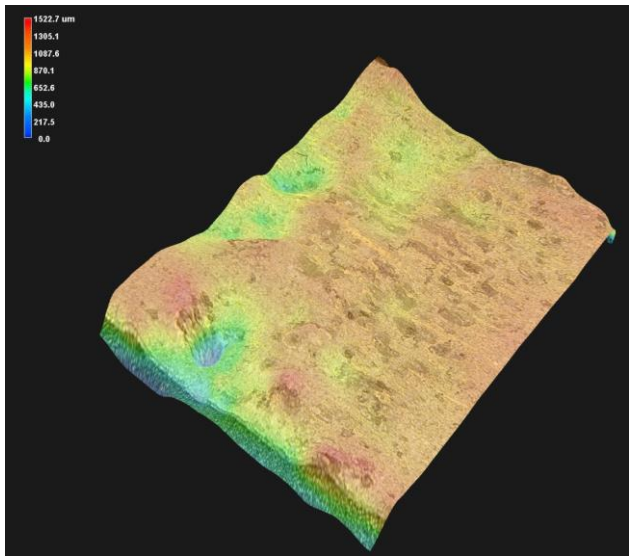
Results
Untreated Aluminium

- Corrosion rate
  - SP24E: 7.4±1.1 mg/cm²year
  - SP50: ≈ 0 mg/cm²year





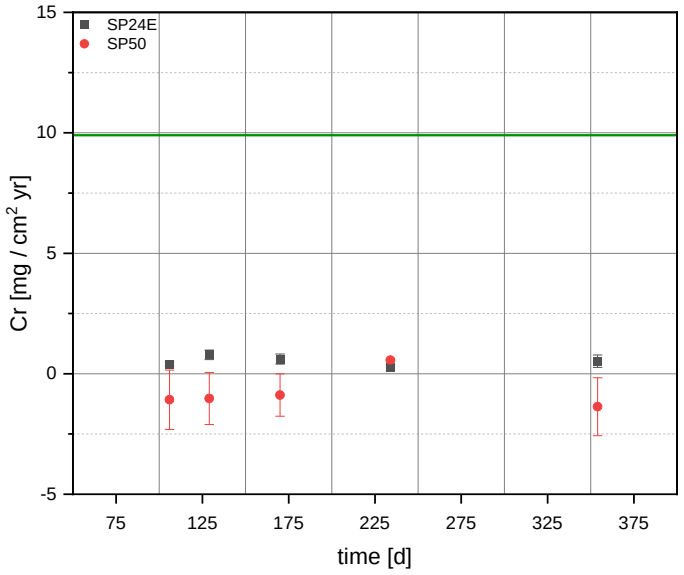
Surface of the untreated aluminium coupon in SP24E by the end of the immersion test

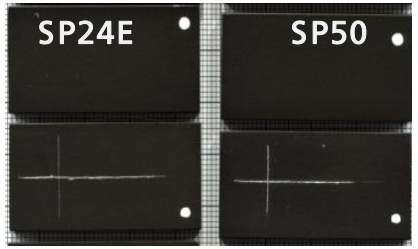


3D representation of the surface of the untreated aluminum sheets in SP24E by the end of the immersion tests

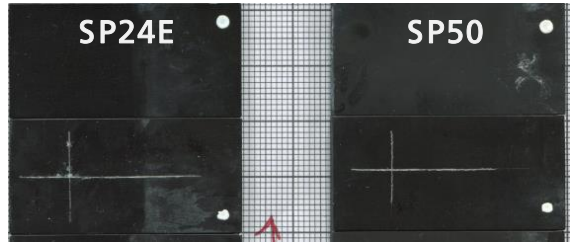
Results
Anodized Aluminium

- No corrosion traces were observed
  - C_R SP24E: 0.8±0.2 mg/cm²year
  - C_R SP50: ≈ 0 mg/cm²year





