Electrochemical Mitigation of Corrosion in Molten Chloride Salts During CSP Plant Operation

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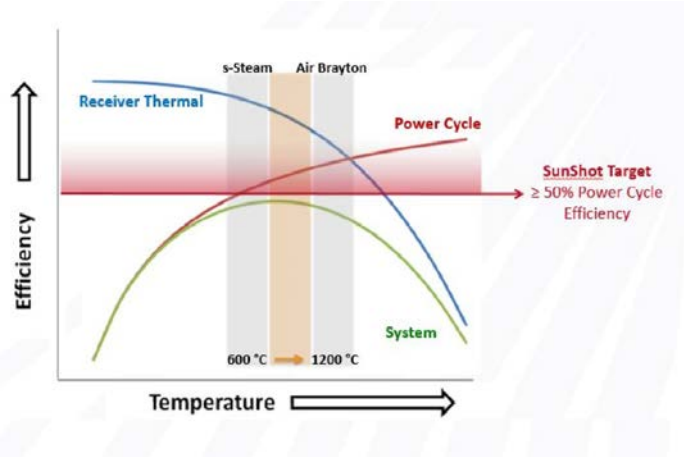
Molten Chloride Salt

Molten chloride salts are stable at higher temperatures than other molten salts

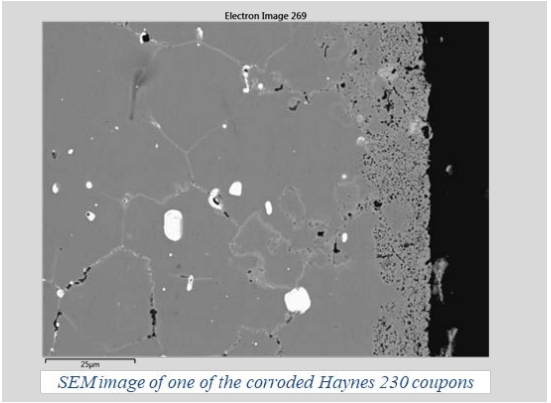
- Could enable more efficient operation of CSP plants, leading to lower LCOE
- Also useful for other reactors types (nuclear, electrochemical synthesis, etc.)

For this work, we are using a ternary $NaCl/KCl/MgCl_2$ salt

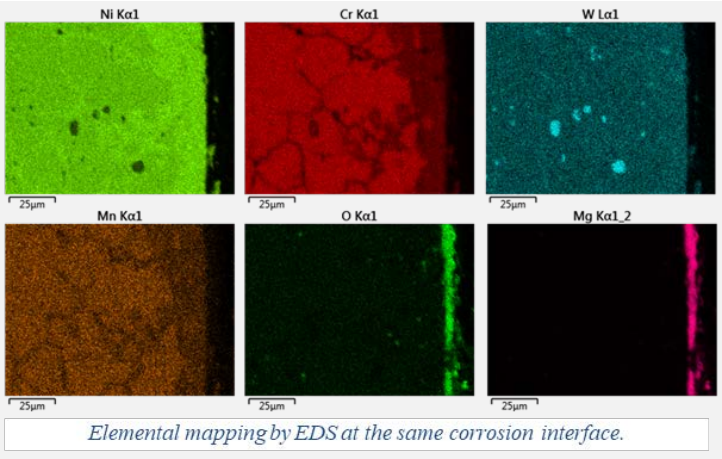
- Has favorable properties including low melting point
- Can be inexpensively sourced



Problem: Molten chloride salts are corrosive! The corrosive impurity MgOHCl forms in salt when exposed to H_2O.



