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Corrosion Behavior of SS316H in Non-isothermal Fluoride Fuel Salt

Woo-Hyuk Lee, Amanda Leong, Jinsuo Zhang

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woohyuklee@vt.edu

VIRGINIA TECH

What is special about corrosion testing system?

Experimental methods

- No loop

- A sealed system (Ar cover gas)

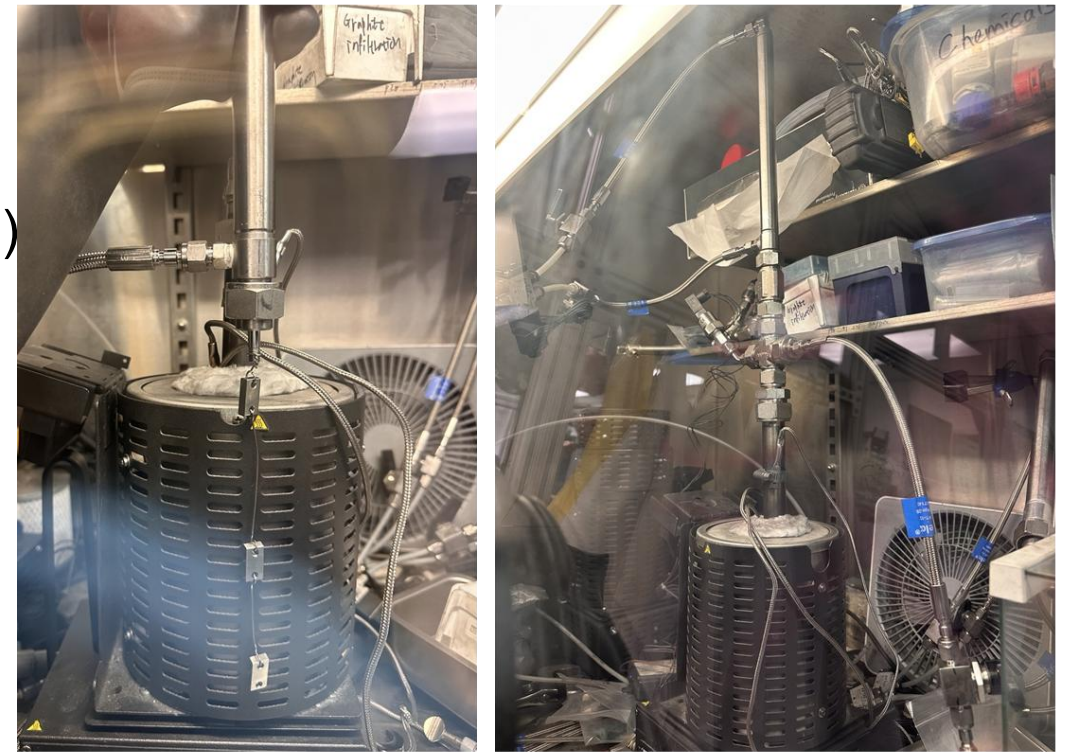
  - Highly purified salt

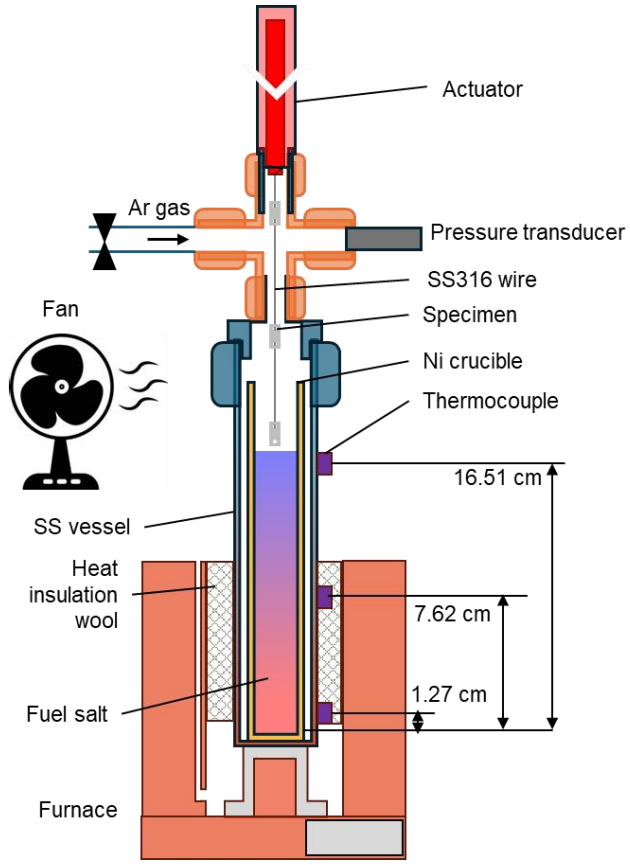