Start

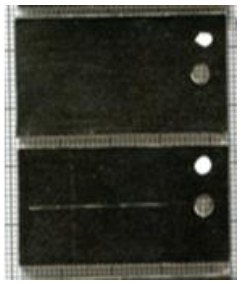


End

Results

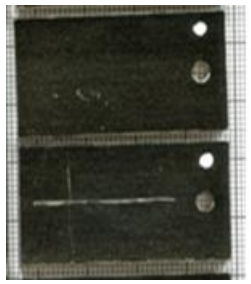
Electroless Nickel-Phosporous

- SP24E
  - First corrosion traces were observed after 7 days
  - Metal degradation after 35 days
  - High bubble formation in glass bottles and low pH value
- SP50
  - Uniform/general corrosion
  - Strong green coloration and bubbling in glass bottles.
  - High pH value



Start

End

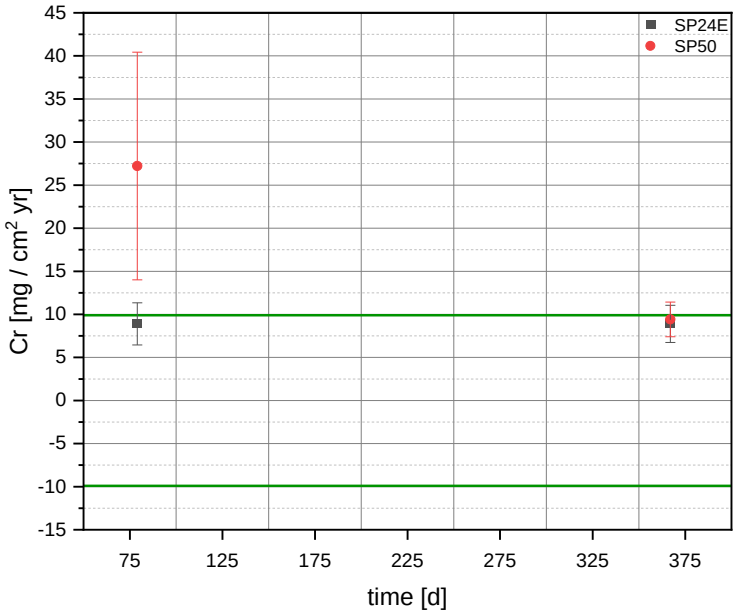


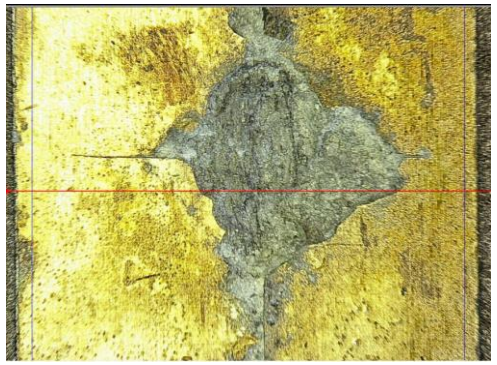
Start

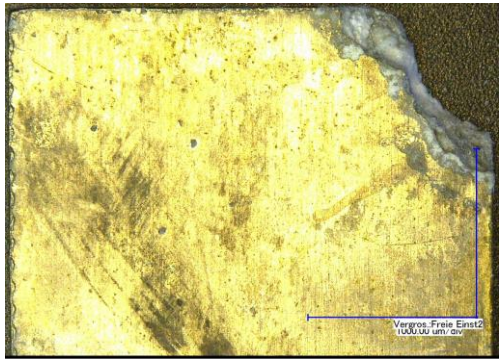
End

Results
Electroless Nickel-Phosporous

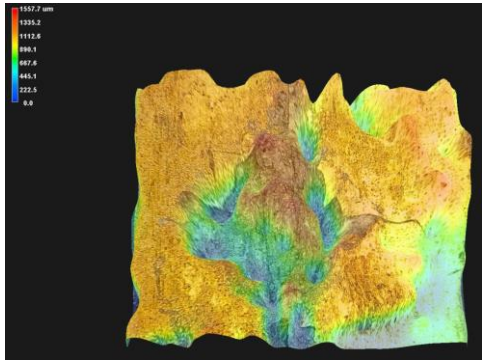
- Corrosion rate
  - SP24E: 8.9±2.5 mg/cm²year
  - SP50: 27.2±13.2mg/cm²year

