High Temperature Corrosion in systems for heat storage (corrosion in melts for concentrated thermal solar power)

HTC 3b

Project overview

Project manager: L.-G. Johansson, Chalmers

Company stakeholders: Kanthal, Sandvik Materials Technology (SMT), Azelio

Company representatives: M. Lundberg (SMT/KTH), J. Nockert Olovsjo (Kanthal), N. Köppen.

Universities: Chalmers, KTH

Senior researchers: L.-G. Johansson, C. Geers, J.-E. Svensson, P. Szakalos

PhD students: P. Dömstedt (KTH) E. Hamdy (Chalmers)

Project overview

- The project deals with the corrosion of high temperature alloys by melts used for heat transport and heat storage in Concentrating Solar Power (CSP) plants

- The goal is to generate new ideas and strategies for solving the serious materials challenges facing this industry

Project overview

<u>The project has two parts:</u>

- ❑**Corrosion in salt melts**

(Chalmers, Kanthal, Sandvik Materials Technology)

Molten salt is used both to store the heat and to transport it to the boiler where power is generated

- ❑**Corrosion in molten aluminium**

(*KTH, Azelio)*

In this new concept by Azelio, the power is generated by a Stirling engine. The latent heat of melting of aluminium is used to store thermal energy in the process

I. Corrosion in Salt Melts

STATE OF THE ART!

Concentrating Solar Power Gen3 Demonstration Roadmap

Mark Mehos, Craig Turchi, Judith Vidal, Michael Wagner, and Zhiwen Ma
National Renewable Energy Laboratory
Golden, Colorado

Clifford Ho, William Kolb, and Charles Andraka
Sandia National Laboratories
Albuquerque, New Mexico

Alan Kruizenga
Sandia National Laboratories
Livermore, California

CORROSION!!!

The SunShot Initiative 2030

- The 2030 target for concentrated solar power plants (CSP) **≤ 6 hr** of energy storage is **$0.10** per kw-hr.
- For CSP baseload plants with **≥12** hr of energy storage is **$0.05** kw-hr
- High energy conversion efficiency
- To achieve the targeted **cycle efficiency,** the solar energy collected by the receiver and stored in TES must be delivered to the **power turbine** at a **temperature at or above 700°C.**

Mehos, M., *et al.*, NREL, Concentrating Solar Power Gen3 Demonstration Roadmap. In Nrel/Tp-5500-67464, 2017; pp 1-140.

