U-Mo metallic fuel with Al alloy matrix/cladding is being developed as a low enrichment uranium fuel under the program of Reduced Enrichment for Research and Test Reactor (RERTR). Significant interactions have been observed between the U-Mo fuel and the Al alloy during fuel processing and irradiation. U-Zr metallic fuel with stainless steel cladding has been developed for generation IV sodium fast reactor (SFR). The fuel cladding chemical interaction (FCCI), induced by interdiffusion of components, was also observed.

Interaction between fuel and cladding involves multiple components interdiffusion. To determine the ternary interdiffusion coefficients using a single diffusion, a new method based on regression via matrix transformation approach is proposed in this study. This method is clear in physical meaning and simple in mathematical calculation. The reliability and accuracy of this method have been evaluated by three case studies: basic concentration profile, concentration profile with extrema and smoothed concentration profile with noises. Generally, this new method works well in the above three cases.

In order to investigate the interdiffusion behavior in U-Mo alloy, U vs. Mo diffusion couples were assembled and annealed in the temperature range from 650 to 1000 °C. Interdiffusion microstructure and concentration profile were examined by via scanning electron microscopy (SEM) and electron probe microanalysis (EPMA), respectively. Interdiffusion coefficients and their activation energy as functions of temperature and Mo composition were calculated. The intrinsic diffusion coefficients of U and Mo at the marker composition, the activity of U and the thermodynamic factor of U-Mo alloy, atomic mobilities and vacancy wind effects of U and Mo were also determined.

To explore potential barrier materials between the U-Mo fuel and Al alloy matrix/cladding for reducing the fuel cladding chemical interaction, the interdiffusion behavior between U-Mo alloy and Mo, Zr, Nb and Mg were systematically studied. SEM and TEM were applied to characterize the microstructure of interdiffusion zone. XEDS and EPMA were utilized to examine concentration redistribution and phase constituents. The growth rate of interdiffusion zone in U-Mo vs. Mo, Zr and Nb system were much lower than those in the system of U-10wt.%Mo vs. Al or Al-Si. For the diffusion couple of U-Mo vs. Mg, U-Mo was bonded very well with Mg and there was negligible diffusion observed after 96 hours annealing at 550 °C.

U vs. Fe, Fe-15wt.%Cr and Fe-15wt.%Cr-15wt.%Ni diffusion couples were examined to investigate the interdiffusion behaviors between U and Fe and effects of alloy elements Cr and Ni to form a base line for further study. Two intermetallic phases U₆Fe and UFe₂ developed in all diffusion couples, and U₆Fe phase layer grew faster than UFe₂. It is noted that U₆Fe impeded the growth of UFe₂, and the boundary change caused by allotropic transformation of U played a role on the growth of U₆Fe and UFe₂ by examining the intrinsic and extrinsic growth rate of both phases. Addition of Cr and Ni into Fe affected the growth rates of U₆Fe and UFe₂ and it is found Cr diffused into U slower than Fe or Ni.

Major: Material Science and Engineering

Educational Career:
Bachelor's of Material Science and Engineering, BS, 2007, Harbin Institute of Technology, China

Committee in Charge:
Dr. Yongho Sohn, Chair, Mechanical, Materials and Aerospace Engineering
Dr. Kevin R. Coffey, Mechanical, Materials and Aerospace Engineering
Dr. Helge Hermann Heinrich, Physics
Dr. Linan An, Mechanical, Materials and Aerospace Engineering
Dr. Chengying Xu, Mechanical, Materials and Aerospace Engineering

Approved for distribution by Dr. Yongho Sohn, Committee Chair, on May 1, 2012.
The public is welcome to attend.