  : To minimize impurity effect

- Hot-bottom/cold-top

  - 40% salt in cooling zone

  : to achieve thermal gradient





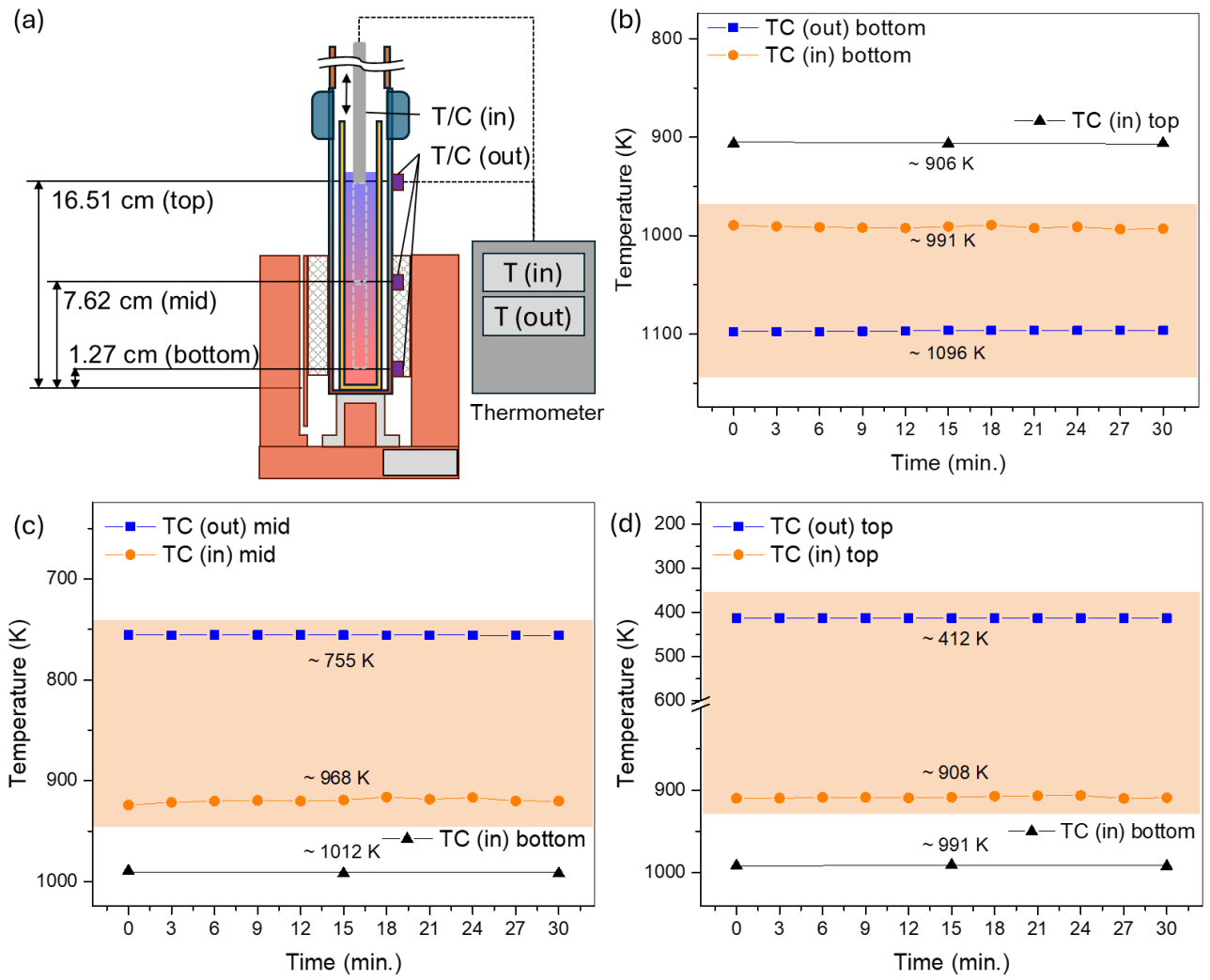
Actual and schematic image of non-isothermal corrosion testing system

How to monitor the temperature gradient?

Experimental methods

- Purpose
  - Avoid direct immersion of T/C

- How to calibrate?
  - T/C in salt
  - T/C on vessel wall
  - At three different heights
    : 1.27, 7.62, and 16.51 cm

