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Advanced Electron Microscopy Characterization of Intergranular Corrosion in Ni-20Cr Alloy Under Molten Salt Environment

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Molten salt reactors (MSR) are one of the next generation nuclear reactors that could enable much higher safety and economy with reduced radioactive waste. MSR utilizes a special coolant, *i.e.*, molten salt, working at temperatures as high as 700^{o}C. While such coolant has been shown to have multiple benefits, the lack of understanding of the response of structural materials to simultaneous molten salt corrosion and radiation damage has limited materials selection, research and development and the licensing of the nuclear reactors. Here we report advanced microscopy techniques to characterize materials after molten salt corrosion with and without concurrent proton irradiation. We discovered that proton irradiation could slow down intergranular corrosion under certain situations [1].

A dedicated facility [2] that enables concurrent proton irradiation and molten salt corrosion has been constructed at MIT. With this facility, we prepared two batch of samples: (1) corrosion only; (2) concurrent corrosion and proton irradiation. Ni-20Cr alloy was chosen as a model system, while LiF-NaF-KF (FLiNaK) at 650^{o}C is chosen as the molten salt environment. Scanning electron microscopy (SEM) images shown that intergranular corrosion is the dominant degradation mechanism in both samples. Statistical analysis of SEM images shown that intergranular corrosion in the region without proton irradiation is more severe than that under proton irradiation. Focused ion beam (FIB) lift-out technique was used to prepare electron-transparent at selected regions for transmission electron microscopy (TEM) imaging. Ni enrichment and Cr depletion are found in both samples by energy-dispersive x-ray spectroscopy (EDX) analysis. FIB-SEM based 3D tomography was used to probe the three-dimensional structural degradation in the samples. Four-dimensional scanning electron microscopy (4D-STEM) was applied to analyze strain around the corrosion pits. In this presentation, we will try to address several fundamental questions of the detailed mechanisms of transport in the grain-boundary regions, and how they are affected by nonequilibrium point-defect concentrations, strain and microstructures [3].

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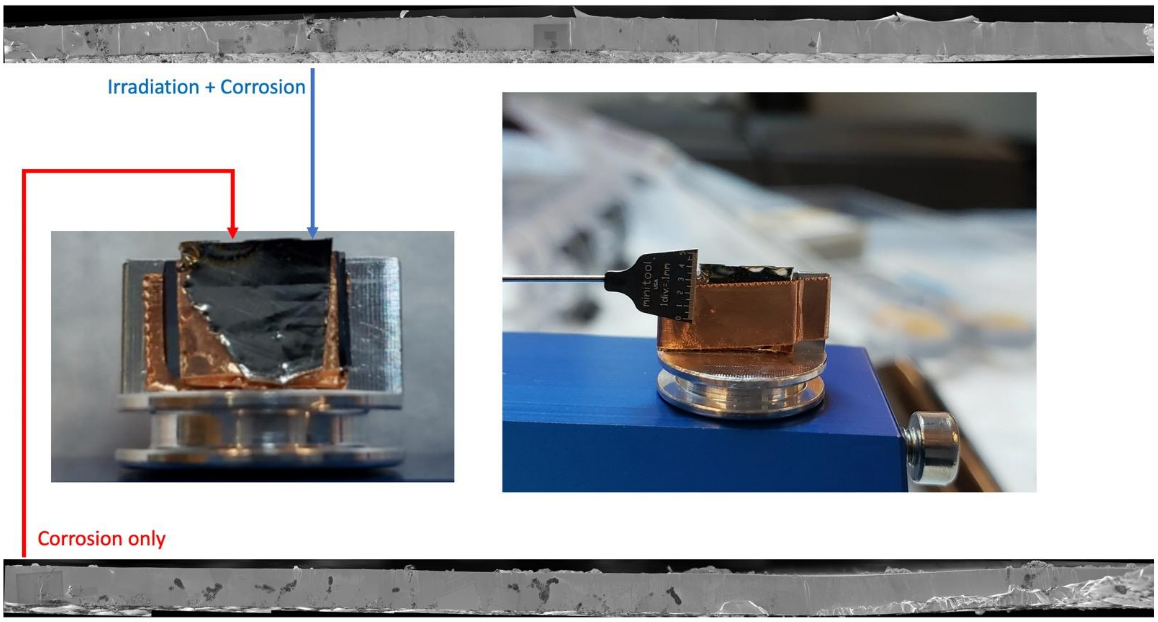

Figure 1. SEM images showing the cross-section of the samples under different corrosion conditions.

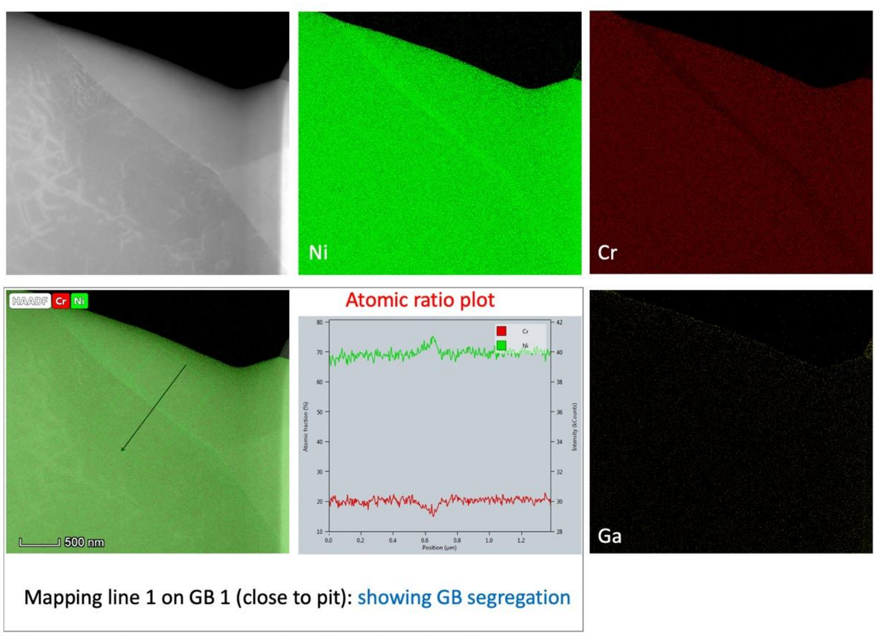

Figure 2. TEM-EDX mapping of samples showing Ni enrichment and Cr depletion at grain boundary after molten salt corrosion.

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