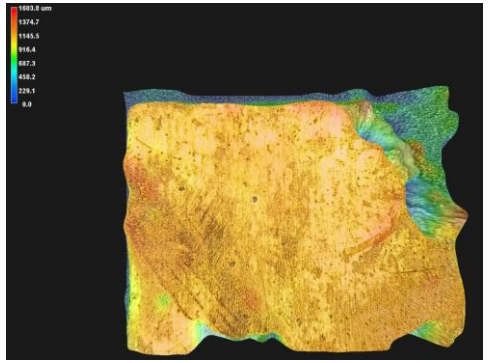






Surface of the untreated aluminium coupon in SP24E by the end of the immersion test

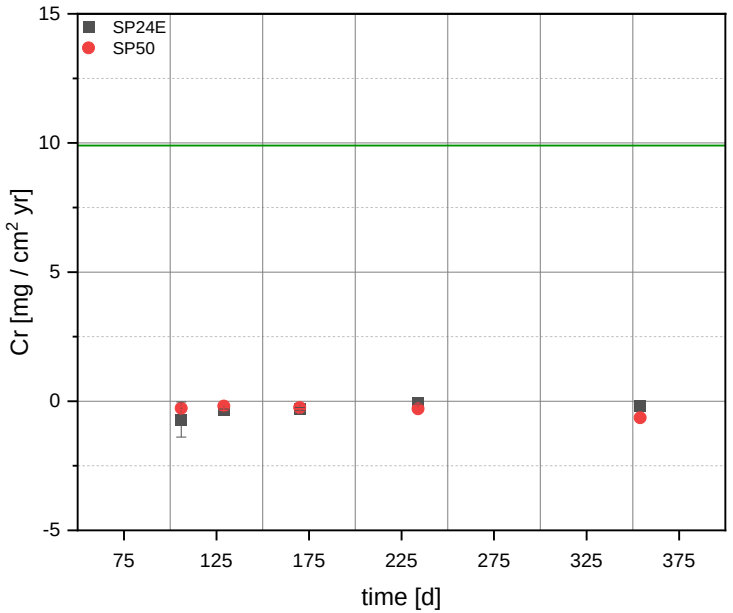


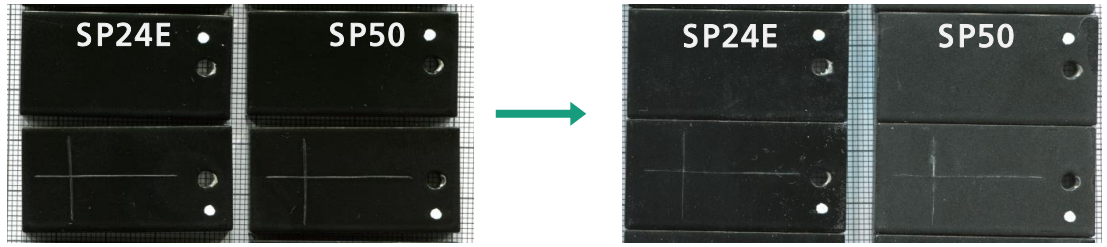


3D representation of the surface of the untreated aluminum sheets in SP24E by the end of the immersion tests

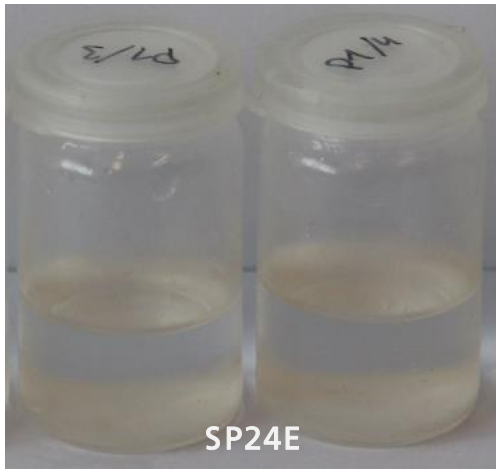
Results
Powder coating

- No corrosion traces were observed
  - C_R SP24E: ≈ 0 mg/cm²year
  - C_R SP50: ≈ 0 mg/cm²year