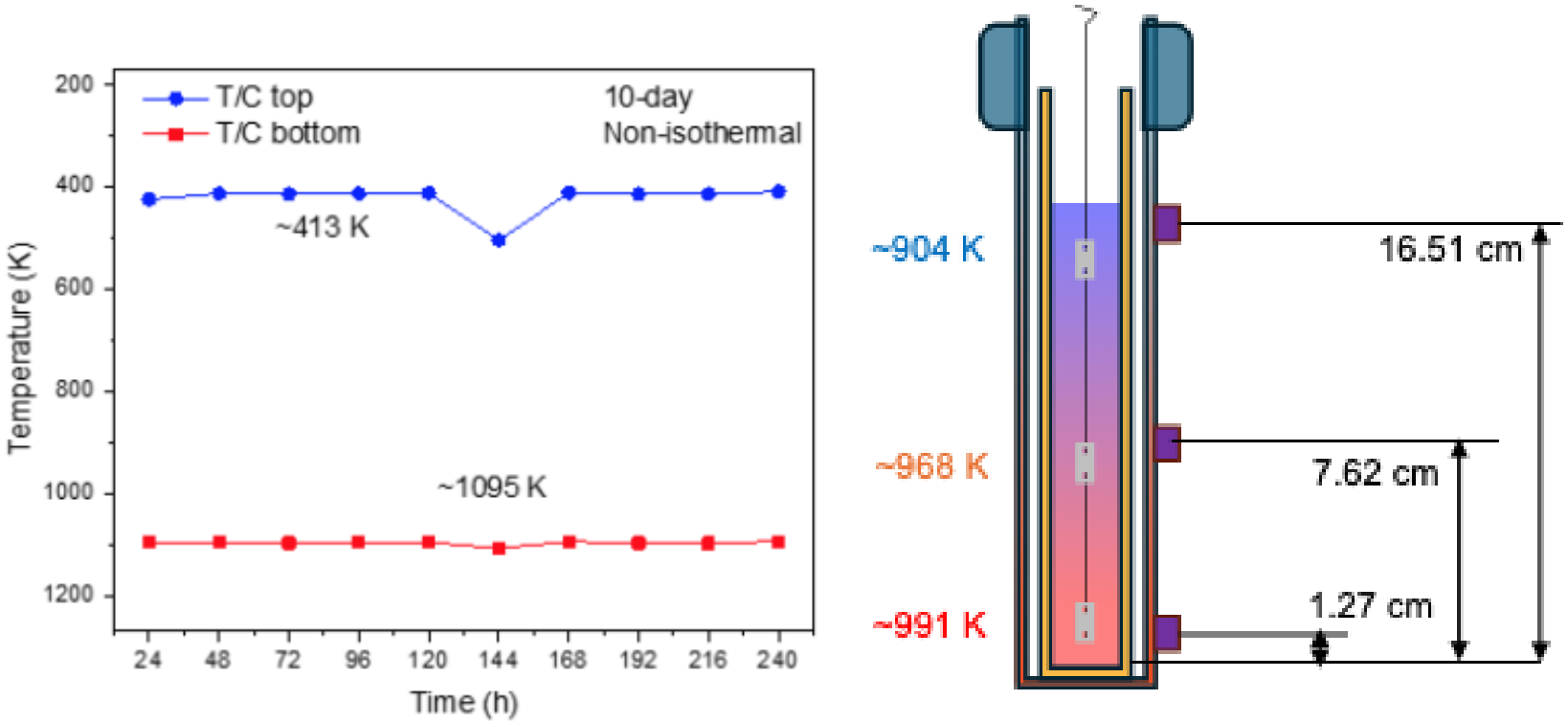


Temperature measurement result at different heights

Test condition

Experimental methods

- Materials
  - $NaF\text{-}BeF_2\text{-}UF_4\text{-}ZrF_4$
  - SS316H
- Test duration
  - 10-day (240 h)
- Temperature monitoring
  - hot-top/cold-bottom ~83 K



Temperature monitoring result for 240 h (left) and schematic image of specimen configuration (right)

Corrosion was influenced by position

Corrosion behavior under imposed thermal gradient

- A small weight loss in cold region

- Considering temperature effect on kinetics

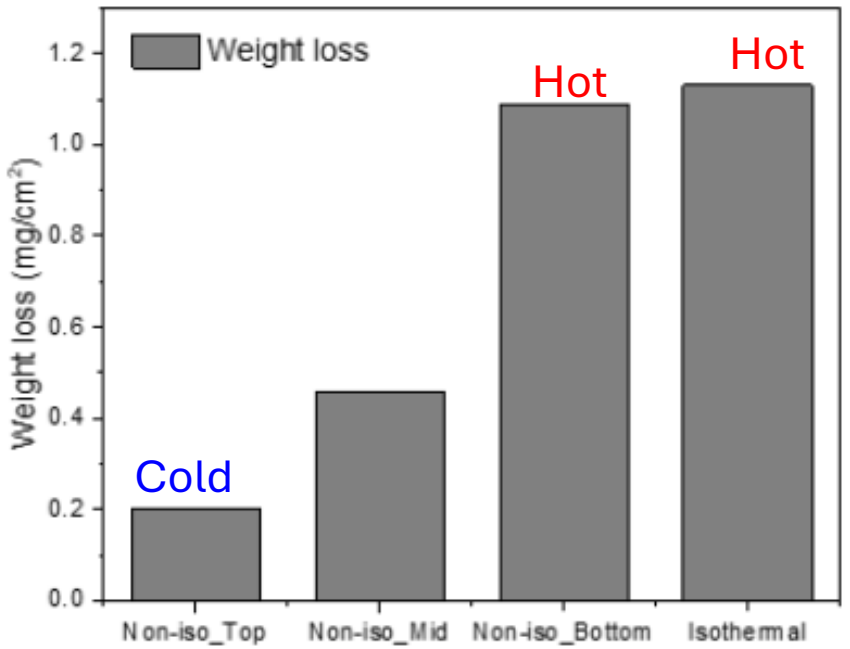
  - Reaction kinetics

$$\frac{\Delta m_{hot}}{\Delta m_{cold}} = \frac{1.09}{0.02} = 54.5 \qquad \frac{i_{corr,h}}{i_{corr,c}} = \exp\left[\frac{E_a}{R}\left(\frac{1}{T_c} - \frac{1}{T_h}\right)\right]$$

- Comparison non-isothermal with isothermal

  - Considering SA/V,

    more severe in non-isothermal



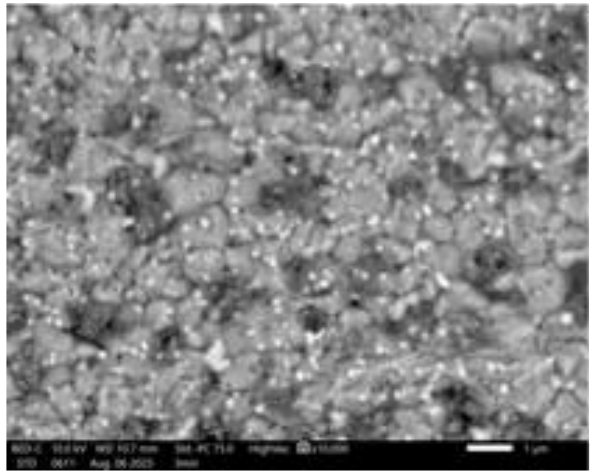
	Specimen	Weight loss (mg/cm^2)	Corrosion rate (mm/year)	SA/V (cm^{-1})
Non-isothermal	Top (cold)	0.02	0.001	0.88
	Mid (moderate)	0.46	0.021	
	Bottom (hot)	1.09	0.050	
Isothermal	N/A (hot)	1.13	0.052	0.54

Corrosion was influenced by position (cont.)

