Coatings for Heat Storage Reactors with Hygroscopic Salts (MERITS project)

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Seasonal Heat Storage for the build environment

- Business case
  - Yearly heat demand of single family dwelling versus solar energy supply
  - Typical house in NL → Store 10GJ for cold season
  - Hot water storage 90°C → 50m³
  - Thermochemical storage → 5m³ (compact)
The international MERITS consortium is working on a new solution for improved use of renewable sources for heating and cooling and hot water applications in individual dwellings (new & existing) for all three European climate zones.

The aim is to build a prototype of a fully functioning compact rechargeable thermal battery that would fit in for example a cellar or underground a garden including business models and market strategies to foster market take-up before 2020.
Thermochemical heat storage (TCS) system

System level

- Balancing supply & demand
- Dimensioning heat & power
- Open/closed system?
- Vacuum/atmospheric?

Component level

- HX implementation
- **HX corrosion prevention**
- Evap/Cond implementation
- Reservoir implementation

Material level

- TCM type
- Composite TCM development
- Cycling stability
- Q/V, vapor & heat transport

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1 AJ de Jong et al, SHC 2013
2 This presentation
3 M. Roelands et al, SHC 2014
Corrosion protection of heat exchanger (HX)

Preferred HX for MERITS
- Cu tubes, Al fin plate → Low cost, mass production, good heat conductivity

Challenges
- Protect Cu and Al in corrosive Na$_2$S environment (coating)
- Complex geometry & sharp fin plates → Difficult for coating application(!)
- Non-destructive coating testing for all HX used within MERITS system
Coating testing

› Testing methods
  › Visual inspection
  › Electric Impedance Spectroscopy → Pinholes
  › Exposure to Na$_2$S, vacuum, T-changes

› Samples (Epoxy coating applied by E-coating)
  › Flat samples
  › Complete Heat Exchanger
EIS flat samples – Setup

Electrolyte (1M H$_2$SO$_4$)

Electrode

Cylinder

Coating

Sample

Pinhole (defect)
**EIS flat samples – Method**

- **No defects**

  ![Diagram of EIS flat samples with no defects]

  - Equivalent network
  - Bode plot

- **Pinhole present**

  ![Diagram of EIS flat samples with pinhole present]

  - $R_{ct} = \text{charge transfer resistance}$
  - $\propto \frac{1}{\text{defect area}}$

  - Equivalent network
  - Bode plot
EIS flat samples – Results

1. Straight line → no defects
2. Height scales with area → no stray capacity
3. Since $R_{ct}$ is related to the defect area we can use the artificial defect with known area to calibrate the measurement
4. If the impedance spectrum is monitored for 24h the defect develops ($R_{ct}$ decreases)

| $f$ [Hz] | $|Z|$ [Ohm] |
|----------|-------------|
| 10       | 10          |
| 100      | 100         |
| 1000     | 1000        |
| 10000    | 10000       |

No defects

Artificial defect (puncture)
EIS flat sample – Results for edges

› No perfect Capacitor behaviour → Are edges more prone to defects?
› Edges covered with tape → Reduced defect area!
› Microscopy → Bubbles, pinholes near edges
EIS of complete heat exchanger

- Immersion of only Cu tubing → Acceptable
- Immersion until first fin → Defect area \( \geq 10\text{mm}^2 \)
- Immersion 10cm → Defect area \( \geq 30\text{mm}^2 \)
- Conclusion → heat exchanger coating contains pinholes
Conclusions

› Conclusions impedance testing
  › Valuable electric impedance setup realized for coating testing!

› Conclusions HX coating
  › Surface of flat Al-samples contains no defects
  › Edges of flat Al-samples are prone to defects
  › Heat exchanger shows defects on fins
Thank you.

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