Development of monolithic U-Mo alloy fuel for the Material Management and Minimization Reactor Conversion (MMMRC) program entails a use of Zr diffusion barrier to eliminate the interdiffusion-reactions between the fuel alloy and Al-alloy cladding. Phase constituents and microstructure changes in MMMRC fuel plate assemblies as functions of temperature, duration and ramp-cool rate of HIP were examined. Phase constituents and microstructural development were analyzed by SEM and TEM. At the U10Mo/Zr interface, following the co-rolling, the UZr2 phase was observed, and the α-U phase was found between the UZr2 and U10Mo, while the Mo2Zr was found as precipitates mostly within the α-U phase. Observable growth due to HIP was only observed for the (Al, Si)3Zr phase at the Zr/AA6061 interface with a large activation energy of 457 ± 28 kJ/mol. Decomposition of γ-phase into α- and γ'-phases was observed in U10Mo alloy. The volume fraction of α and γ' increased as HIP temperature and ramp-cool rate decreased with negligible duration. The anomalies observed are carbide/oxide inclusions within the U10Mo fuel alloy, and regions of limited interaction at the U10Mo/Zr interface, frequently associated with carbide/oxide inclusions. In the U10Mo alloy, The volume percent of the UC-UO2 inclusions within the U10Mo alloy did not change as functions of HIP temperature and time. These inclusions phases, located near the surface of the U10Mo alloy, were frequently observed to impede the development of interdiffusion and reaction between the U10Mo alloy and Zr diffusion barrier. The regions of limited interaction between the U10Mo and Zr barrier decreased with an increase in HIP temperature, however no noticeable trend was observed with an increase in HIP duration at constant temperature.

Investigation for interdiffusion and reaction between U and Zr were carried out using solid-to-solid diffusion couples annealed from 580 °C to 710 °C. The microstructure consisted of three layers, αU(oC4) with Zr acicular precipitate, α'(assumed as oC4) and γU+βZr(cl2) (or δ(hP3) at 580 °C) solid solution. Concentration profiles were employed to estimate the interdiffusion fluxes and coefficients. The activation energies, 209.35, 229.97 and 199.45 kJ/mol, and pre-exponential factors, 1.66×10-4, 4.58×10-6 and 3.43×10-4 m2/s, were calculated for αU with Zr precipitate, α' and γU+βZr (δ at 580 °C), respectively.

Phase constituents, microstructure and diffusion kinetics of U-10wt.%Mo and Zr were examined using solid-to-solid diffusion couples annealed at 650 °C for 240, 480 and 720 hours. Concentration profiles were mapped as diffusion paths on the isothermal ternary phase diagram. Within the diffusion zone, single-phase layers of γ-U+β-Zr were observed along with a discontinuous layer of Mo2Zr between the β-Zr and β-U layers. In the vicinity of Mo2Zr phase, islands of α-Zr phases were also found. In addition, acicular α-Zr and U6Zr3Mo phases were observed within the γ-U(Mo). Growth rate of the interdiffusion-reaction zone was determined to be 1.81 × 10-15 m2/sec at 650 °C, however with an assumption of a certain incubation period.
Approved for distribution by Yongho Sohn, Committee Chair, on March 21, 2016.

The public is welcome to attend.