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Changing the World's Energy Future

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Nuclear Thermocouples

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Project Description: For temperature measurements, thermocouple (TC) instrumentation is typically comprised of one or more sensing elements, interrogation systems, and a data acquisition system, as well as processes and procedures to collect, analyze, and calibrate data. The instrumentation is used to measure process parameters (e.g., temperature) independently of the experiment, component, or process in which it is deployed. The focus of this activity is to extend the operation range, improve the accuracy, and reduce the performance degradation of TCs under irradiation. The demonstration activities in fiscal year (FY) 2021 focused on three main topics: 1) apply the High Temperature Irradiation Resistant Thermocouple (HTIR-TC) technology to pressurized water reactor (PWR) conditions for planned deployment in the ATR center loop, 2) leverage modeling and simulation to guide optimum material selection for water and oxygen (O2) interaction, and 3) leverage DOE-NE TCF to commercialize HTIR-TC.

Impact and Value to Nuclear Applications: Real-time temperature measurement is arguably the most important operational parameter for characterizing irradiation experiments and controlling power plant systems. Potential areas of application are material test reactors, advanced fuel validation tests, and advanced nuclear power plants. Certain impacts to these fields include getting closer proximity to the fuel, either through the surface cladding or inside the fuel itself, thus reducing the uncertainties in fuel burnup, fuel/coolant interaction, and modeling (i.e., digital twinning). Another outcome is higher temporal resolution during nuclear transients. In summary, better “drivability” of the reactor fuel can be achieved.

Recent Results and Highlights: Quantifiable drift of nuclear grade TCs in an out-of-pile furnace was recently performed, and the results showed the drift of the HTIR-TCs to be 1–1.15% after ~125 effective full power days. Both traditional two-wire, ungrounded HTIR-TCs and coaxial, single wire HTIR-TCs were tested. Further, modeling and experimentation on both the localized Seebeck coefficient and oxidation intercalation into the niobium and molybdenum thermoelements was performed. Our simulations suggest Mo-1%Nb would be the most resistant of the studied alloys to both oxidation and corrosion. Of the predominantly Nb alloys, Nb-1%Zr is most oxidation resistant up to 600°C while Nb-1%Mo is most oxidation resistant from 600 to 1600°C. Nb-1%Mo is also expected to have the best overall corrosion resistance of the Nb alloys.

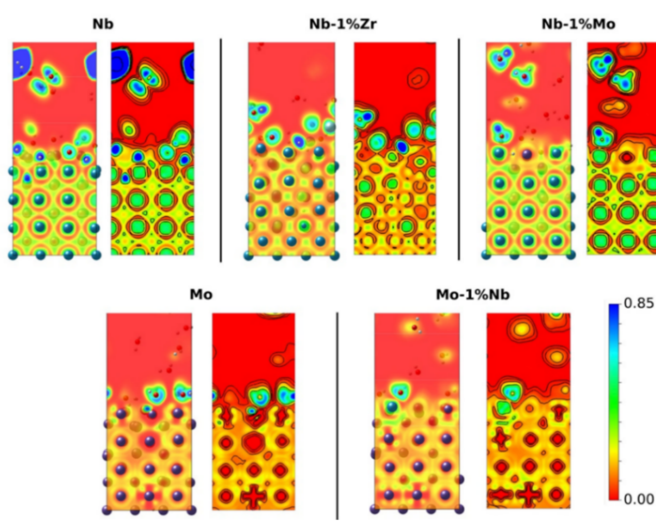

Figure 1. Electron Localization Functions of metal surfaces under H_20 after 1 ps at 1600°C.