The corrosion experiments

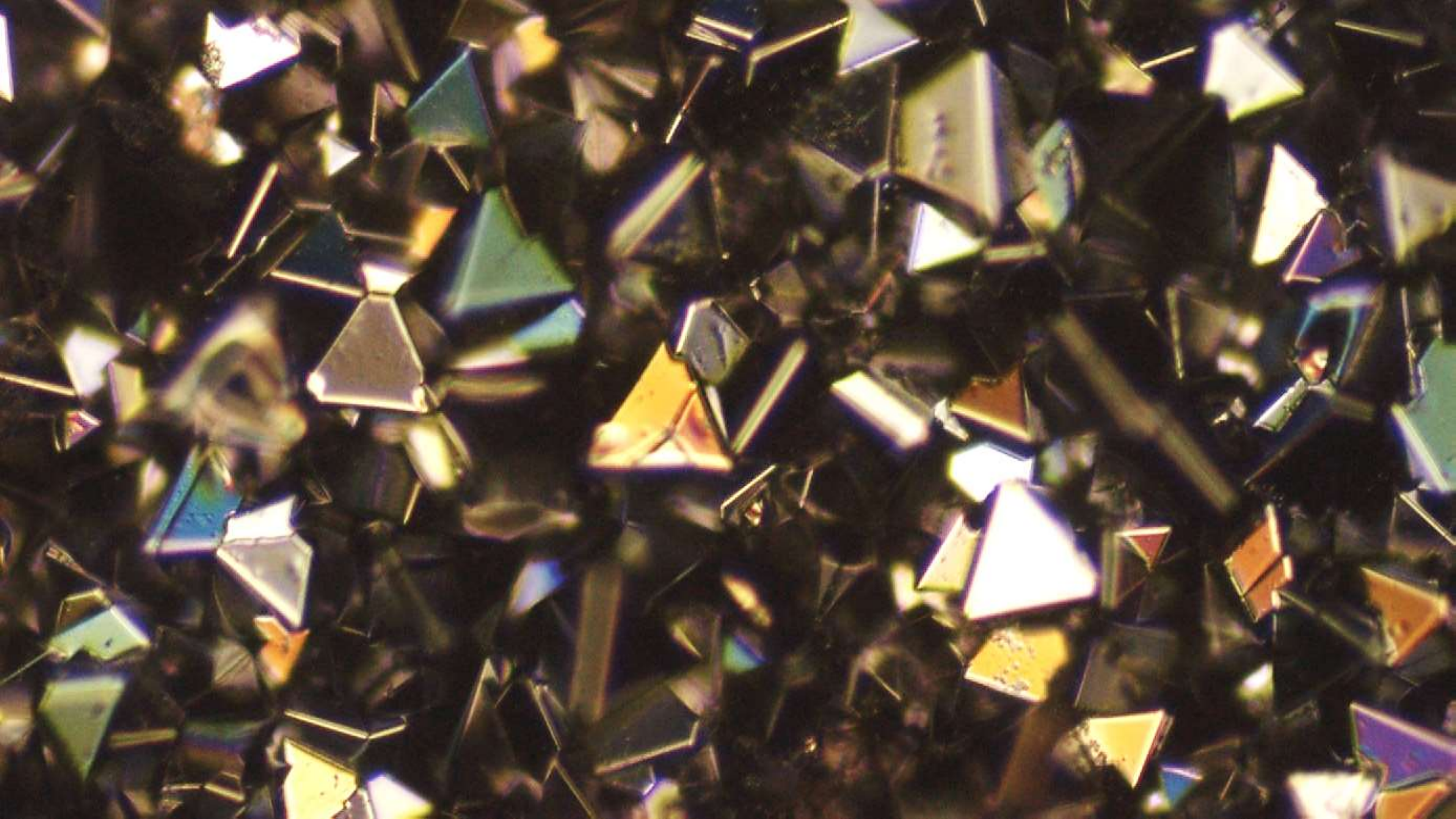
32.1 Li_2CO_3-33.4 Na_2CO_3-34.5 K_2CO_3

- **Chromia Former vs. Alumina Former**

  304L vs. Kanthal© APMT

- **Gas flow, CO_2 50 ml/min**
- **Temp: 800°C**
- **Exposure Time: 72 h, 168, 500 & 1000 h**

Why is Kanthal© APMT a very good candidate ?