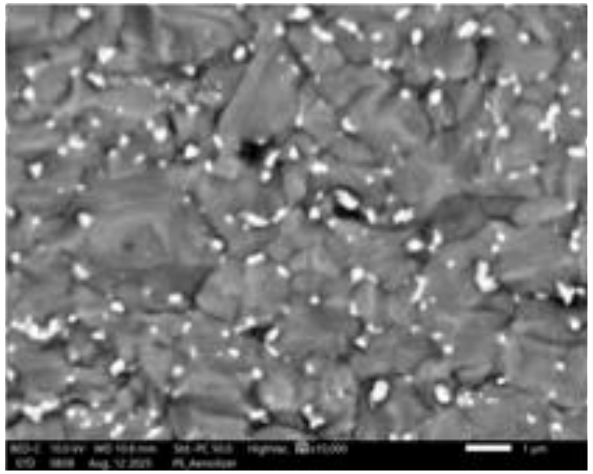
Corrosion behavior under imposed thermal gradient

- Surface micrographs of post-test specimens
- The specimens in hot regions exhibited apparent intergranular corrosion features.
- Non-isothermal exposure does not uniformly increase corrosion throughout the specimen, but rather concentrates degradation in the hottest region

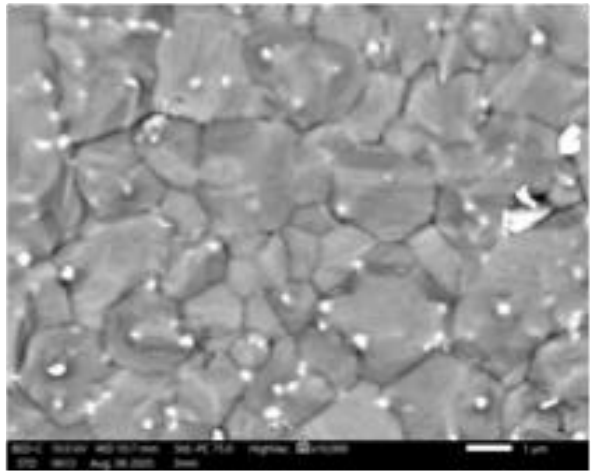
Non-isothermal; Top (cold)



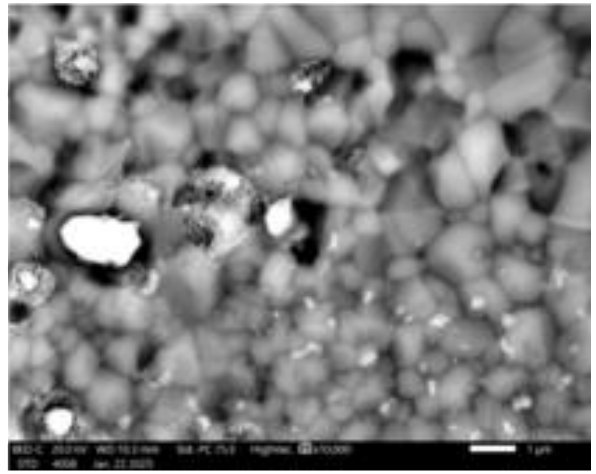
Non-isothermal; Mid (moderate)



Non-isothermal; Bottom (hot)



