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4D-STEM Imaging of nanostructural heterogeneities in Ni-20Cr after corrosion in molten salt

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Nanostructural heterogeneities induced by processes such as chemical segregation, void nucleation, and strain localization are often observed in metals after corrosion, compromising materials performance. It is a prominent challenge to decipher how different kinds of heterogeneities develop and interact with each other to lead to the failure of materials. In molten salt nuclear reactors, the structural materials in contact with the high temperature (above 600˚C) salt could also develop such heterogeneities. Previously, it has been shown that many of these structural defects induced by corrosion are localized near the grain boundary (Zhou et al., 2020). While the preferential intergranular corrosion in molten salt may lead to through-thickness penetration (i.e., generation of heterogeneity), it may be slowed down by the introduction of proton irradiation which enhances the diffusion of interstials to self-heal the regions with excess free volumes (i.e., promotion of homogenity).

Here, using a combination of advanced electron microscopy techniques including focused-ion-beam lift out, three-dimensional (3D) electron tomography, and four-dimensional scanning transmission electron microscopy (4D-STEM), we report on the characterization of the localized structural heterogeneities in a Ni-20Cr alloy induced by molten-salt corrosion (Fig. 1). Molecular dynamics simulation (MD) and density functional theory (DFT) simulations have also been performed to elucidate the generation of excess free volumes during the dealloying process. In this presentation, we attempt to explain how defect transport near the grain boundaries induces void growth and how the void morphology is affected by the nonequilibrium point-defect concentrations and the local strain "hot spots".

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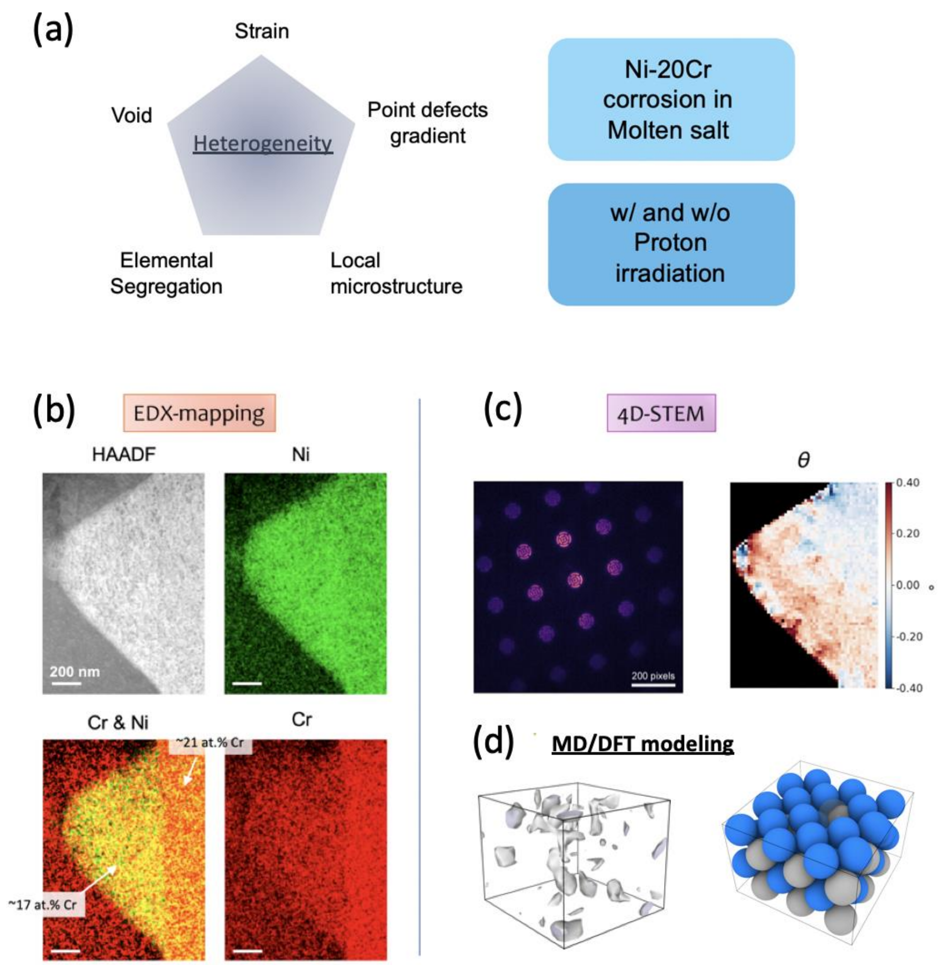

Figure 1. (a) An overview of the research; (b) Elemental mapping showing the local Ni enrichment and Cr depletion at a corroded GB; (c) 4D-STEM characterization using a bullseye condenser aperture (Zeltmann et al., 2020); (d) MD/DFT modeling of the corrosion process.

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