MASS GAIN OF 304L AND KANTHAL© APMT IN CARBONATE MELTS AT 800°C

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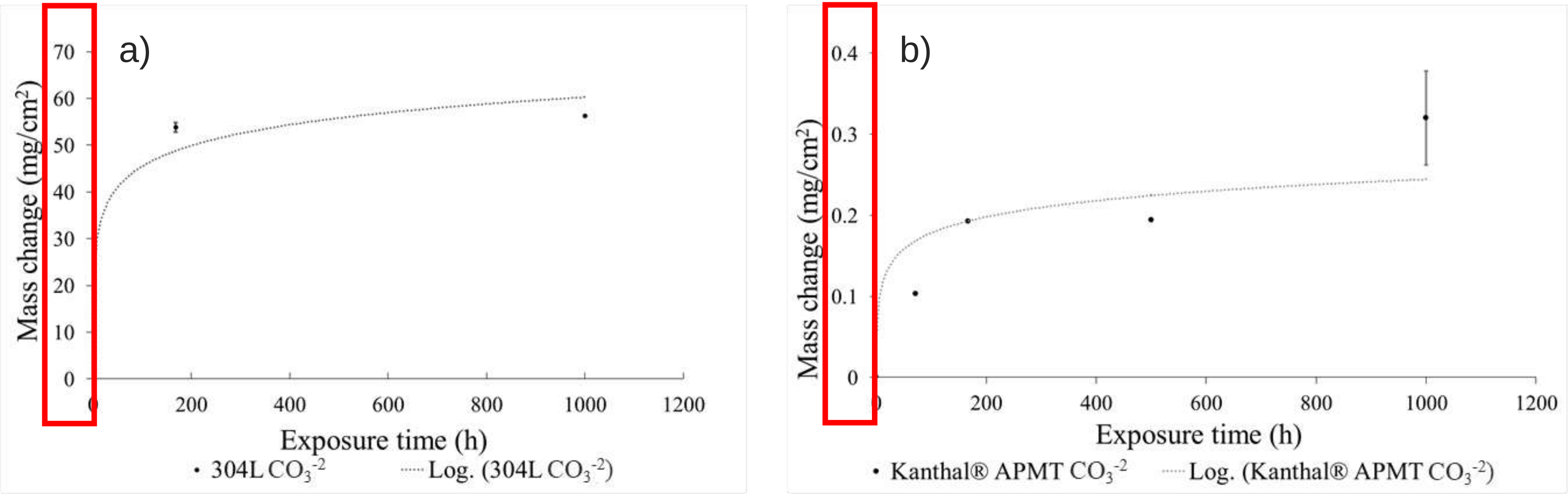
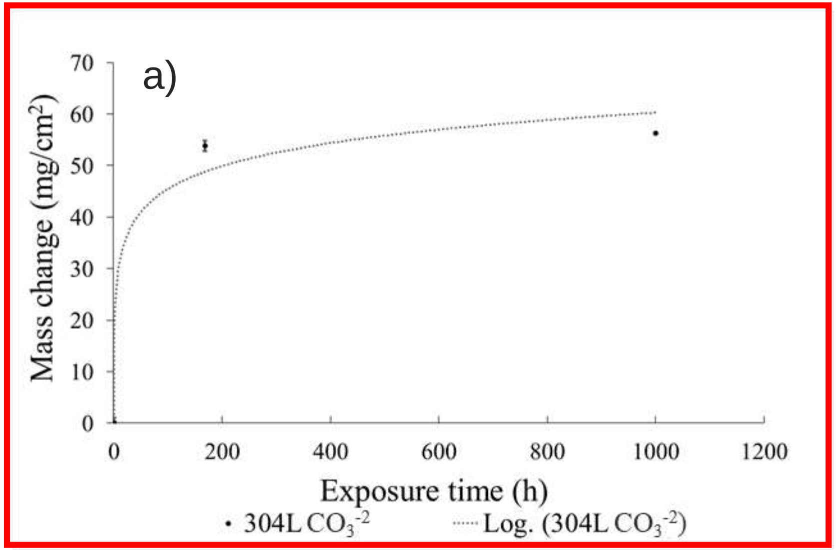
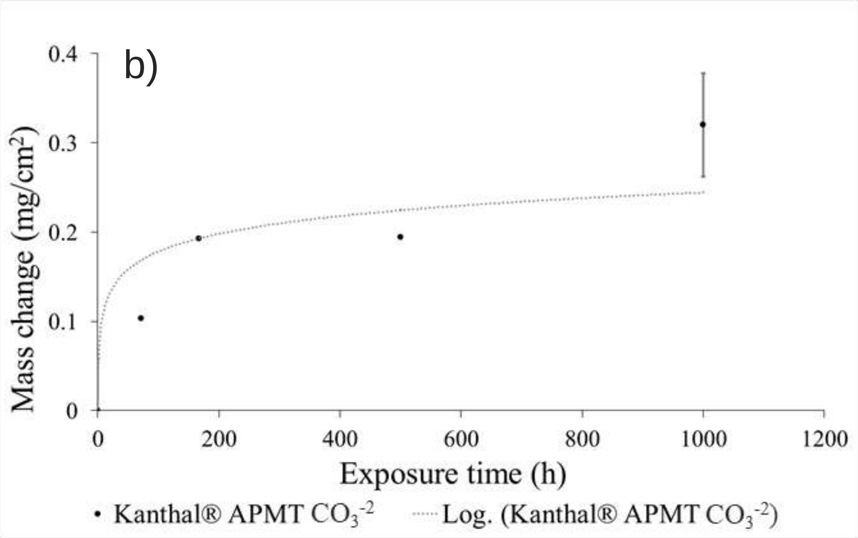


a) mass gain of Kanthal® APMT in carbonate melt and trendline, b) mass gain of alloy 304L in carbonate melt and trendline

