The Reduced Enrichment for Research and Test Reactor (RERTR) now known as the Material Minimization and Management Reactor Control program (MMMRC) seeks to replace the use of highly enriched uranium (HEU) fuels used in research and test nuclear reactors around the world. The low enriched uranium (LEU) fuels must have fissionable uranium densities comparable to the HEU fuels. After extensive investigation by various researchers around the world, the U–Mo alloys were selected as a promising candidate. The Mo alloyed with U allows for the stabilization of the face-centered cubic $\gamma$–U phase, which demonstrated favorable irradiation behavior. However, deleterious diffusional interaction between the fuel and the cladding, typically Al–base alloy, remain a challenge to overcome for application of U–Mo alloys as the LEU fuel.

Zr has been identified as a potential diffusion barrier between monolithic U–10 wt.% Mo ($U_{10}Mo$) metallic fuel and AA6061 cladding alloys for the development of a LEU fuel system. However, interdiffusion and reaction between the Zr barrier and $U_{10}Mo$ fuel can produce phases such as $Mo_2Zr$, and promote the destabilization of $\Gamma\alpha\gamma$–U phase into $\Gamma\alpha\gamma$–$\Gamma\alpha\delta$–U ($U_{2}Mo$) and $\Gamma\alpha\gamma$–$\Gamma\alpha\delta$–U. In order to better understand this phenomenon, this study examined the phases that are present in the $U_{10}Mo$ alloys with varying Zr concentration, 0, 0.5, 1.0, 2.0, 5.0, 10.0, 20.0 wt.% at room temperature after heat treatment at 900°C for 168 hours and 650°C for 3 hours. These two temperatures are relevant to fuel plate fabrication process of homogenization and hot-rolling, respectively. Scanning electron microscopy and X-ray diffraction were employed to identify and quantitatively document the constituent phases and microstructure to elucidate the nature of phase transformations.

For $U_{10}Mo$ alloys containing less than 1.0 wt.% Zr, there was no significant formation of $Mo_2Zr$ after 900°C homogenization and subsequent heat treatment at 650°C for 3 hours. The $\Gamma\alpha\gamma$–U phase also remained stable correspondingly for these alloys containing less than 1.0 wt.% Zr. For $U_{10}Mo$ alloys containing 2 wt.% or more Zr, a significant amount of $Mo_2Zr$ formation was observed after 900°C homogenization and subsequent heat treatment at 650°C for 3 hours. For these alloys, destabilization of $\Gamma\alpha\gamma$–U into $\Gamma\alpha\gamma$–$\Gamma\alpha\delta$–U ($U_{2}Mo$), $UZr_2$ and $\Gamma\alpha\gamma$–$\Gamma\alpha\delta$–U was observed. The alloy containing 20 wt.% Zr, however, did not demonstrate $\Gamma\alpha\gamma$–U decomposition even though $Mo_2Zr$ was observed after heat treatments. The formation of $Mo_2Zr$ effectively reduced the stability of the metastable $\Gamma\alpha\gamma$–U phase by depleting the $\Gamma\alpha\gamma$–stabilizing Mo. The destabilization of $\Gamma\alpha\gamma$–U phase into the $\Gamma\alpha\gamma$–$\Gamma\alpha\delta$–U phase is not favorable due to anisotropic and poor irradiation behavior of $\Gamma\alpha\gamma$–$\Gamma\alpha\delta$–U phase. Therefore the formation of $Mo_2Zr$ at the interface between $U_{10}Mo$ fuel and Zr diffusion barrier must be carefully controlled during the fabrication of monolithic LEU fuel system for successful implementation.

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The public is welcome to attend.