Diffusion plays a significant role in most materials systems by controlling microstructural development. Consequently, the overall properties of a material can be largely dependent upon diffusion. This study investigated the interdiffusion behavior of three binary systems, namely, Mo-Zr, Fe-Mo, and Fe-Zr. The main interest in these particular metals is for application in nuclear fuel assemblies. Nuclear fuel plates generally consist of two main components which are the fuel and the cladding. Due to diffusional interactions that can occur between these two components, a third is sometimes added between the fuel and cladding to serve as a diffusion barrier layer. Both Mo and Zr act as alloying additions in uranium based metallic fuels while Fe, Mo, and Zr can all serve as either cladding or barrier layer constituents. Therefore, a fundamental understanding of the diffusional interaction in these systems is critical in predicting the performance and lifetime of these fuels.

In order to study this diffusion behavior, a series of solid-to-solid diffusion couples were assembled between Fe, Mo, and Zr. These couples were then diffusion annealed isothermally for various predetermined times over a range of temperatures, including some both above and below the allotropic transformation temperatures for Fe and Zr. Following the diffusion anneal, the couples were water quenched, cross-sectioned, and prepared for microstructural and compositional characterization. A combination of scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), and electron probe microanalysis (EPMA) were used to obtain micrographs showing the microstructure and to collect compositional data for identifying intermediate phases and determining concentration profiles across the interdiffusion zone.

Based on this characterization, the phases that developed in the diffusion zones were identified. In the Mo-Zr system, a large Zr solid solution layer developed in the couples annealed at and above 850°C and a thin (~1-2 μm) layer of Mo2Zr formed in all couples. Growth constants and concentration dependent interdiffusion coefficients were calculated for the Mo2Zr and Zr solid solution phases, respectively. In the Fe-Mo system, both the λ-Fe2Mo and η-Fe7Mo6 phases were observed in couples annealed at 900°C and below while η-Fe7Mo6 and α-Fe solid solution layers were observed in couples annealed above 900°C. The relevant growth constants and activation energies for growth were calculated. In the Fe-Zr system, the couple annealed at 750°C developed an FeZr2 and an FeZr3 layer while the couple annealed at 850°C developed an Fe2Zr and Fe23Zr6 layer in the diffusion zone. The results of this analysis were then compared to available information from literature and the corresponding binary phase diagrams for each system. The results are also discussed with respect to the effects of the allotropic transformations of Fe and Zr on the interdiffusion behavior in these systems.