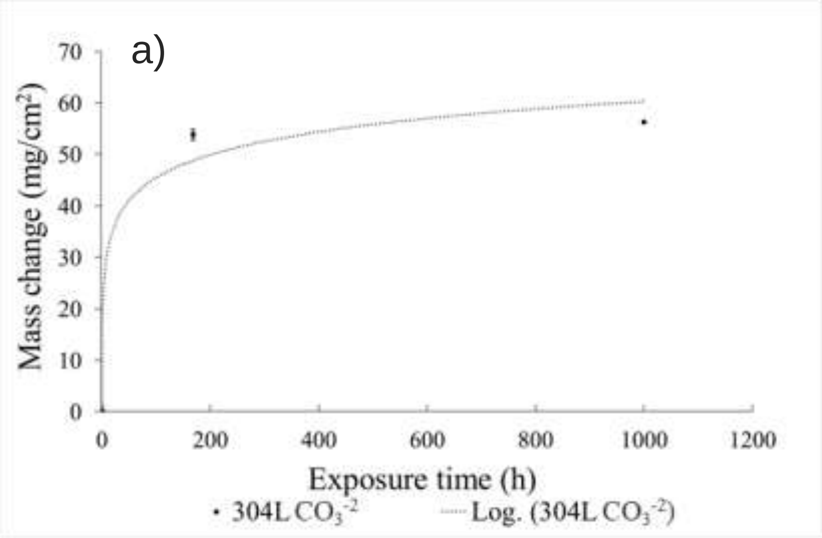
MASS GAIN OF 304L AND KANTHAL© APMT IN CARBONATE MELTS AT 800°C





a) mass gain of Kanthal® APMT in carbonate melt and trendline, b) mass gain of alloy 304L in carbonate melt and trendline

MASS GAIN OF 304L IN CARBONATE MELTS AT 800°C



Microstructural analysis section, indications corrosion-dissolution process!

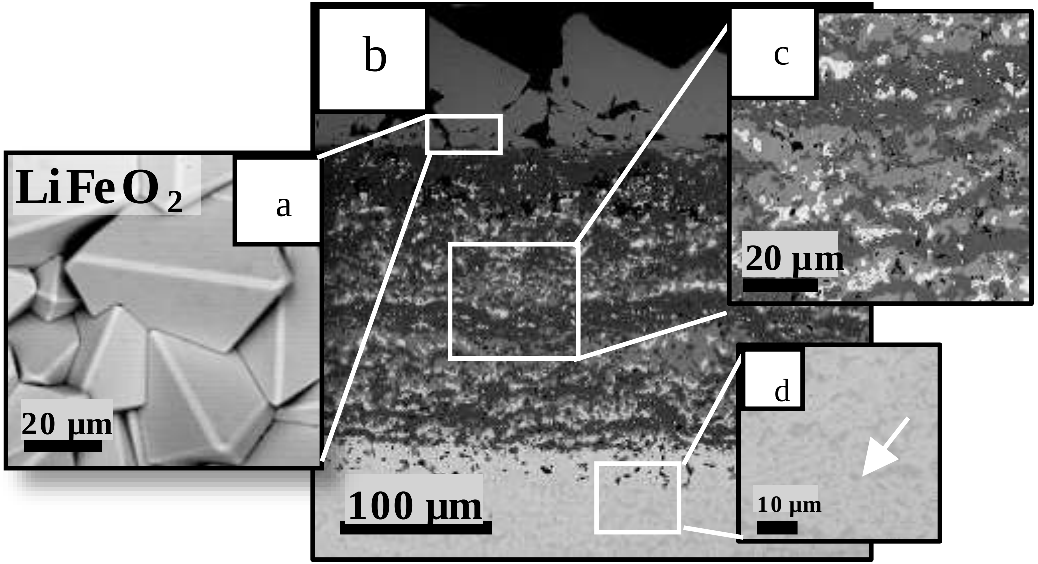
Salt color!

EDS analysis

ICP-OES

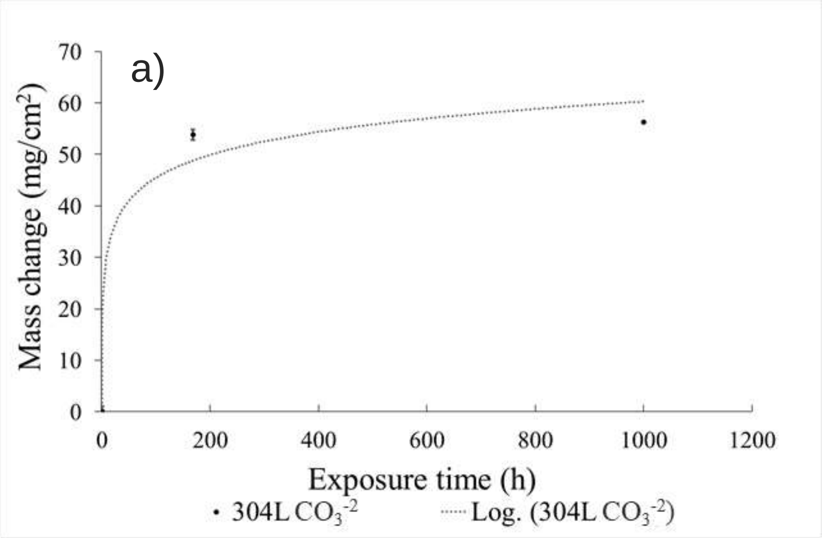
a) mass gain of Kanthal® APMT in carbonate melt and trendline