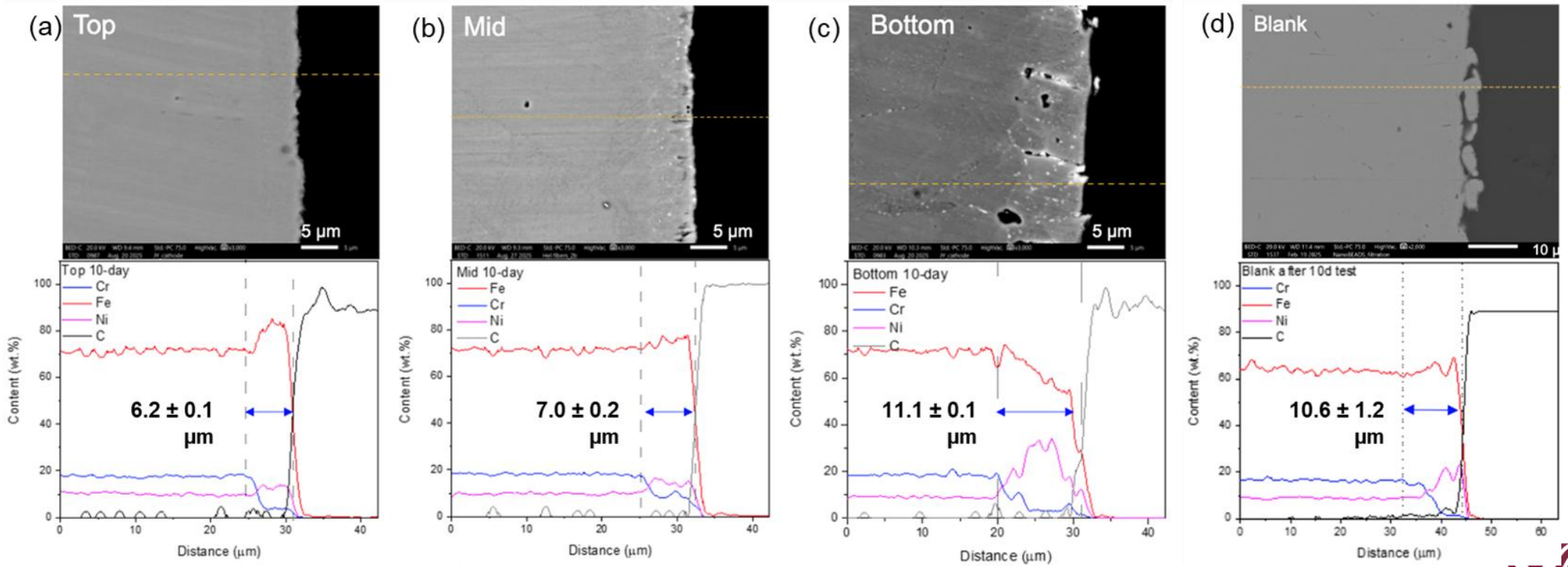
Isothermal; hot



Corrosion was influenced by position (cont.)

Corrosion behavior under imposed thermal gradient

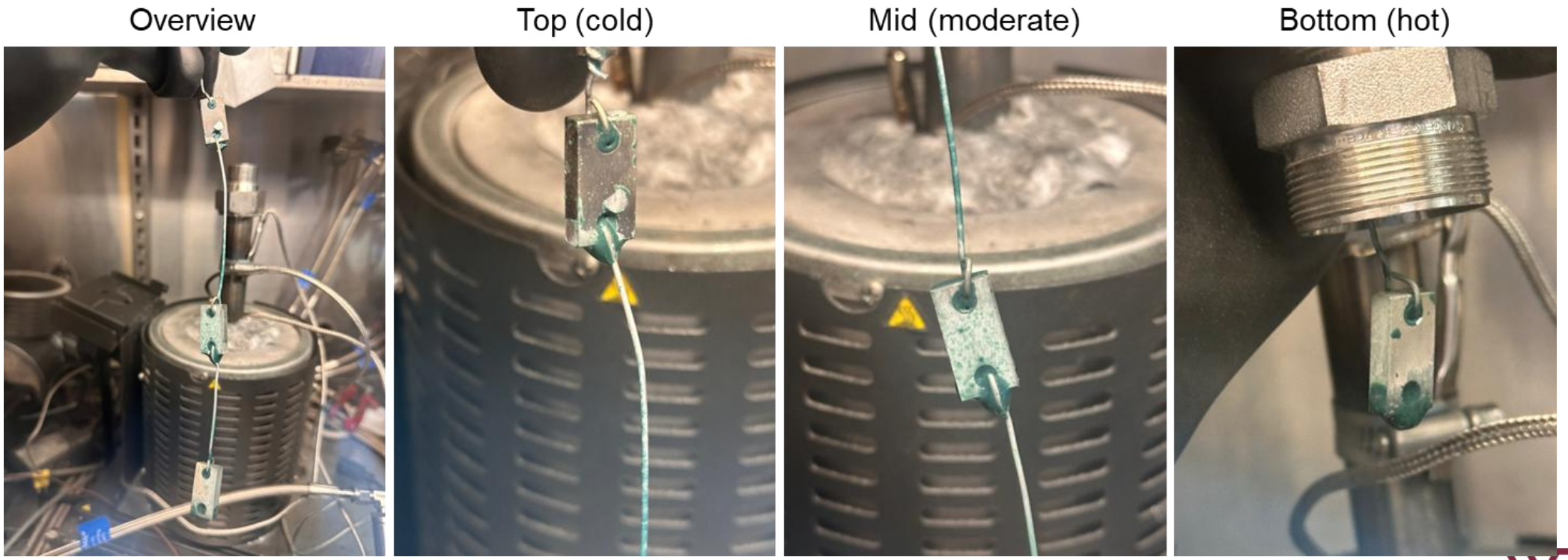
- Plots of Cr-depletion depths of post-test specimens.
- The specimens in hot regions exhibited apparent intergranular corrosion features.



Surface deposition on the specimen in cold region

Analysis of surface deposition on the top specimen

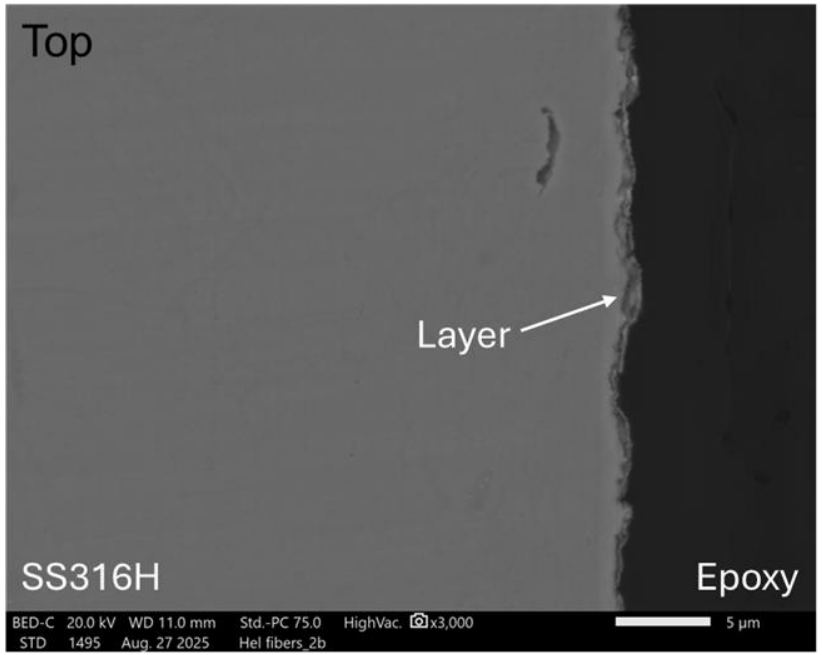
- Appearance of the post-test specimens after 10-day exposure
- The top specimens exhibited pronounced discoloration relative to the other specimens