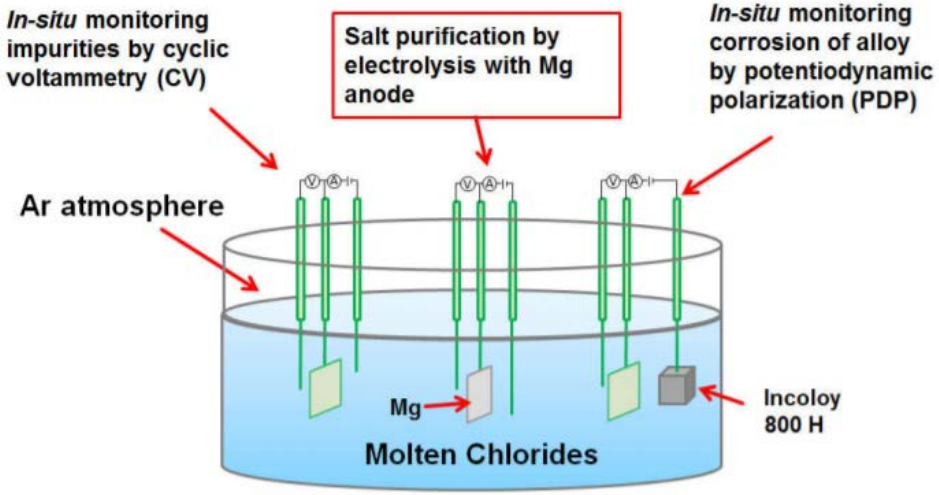
SEM image of one of the corroded Haynes 230 coupons



Elemental mapping by EDS at the same corrosion interface.

Alloy	OCP vs. pseudo-RE [mV]	E_{corr} vs. pseudo-RE [mV]	j_{corr} [µA/cm^2]	CR [mm/year]
650 °C				
SS347	–784±113	–847±91	713.00±30.74	7.49±0.32
SS310	–888±170	–938±218	626.16±38.72	6.42±0.40
In800H	–876±32	–910±22	573.79±34.19	5.94±0.33
IN625	–849±73	–856±57	233.00±94.68	2.80±0.38
700 °C				
SS310	–506±70	–571±75	1213.61±148.10	12.45±1.52
In800H	–453±5	–474±3	1387.79±131.96	14.31±1.36

Gomez-Vidal, J. C.; Tirawat, R., Solar Energy Materials and Solar Cells. **2016**



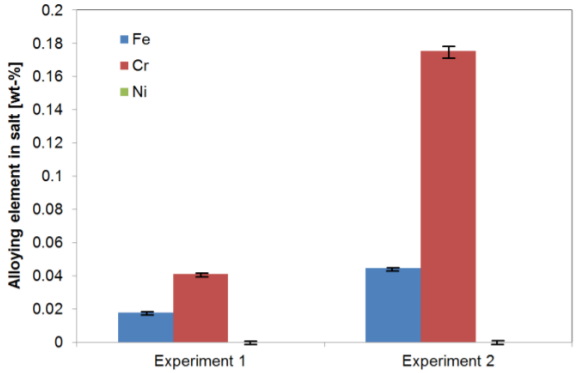


Figure 13: Alloying elements Cr, Fe and Ni dissolved in the chloride salts after 450 h (Experiment 1, purified salt) and 340 h (Experiment 2, unpurified salt) exposure, measured with AAS. Ni Content is below the detection limit of AAS (10 ppm in weight). The error bar represents the standard deviation of three measurements.

Ding, W.; et. Al. *Solar Energy Materials and Solar Cells* **2019**.

MgOHCl can be removed using electrolysis!

$2MgOHCl \rightarrow 2MgOH^+ + 2Cl^-$ [*molten salt*]

$Mg^{2+} + 2Cl^- \rightarrow MgCl_2$ [*molten salt*]

$2MgOH^+ + 2e^- \rightarrow 2MgO + H_2(g)$ [*cathode*]