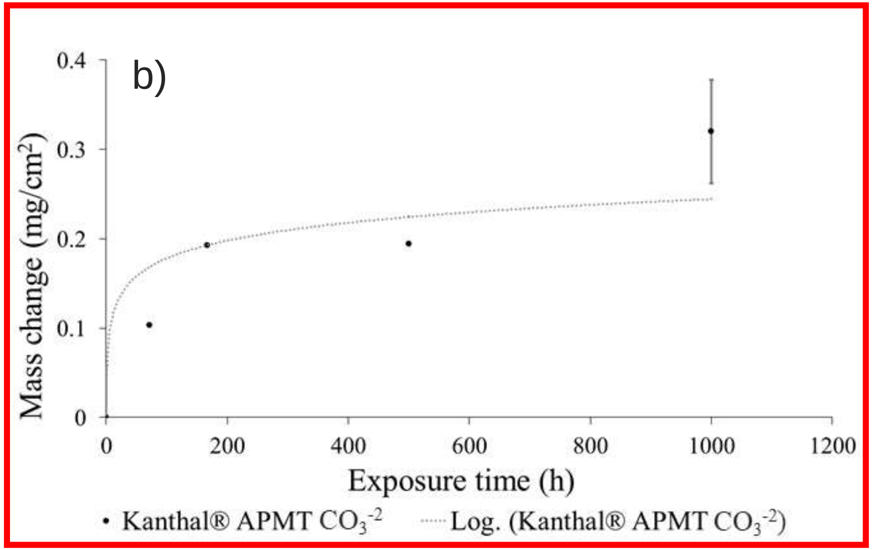
304L , CARBONATE MELT, 800 °C, 1000 H



a) SEM surface morphology of 304L alloy exposed to carbonate melt at 800 °C for 1000h, b, c) SEM cross section of 304L alloy exposed to carbonate melt at 800 °C for 1000h and d) High magnification cross section image showing carbide precipitates.

MASS GAIN OF 304L AND KANTHAL© APMT IN CARBONATE MELT AT 800°C





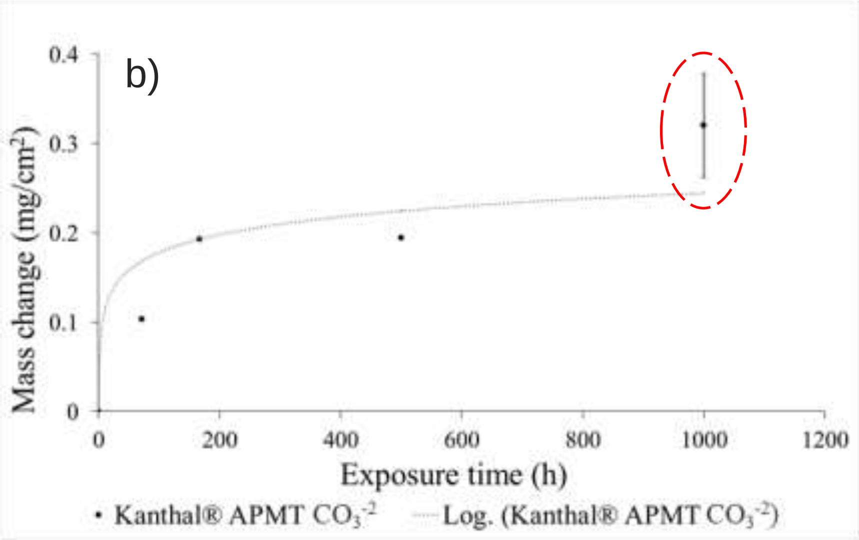
a) mass gain of Kanthal® APMT in carbonate melt and trendline, b) mass gain of alloy 304L in carbonate melt and trendline

MASS GAIN OF KANTHAL© APMT IN CARBONATE MELT AT 800°C

Aluminum consumption?!