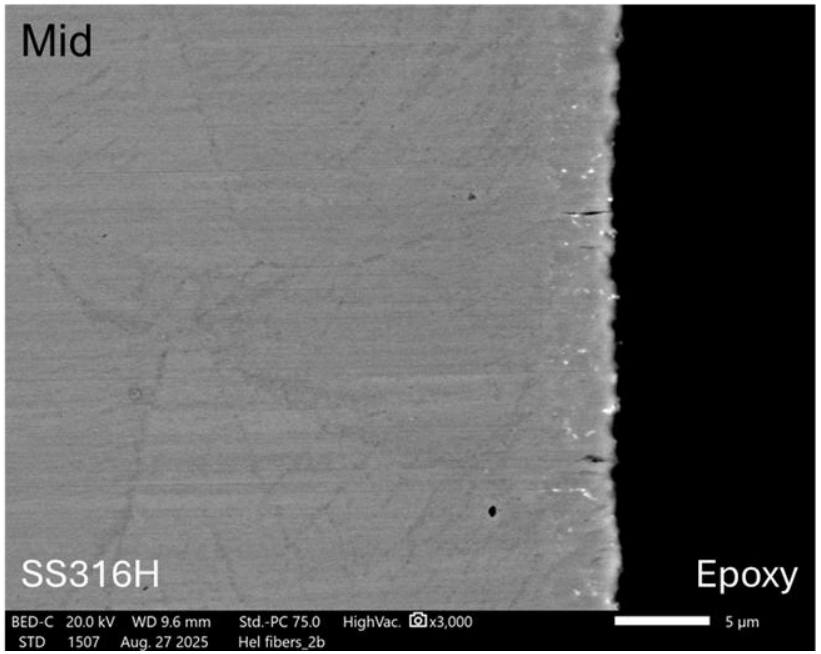


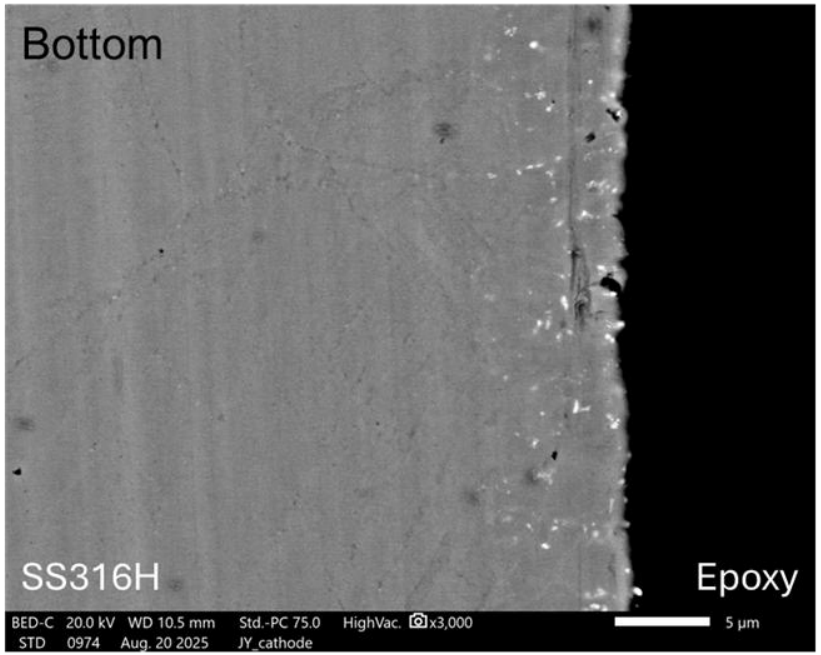
Surface deposition on the specimen in cold region

Analysis of surface deposition on the top specimen

- After cleaning the specimens, a distinct surface layer was observed only on the top specimen.
- Top specimen experienced surface accumulation, whereas the mid and bottom specimens were dominated mainly by net material loss.