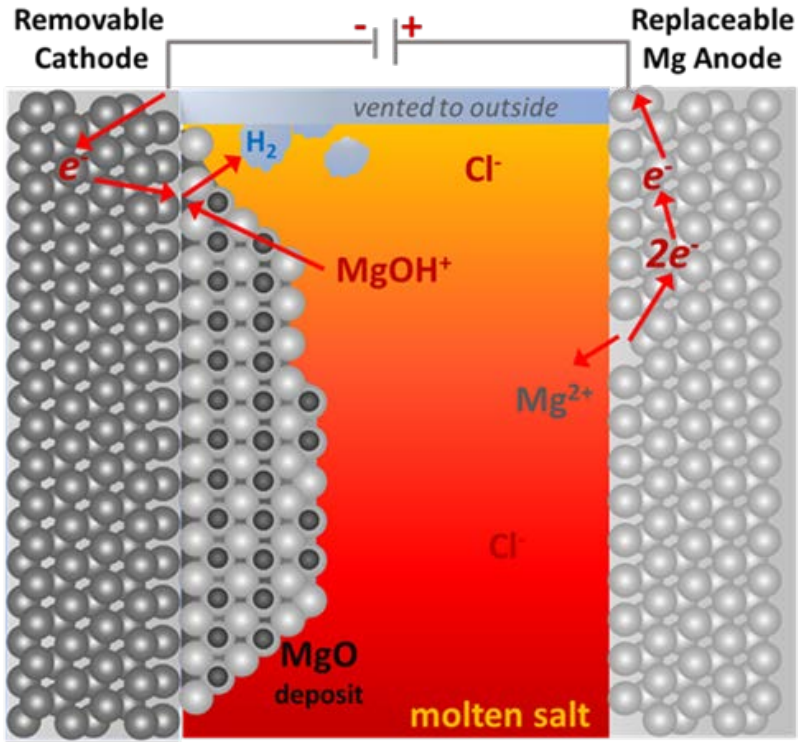
$Mg(s) \rightarrow Mg^{2+} + 2e^-$ [*anode*]

$2MgOHCl + Mg(s) \rightarrow MgCl_2 + 2MgO + H_2(g)$ [*overall reaction*]

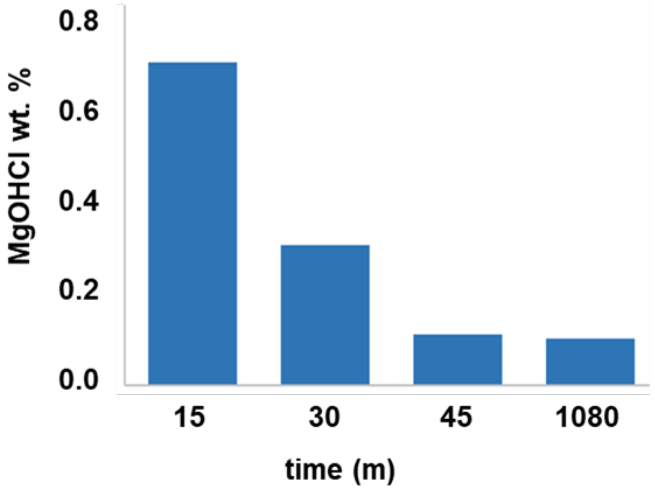
Goal: Design a purification cell for a Gen3 CSP Plant

overall reaction:

