CHARACTERISATION OF ACTINIDE ALLOYS AS NUCLEAR TRANSMUTATION FUELS

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Abstract

Argonne National Laboratory – West has produced and characterized a series of non-fertile and low-fertile metal alloy test nuclear fuels for the transmutation of actinide isotopes in either fast spectrum reactors or accelerator driven systems under the United States Department of Energy (US-DOE) Advanced Fuel Cycle Initiative (AFCI). Specifically, the binary (in wt.%) Pu-40Zr and Pu-60Zr alloys, the ternary Pu-10Np-40Zr and Pu-12Am-40Zr alloys, the quaternary Pu-10Np-10Am-40Zr and U-28Pu-7Am-30Zr alloys and the quintary U-34Pu-4Am-2Np-20Zr, U-29Pu-4Am-2Np-30Zr and U-25Pu-3Am-2Np-40Zr alloys have been prepared via an arc-casting method. The non-fertile uranium free alloys are currently under irradiation testing in the Advanced Test Reactor (ATR) in the United States and two of the fuel compositions (Pu-12Am-40Zr and U-29Pu-4Am-2Np-30Zr) will begin irradiation testing in the Phénix reactor in France under the FUTURIX program in 2006.

There are a good number of challenges associated with the fuel development program and many of them are a direct result of the deficiency in the database of the fundamental properties and reactivities of the actinides and their alloys. For example, of the 10 possible binary systems in the U-Np-Pu-Am-Zr system, only 7 have partial to full phase diagrams experimentally investigated with the rest having either only extremely limited data or having been studied from theoretical modeling aspects. In some cases, there are conflicting experimental results. The scarcity of data in the ternary systems is even more pronounced and virtually nonexistent in the quaternary and higher systems.

Characterization efforts on the as-cast products include phase identification (XRD), microstructure analyses (SEM), fuel-cladding-chemical-interaction (fcci) diffusion couple studies, thermal expansion (TMA), heat capacities and enthalpies of transition (DSC) and thermal conductivities (LFD). These studies have proffered some initial data points to establishing the phase diagrams of the Pu-Np-Zr and Pu-Am-Zr ternary systems as well as the higher order systems up to 1000ºC. With respect to the neptunium bearing alloys, the concern with the formation of low-melting phases has been addressed to the satisfaction that no indication of melting, either on the micro or macro scale, was observed from the thermal studies nor the diffusion couple studies. The fabrication of nuclear fuels containing americium, whether metal alloy or other, is problematic due to the high volatility (vapor pressure) of americium and consequential loss during extended high temperature heating processes. Quantitative analysis of Am retention from the arc-casting fabrication process used to produce these fuels has been performed and shows very low losses as well as good distribution of the elements throughout the fuel samples. These issues will be discussed during the presentation together with pertinent experimental results.