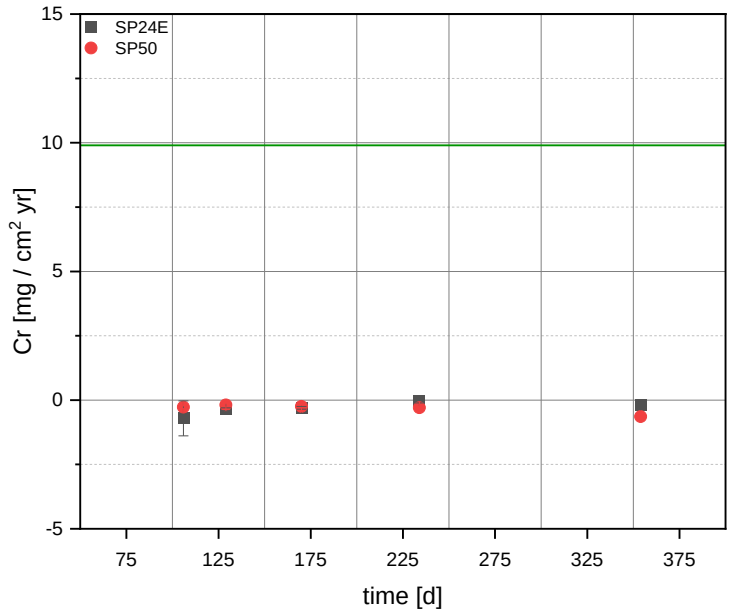
Start End

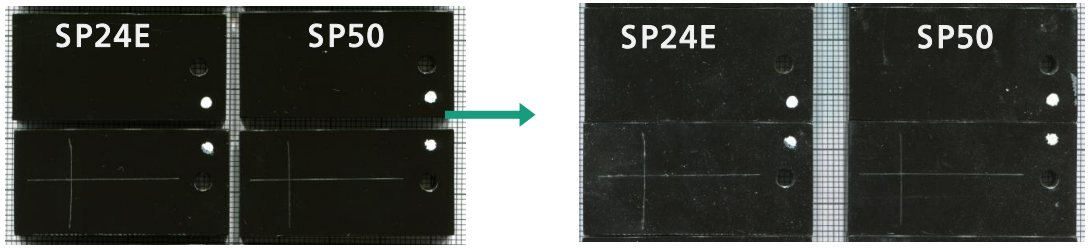


Results

Cathodic dip-paint lacquering (KTL)

- No corrosion traces were observed
  - C_R SP24E: ≈ 0 mg/cm²year
  - C_R SP50: ≈ 0 mg/cm²year





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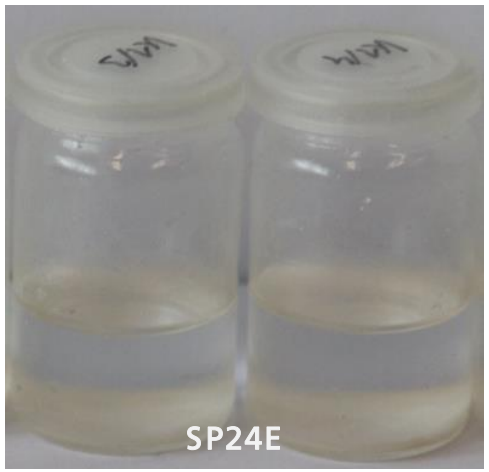


Conclusion

- Chemical compatibility for all tested materials with SP24E and SP50 as determined from the corrosion rates measured at 40°C and 60°C, respectively:

