Fission Product Simulation in Monolithic U8wt.-%Mo by Heavy Ions

R. M. Hengstler [a], L. Beck, C. Bogenberger [a], H. Breitkreutz [a], W. Carli, C. Jarousse [b], R. Jungwirth [a], W. Schmid [a], J. Schneider [c], and W. Petry [a]
[a] Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II), 85747 Garching
[b] AREVA-CERCA, cLes Bérauds BP114, 26104 Romans Cedex, France
[c] LMU, Dept. of Earth- and Environmental Sciences, 80333 Munich

The research neutron source Heinz Maier-Leibnitz (FRM II) is operating with a 93% enriched fuel element which provides, in combination with the compact core design, the high thermal neutron flux of $8 \cdot 10^{14}\,cm^{-2}s^{-2}$ (unperturbed). In the context of international efforts for research reactor core conversion [1], the Technische Universität München is working on the qualification of an uranium-molybdenum alloy with 8 wt.-% Mo ("U8Mo") as a new FRM II fuel [2,3]. U8Mo provides the same ^{235}U density as the current highly enriched U_3Si_2 fuel in the unchanged fuel element and core geometry, but with a degree of enrichment lower than 50 at.-%. There are two possible fuel meat structures: monolithic U8Mo and disperse U8Mo, with the latter being U8Mo spheres rolled in aluminum. For the qualification process of the monolithic fuel, its thermal properties are of high interest. Thus, the thermal diffusivity, specific heat capacity and thermal conductivity of non-irradiated U8Mo were examined. Also, the lattice structure in rolled U8Mo foils was analyzed by X-ray diffraction. However, material properties change under irradiation; since irradiation of the material in a nuclear reactor takes months and leads to high activation levels, heavy ion irradiation with typical fission product elements and energies is an attractive alternative to in-pile irradiation.

Monolithic U8Mo was irradiated with ^{127}I ions with 80 MeV as a typical fission product mass number and energy. The ion fluence was in the range of $9 \cdot 10^{21}\,cm^{-2}$ which leads to a iodine density in the damage peak region corresponding to the fission product density at the targeted nuclear burn-up of the FRM II fuel. To create a broader and more homogeneous ion damage peak in the material, two different methods were used. On the one hand, the beam's incident angle was varied which was done by a turnable sample holder. On the other hand, the samples were irradiated with ions of different energies. For that method, a new irradiation setup was built behind the analyzing magnet in the tandem hall, in line of sight to the accelerator tank. Thus, all ion charge states created in the stripper and consequently ions with all different energies reach the target; their relative fraction can be controlled by adjusting the lens 5 magnets. The Wien filter can be used if only one energy is required.

With the damage peak's width being in the range of 4 μm, the sample's thickness was kept as low as possible to resolve any changes in the electric or thermal properties by irradiation. However, mechanical thinning of the samples was only possible to a lowest thickness of 130 μm. Thus, changes in the electric or thermal properties of the material by irradiation could not be resolved.

X-ray diffraction of two irradiated samples showed the presence of UO_2 on the sample surfaces which is not found before irradiation (see fig. 1).

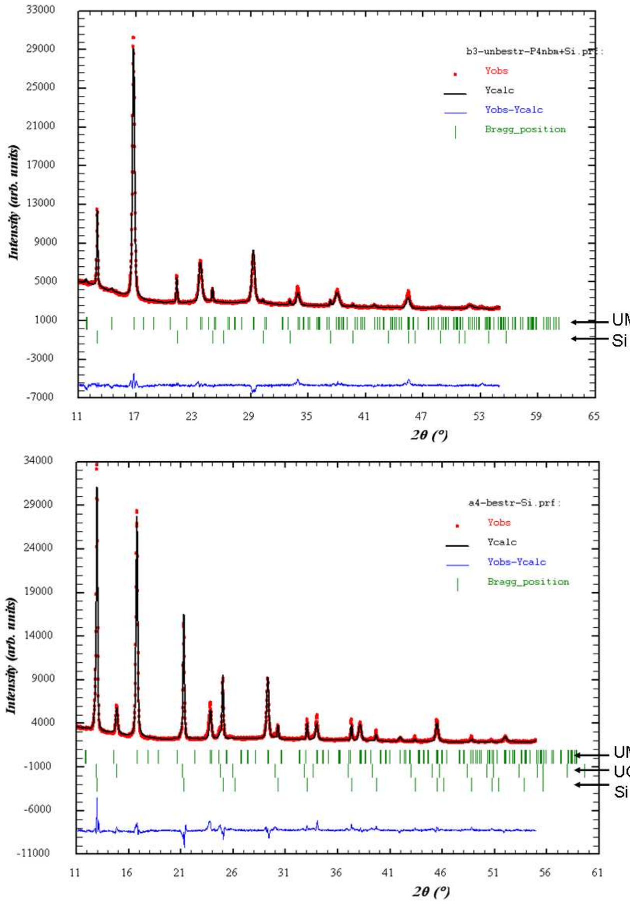

Fig. 1: XRD analysis of rolled U8Mo before and after irradiation

sample	fluence (cm^{-2})	a (Å)	c (Å)	volume a^2c
non-irr.	0	6.8563(4)	3.4524(2)	162.36(2)
irr. 1	$9.0 \cdot 10^{17}$	6.8747(5)	3.4235(4)	161.80(3)
irr. 2	$9.9 \cdot 10^{17}$	6.8552(5)	3.4409(4)	161.70(3)

Table 1: U8Mo lattice parameters

Also, the lattice parameters of the tetragonal primitive lattice structure differed from the parameters before irradiation, while the lattice structure itself remained constant; in both samples, the irradiation lead to a decrease in the UMo unit cell volume (see table 1). In continuative experiments with very thin samples produced by other methods, e.g. magnetron sputtering, the changes in the electric and thus thermal conductivity of monolithic U8Mo are expected to be resolvable by the used experimental techniques.

References

[1] Reduced Enrichment for Research and Test Reactors (RERTR), http://www.rertr.anl.gov/index.html (Nov. 2008)
[2] W. Petry *et al.*, "IRIS-TUM Program on Full Size Plates-UMo Dispers", RRFM (2008)
[3] N. Wieschalla *et al.*, "Heavy Ion Irradiation of U-Mo/Al Dispersion Fuel", J. Nucl. Mater. **357** (2006) 191