$MgOH^+ + e^- \rightarrow MgO_{(s)} + \frac{1}{2}H_{2(g)}$



Lattice strain minimized at interface



Lab Scale Results

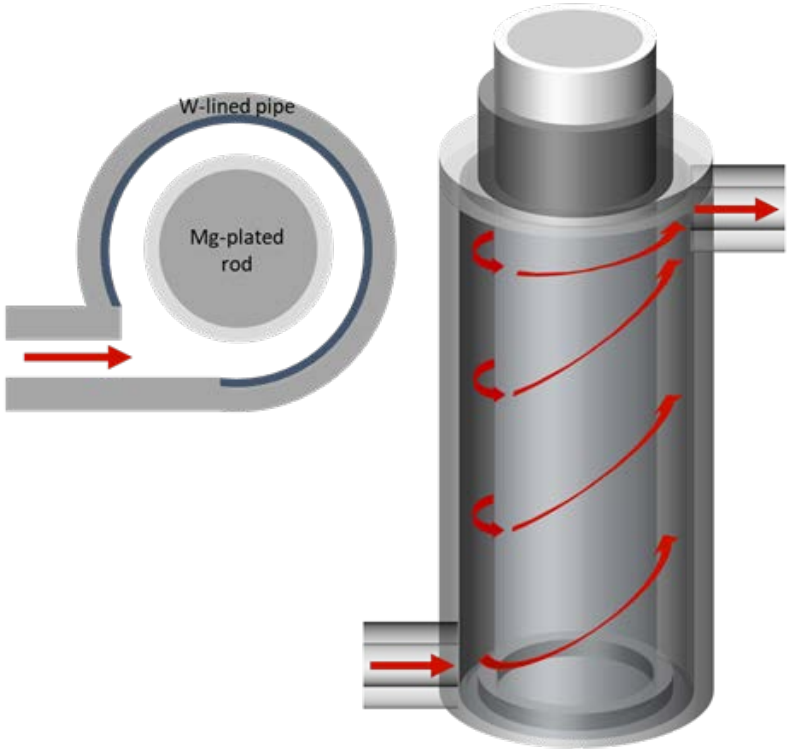
- **Titration**
- **CV**
- **H_2 detection**

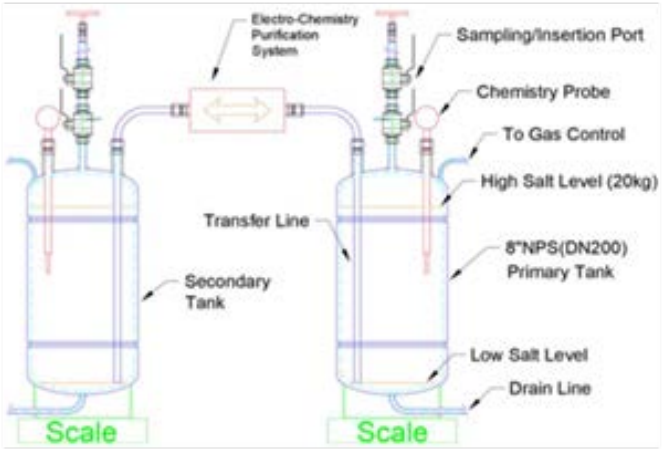
In a lab-scale batch reactor, MgOHCl can be reduced to target 0.1 wt% in about 45 min.

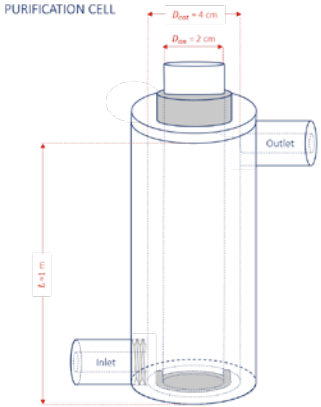
Challenges:

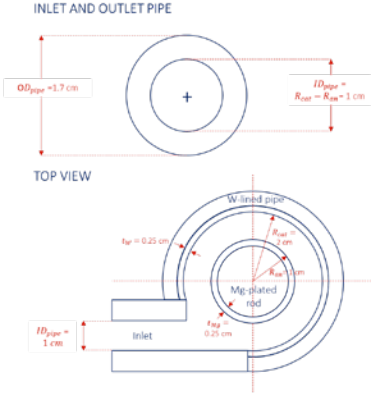
- **Mass Transfer**
- **Passivation of electrode due to MgO buildup**

We believe these challenges will be mitigated in a flow cell









Outlook and next steps:

- **Building a lab-scale flow system and flow purification cell**
- **Evaluate and optimize kinetics for *in-situ* control of corrosive impurities during operation of molten-chloride salt based CSP plants**
- **Maintenence cost, materials costs, and ultimately LCOE of CSP could be reduced**

Thank you for your attention!

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