U-Mo dispersion and monolithic fuels embedded in Al-alloy matrix are under development to fulfill the requirements of research reactors to use low-enriched molybdenum stabilized uranium alloys as fuels. The system under consideration in this study was the body centered cubic U-Mo alloys embedded in an Al structural matrix. Significant interaction has been observed to take place between the U-Mo fuel and the Al matrix during manufacturing of the fuel-plate system assembly and during irradiation in reactors. These interactions produce Al-rich phases with physical and thermal properties that adversely affect the performance of the fuel system and can lead to premature failure.

In this study, interdiffusion and microstructural development in the U-Mo vs. Al and U-Mo vs. Al-Si systems was examined using solid-to-solid diffusion couples consisting of U-7wt.%Mo, U-10wt.%Mo and U-12wt.%Mo vs. pure Al, annealed at 600°C for 24. The influence of Si alloying addition (up to 5 wt.%) in Al on the interdiffusion microstructural development was also examined using solid-to-solid diffusion couples consisting of U-7wt.%Mo, U-10wt.%Mo and U-12wt.%Mo vs. pure Al, Al-2wt.%Si, and Al-5wt.%Si annealed at 550°C for 1, 5 and 20 hours. To further clarify the diffusional behavior in the U-Mo-Al and U-Mo-Al-Si systems, Al-rich 85.7Al-11.44U-2.86Mo, 87.5Al-10U-2.5Mo, 56.1Al-18.9Si-21.9U-3.1Mo and 69.3Al-11.9Si-18.8U (at.%) alloys were cast and homogenized at 500°C to determine the equilibrium phases of the system. Scanning electron microscopy (SEM), transmission electron microscopy (TEM) and electron probe microanalysis (EPMA) and X-ray diffraction (XRD) were employed to examine the phase development in the diffusion couples and the cast alloys.

In ternary U-Mo-Al diffusion couples annealed at 600°C for 24 hours, the interdiffusion microstructure consisted of finely dispersed UAl₃, UAl₄, U₆Mo₄Al₄₃, and UMo₂Al₂₀ phases while the average composition throughout the interdiffusion zone remained constant at approximately 80 at.% Al. The interdiffusion microstructures observed by EPMA, SEM and TEM analyses were correlated to explain the observed morphological development in the interdiffusion zones. The concept of thermodynamic degrees of freedom was used to justify that, although deviations are apparent, the interdiffusion zones did not significantly deviate from an equilibrium condition in order for the observed microstructures to develop. Selected diffusion couples developed periodic bands within the interdiffusion zone as sub-layers in the three-phase regions. Observation of periodic banding was utilized to augment the hypothesis that internal stresses play a significant role in the phase development and evolution of U-Mo vs. pure Al diffusion couples.

The addition of Si (up to 5 wt.%) to the Al significantly reduced the growth rate of interdiffusion zone. The constituent phases and composition within the interdiffusion zone were also modified. When Si was present in the Al terminal alloys, the interdiffusion zones developed layered morphologies with fine distributions of the (U,Mo)(Al,Si)₃ and UMo₂Al₂₀ phases. The U₆Mo₄Al₄₃ phase was observed scarcely in Si depleted regions within the interdiffusion zone. The phase development and evolution of the interdiffusion zone was described in terms of thermodynamic degrees of freedom with minimal deviations from equilibrium.

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The public is welcome to attend.