	Untreated	Anodized	Electroless Ni-P	Powder	KTL
SP24E	✗	✓	✗	✓	✓
SP50	✓	✓	⚠	✓	✓

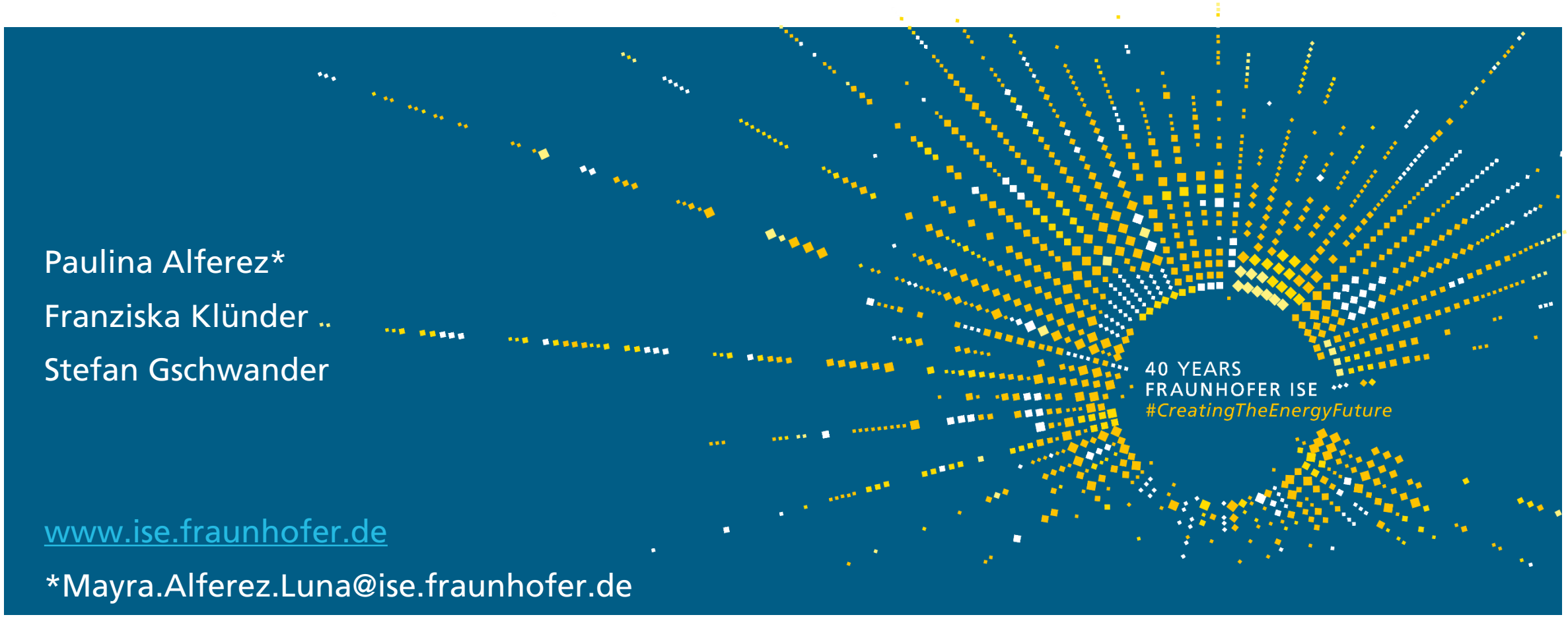
- C_R value of untreated Al with SP24E lies on the “Recommended for long-term service” area. However, severe pitting corrosion was observed.
- Even though C_R value of Al-Electroless Ni-P with SP24E lies on the „Caution recommended, based on specific application“ area, metal disintegration was observed after 35 days.
- Al with electroless Ni-P coating showed uniform corrosion in contact with SP50. Therefore, caution is recommended when using this metal as a long-term container for this PCM.

Thank You for Your Attention!

Paulina Alferez*

Franziska Klünder ..

Stefan Gschwander



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