



POSTER #35

CHARACTERIZATION OF THE $U(Al,Si)_3$ ALLOY AFTER IRRADIATION BY Ar IONS

Gili Yaniv¹, Gennady Rafailov², Isaac Dahan², Jiri Vacik³, Arik Kiv¹, David Fuks¹ and Louisa Meshi¹

¹ Department of Materials Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel

² Nuclear Research Center-Negev, POB 9001, Israel

³ Nuclear Physics Institute, Academy of Sciences of the Czech Republic, Husinec – Rez, Czech Republic

In standard nuclear reactors, where U is used as a fuel, cladding is usually made of Al alloys (with Si as major alloying element). The fuel-cladding chemical interactions (both radiation or/and thermally assisted) are considered to be the life-limiting events of the fuel system and partly determine the level of burnup that can be tolerated. Thus, study of U-Al-Si system, which is the cladding-fuel interaction layer, is of crucial importance. This interaction layer can create dimensional changes in the fuel due to the density changes when new phases form as fuel and matrix species mix. The layer may possess a thermal conductivity that affects fuel performance [1] or it may be brittle such that, in the case of monolithic fuel, fuel/cladding separation could result [2].

Energetic ions can be used to understand the effects of neutron irradiation in reactor components. The damage state and microstructure resulting from ion irradiation, and thus the degree to which ion irradiation emulates neutron irradiation, depend upon the particle type and the damage rate. One of the drawbacks of ion irradiation is the short penetration depth and the continuously varying dose rate over the penetration depth. As a result, regions at well-defined depths from the surface must be able to be reproducibly sampled in order to avoid dose or dose rate variations. Small errors (500nm) made in locating the volume to be characterized can result in a dose that varies by a factor of two from the target value. In order to discard this effect the samples in current research were of low volume. TEM samples were irradiated directly. The same samples were characterized prior and after the irradiation by Ar fluxes of 10^{13} , 10^{14} , 10^{15} , 10^{16} ion/cm². We focused on the $U(Al,Si)_3$ alloy since it contained ordered $UAl_{1.71}Si_{1.29}$ phase (corresponding to the $U(Al_x, Si_{1-x})_3$ stoichiometry with $x=0.57$), atomic structure of which was recently solved by our group as tetragonal ($I4/mmm$, $a=8.347\text{\AA}$ and $c=16.808\text{\AA}$) [3, 4]. Since this phase was not reported earlier, its behavior under the irradiation conditions was not checked. Our results demonstrate that mosaic structure of the ordered phase has gradually disappeared as a function of irradiation dose. At dose 10^{16} ion/cm² the domains disappeared completely at transparent areas of TEM samples. Moreover, the defect free areas were disordered – forming cubic $U(Al,Si)_3$ phase. In the same samples, Al matrix exhibited different trend – accumulating defects as a function of ion dose.

For interpretation of these results – we used models of ion implantation. The simulation softwares TRIM and SRIM [5, 6] were applied to estimate the ion dose which leads to total disorder of the structure. Theoretical results were in full agreement with experimental ones.



References:

1. Ryu, H. J., Kim Y.S., Park J.M., Chae H.T., Kim C.K., "Performance evaluation of U-Mo/Al dispersion fuel by considering a fuel-matrix interaction", *Nuclear Eng. and Technology*, 40 i5, pp 409, (2008).
2. M. R. Finlay, D. M. Wachs, A. B. Robinson and G. L. Hofman, "Post Irradiation Examination of Monolithic Mini-fuel Plates from RERTR-6 & 7," ENS RRFM 2007, 11th International Topical Meeting on Research Reactor Fuel Management, 2007; Lyon, France.
3. V.Y. Zenou, G. Rafailov, I. Dahan, A.Kiv, L. Meshi and D. Fuks, "Ordered U(Al, Si)₃ phase: Structure and bonding", *J. Alloys Compd.*, 690 pp 884, (2017).
4. G. Rafailov, I. Dahan and L. Meshi, "New ordered phase in the quasi-binary UAl₃-USi₃ system", *Acta Crystallogr. B* 70 (3), pp 580, (2014).
5. W. Möller, W. Eckstein, "Tridyn — A TRIM simulation code including dynamic composition changes", *Nucl. Instrum. Methods Phys. Res., Sect. B*, 2, pp. 814-818, (1984).
6. James F. Ziegler, M.D. Ziegler and J.P. Biersack, "SRIM – The stopping and range of ions in matter", *Nucl. Instrum. Methods Phys. Res., Sect. B*, 268, pp 1818 (2010).