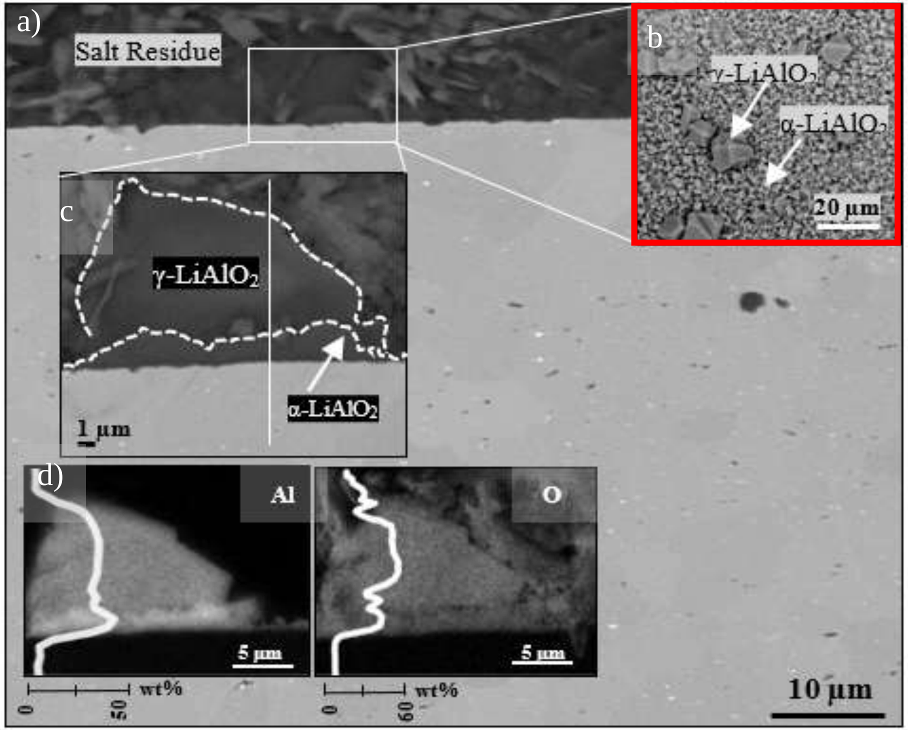
Short-term exposure: α-$LiAlO_2$

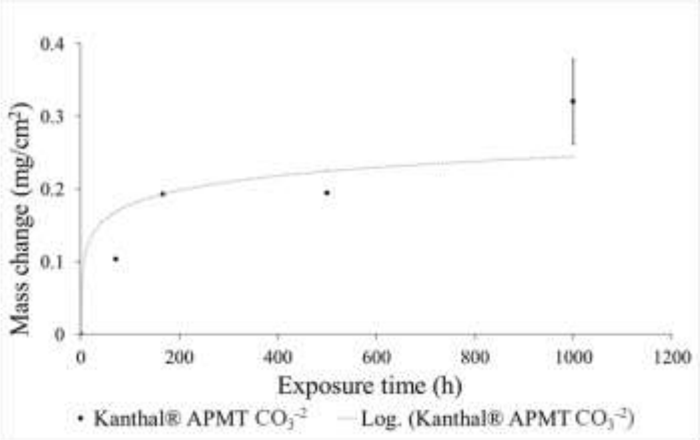
Long-term exposure: α-$LiAlO_2$ & γ-$LiAlO_2$



b) mass gain of alloy 304L in carbonates and trendline

KANTHAL APMT, CARBONATE MELT, 800 °C, 1000 H





No Internal Attack!

SEM surface morphology of Kanthal APMT alloy exposed to molten carbonate salt mixture at 800 °C for 1000h .

Summary

- **304L**
  - Carbide precipitation reaches several hundred micrometers after 168 h, altering the overall stainless-steel chemistry.

- **Kanthal© APMT**
  - Nearly unaffected and does not suffer internal attack.
  - Slow conversion of the film-forming α-$LiAlO_2$ to the larger γ-$LiAlO_2$ crystallites.
  - Long-term effect on aluminum consumption needs further evaluation.

PUBLICATION SUBMITTED!

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THANK YOU!