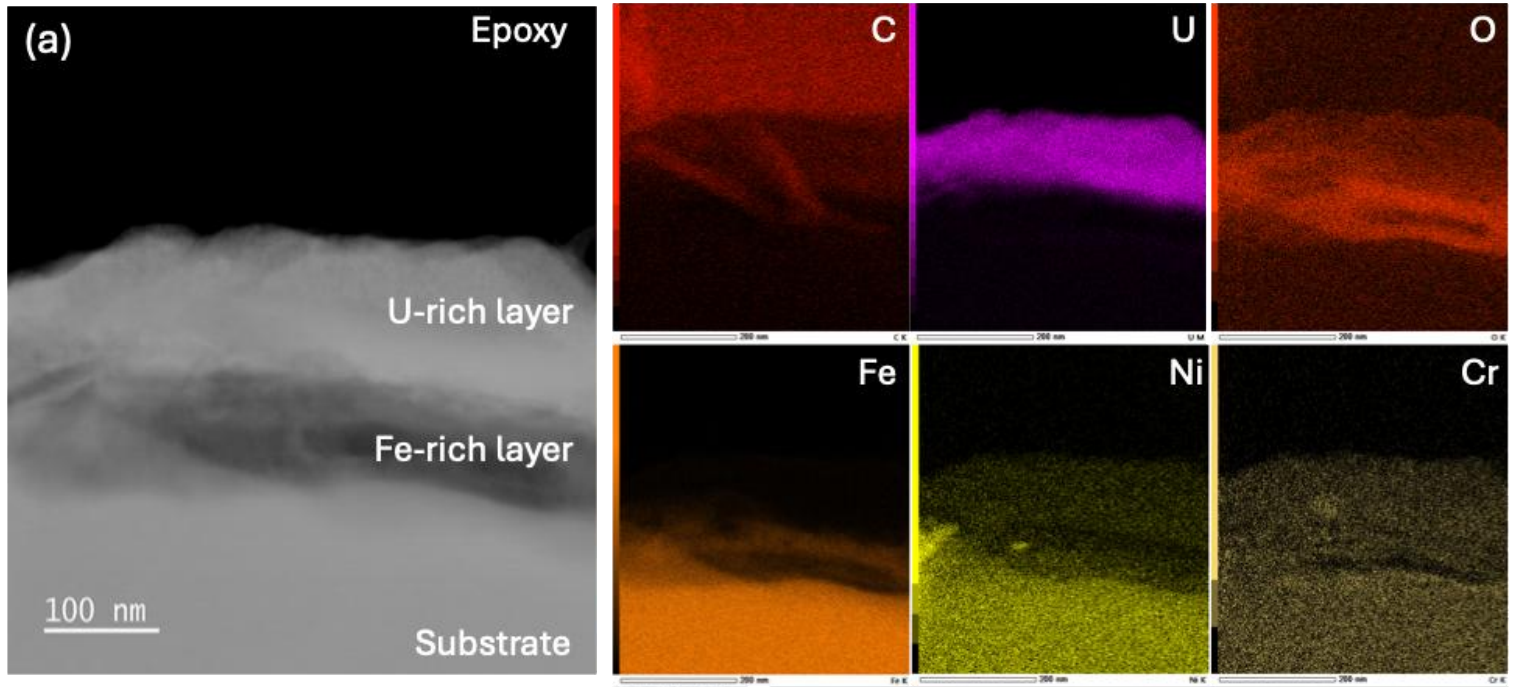


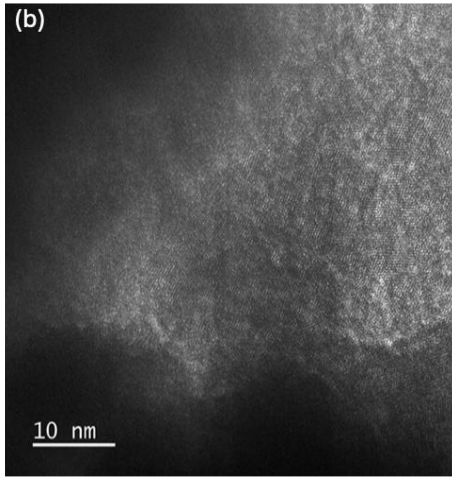


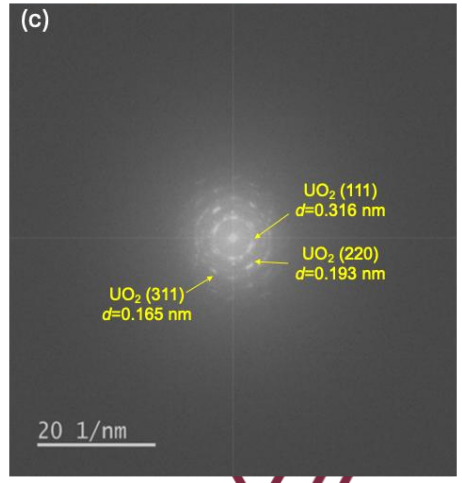
Duplex deposition on the surface

Analysis of surface deposition on the top specimen

- A heterogeneous deposit consisting of an outer U-rich oxide layer and an inner Fe-rich layer.
- Inner Fe-rich layer: Fe deposition & Outer U-rich layer: oxidation of residual salt
- Polycrystalline structure, lattice spacing matches with crystalline UO_2



