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#8-256 Understanding and Optimizing Nuclear Thermocouples through Materials Science

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Stable, accurate, and precise temperature measurements are critical for efficient reactor operation, reactor lifetime extensions, and for the advancement or reliable modeling and simulation routines. In addition, traditionally implemented thermocouples experience decalibration and drift when they are exposed to the high temperatures and neutron fluence, common to the next generation nuclear reactor designs. Accordingly, the INL has recently developed high temperature irradiation resistant thermocouples (HTIR-TCs) composed of phosphorus doped niobium and lanthana doped molybdenum thermoelements, an alumina insulation, and a niobium sheath. In order to stabilize the signal generated from the dissimilar metal junction during extended operation and use, the thermocouples must undergo a preliminary heat treatment above its maximum service temperature. In this presentation, we have used a materials science approach to understand drift mechanisms in HTIR-TCs as well as traditionally used thermocouples. Interaction regions of each component of the thermocouples are individually investigated at each stage of the fabrication process and after extreme environment exposures. Accordingly, prior to reactor deployment, the primary factors altering thermocouple performance are defects from cold working, as well as chemical diffusion and grain restructuring due to preliminary heat treatments. Post reactor deployment, thermocouple drift is primarily attributed to advanced chemical diffusion, secondary phase formation, and transmutation of thermoelement materials. In this study, we demonstrate an understanding of drift mechanisms and present an empirical model to predict drift due to transmutation and thermal phenomena.

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