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

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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.

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, Mahmoodi 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 (CaCl₂, NH₄Cl, KCl and MgCl₂)
  - SP50 (NaNO₃ and C₂H₃NaO₂)
- Al coupons and four different Al coupons-coatings were tested. Dimensions: 40 x 20 x 3 mm
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 → distilled 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

\[
\begin{array}{|l|l|}
\hline
\text{Rate} & \text{Comment} \\
\hline
>1000 \text{ mg/cm}^2 \text{ yr} & \text{Completely destroyed within days} \\
100-999 \text{ mg/cm}^2 \text{ yr} & \text{Not recommended for service greater than a month} \\
50-99 \text{ mg/cm}^2 \text{ yr} & \text{Not recommended for service greater than one year} \\
10-49 \text{ mg/cm}^2 \text{ yr} & \text{Caution recommended, based on the specific application} \\
5-9.9 \text{ mg/cm}^2 \text{ yr} & \text{Recommended for long-term service} \\
<0.5 \text{ mg/cm}^2 \text{ yr} & \text{Recommended for long-term service, no corrosion, other than as a result of surface cleaning, was evidenced.} \\
\hline
\end{array}
\]

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

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

![Images of untreated aluminium samples at start and end of experiment](image_url)
Results

Untreated Aluminium

- Corrosion rate
  - SP24E: 7.4±1.1 mg/cm²/year
  - SP50: ≈ 0 mg/cm²/year

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

3D representation of the surface of the untreated aluminium sheets in SP24E by the end of the immersion tests
Results
Anodized Aluminium

- No corrosion traces were observed
  - CR SP24E: 0.8±0.2 mg/cm²·year
  - CR SP50: ≈ 0 mg/cm²·year
Results

Electroless Nickel-Phosphorous

- **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
Results

Electroless Nickel-Phosphorous

- Corrosion rate
  - SP24E: 8.9±2.5 mg/cm²/year
  - SP50: 27.2±13.2 mg/cm²/year

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

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

Powder coating

- No corrosion traces were observed
  - \( C_R \text{ SP24E: } \approx 0 \text{ mg/cm}^2\text{year} \)
  - \( C_R \text{ SP50: } \approx 0 \text{ mg/cm}^2\text{year} \)
Results
Cathodic dip-paint lacquering (KTL)

- No corrosion traces were observed
- $C_R \text{ SP24E}: \approx 0 \text{ mg/cm}^2\text{year}$
- $C_R \text{ SP50}: \approx 0 \text{ mg/cm}^2\text{year}$
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:

<table>
<thead>
<tr>
<th></th>
<th>Untreated</th>
<th>Anodized</th>
<th>Electroless Ni-P</th>
<th>Powder</th>
<th>KTL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP24E</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>SP50</td>
<td>✓</td>
<td>✓</td>
<td>!</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

- $C_R$ 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!

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