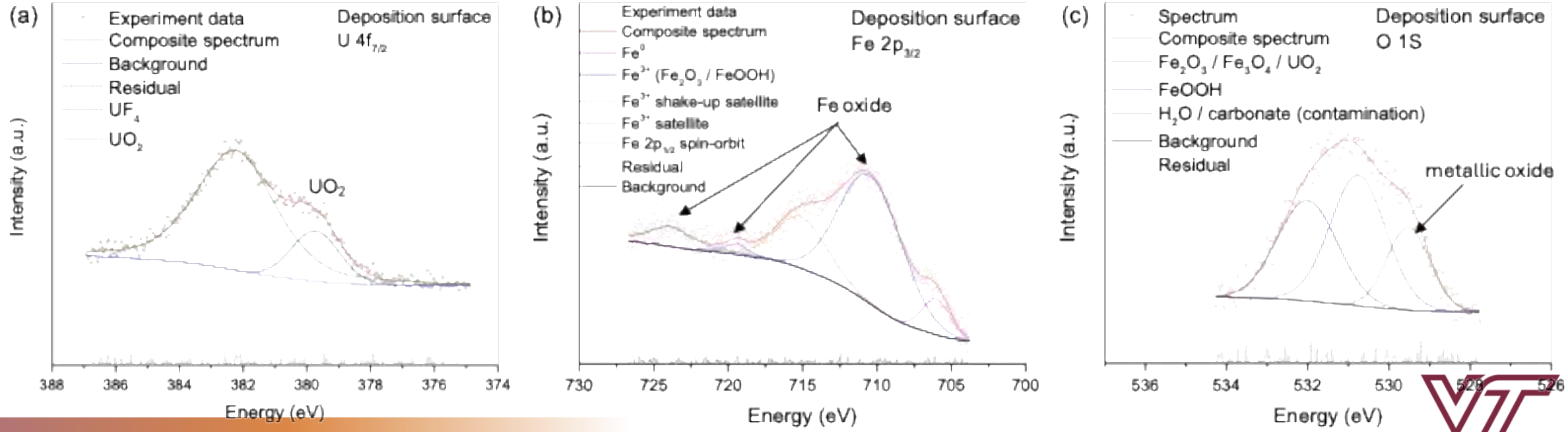




Duplex deposition on the surface (cont.)

Analysis of surface deposition on the top specimen

- XPS results are consistent with the TEM observations.
- In U 4f, UO_2 peak. In Fe 2p, Fe oxide or mixed-valance state. In O 1s, metal oxide peak.
- Non-isothermal exposure influenced not only the severity of corrosion, but also the spatial redistribution of corrosion products within the system due to the mass transfer.



Changes in metallic and non-metallic impurities

Post-test salt chemistry

- For both cases,

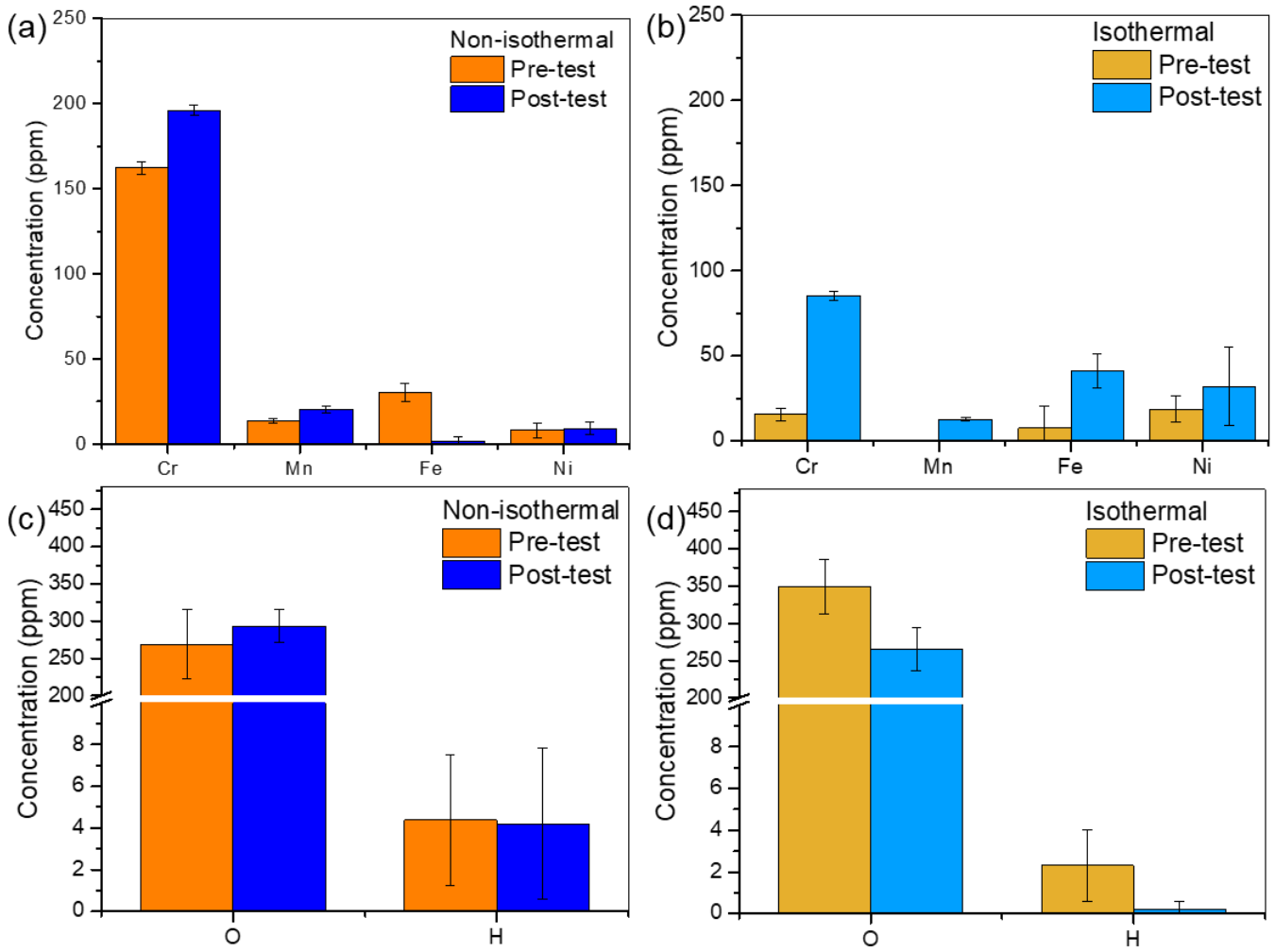
  - Cr increase: selective dissolution of Cr

- When comparing Fe concentrations,

  - Non-isothermal: decrease

  - Isothermal: increase

- Oxygen concentration



Summary

- Corrosion was influenced by position within thermal gradient.
- Surface deposition in the cold region