Neutron Powder Diffraction of Irradiated Low-Enriched U-Mo-Al Dispersion Fuel

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Atomic Energy of Canada Ltd. (AECL) is developing low-enriched (LEU < 20 % ^{235}U) Al-UMo dispersion fuel for potential use in test reactors. Significant efforts are currently underway around the world to develop this fuel for materials test reactors. The main reasons are that the uranium loadings can be higher than in the presently qualified dispersion fuel, and that spent UMo dispersion fuel is suitable for reprocessing.

Post-Irradiation Examinations (PIE) of irradiated fuel specimens performed at AECL and elsewhere show evidence of a significant chemical reaction between the UMo particles and the Al matrix. At low burnup, the contribution of fission product formation to the swelling behaviour is negligible, and thus swelling behaviour is attributed to chemical interaction of U-Mo-Al and the subsequent formation of low-density reaction product(s), with inter-diffusion enhanced by irradiation. Neutron Diffraction Analysis of the results obtained from an UMo fuel core irradiated to 20 atom % burnup identified the predominant crystalline reaction product as isomorphous with UAl_3 [1]. At 60 atom % burnup, the reaction products are predominantly isomorphs with UAl_x compounds (x = 2,3). A comparison of the NDA data obtained from UMo fuels at lower burnup (20 atom %) [1], suggested that (U,Mo)Al_3 decomposes to form (U,Mo)Al_2. There is also evidence of transformation of the UMo particles into α-U and δ U_2Mo, and the formation of small quantities of UMo_2Al_{20} [1].

Recently, new neutron diffraction results show that both crystalline and non-crystalline phases form at different regions within the same fuel element, depending on the local operating conditions within the fuel core. The extent of the reaction and the structure of the reaction product is clearly influenced by the local fuel operating temperature, as evidenced by differences in the morphology of the reaction products observable optically in the region the of fuel near the end-plug region (Figure 1). Specifically, the fuel core in the annular region exhibits intact UMo particles, residual aluminium and an interaction product at the particle-matrix interface, while the fuel core towards the mid-plane exhibits a fully reacted microstructure and a total absence of residual aluminium. Neutron diffraction results obtained from the annular region do not show any significant crystalline phases, despite clear evidence of a reaction product (Figure 1). This suggests that the phase is amorphous.

A finite element model of the fuel element is being developed to assess the temperature field within the fuel element and to provide a reasonable estimate of the recrystallization temperature of the reaction product.

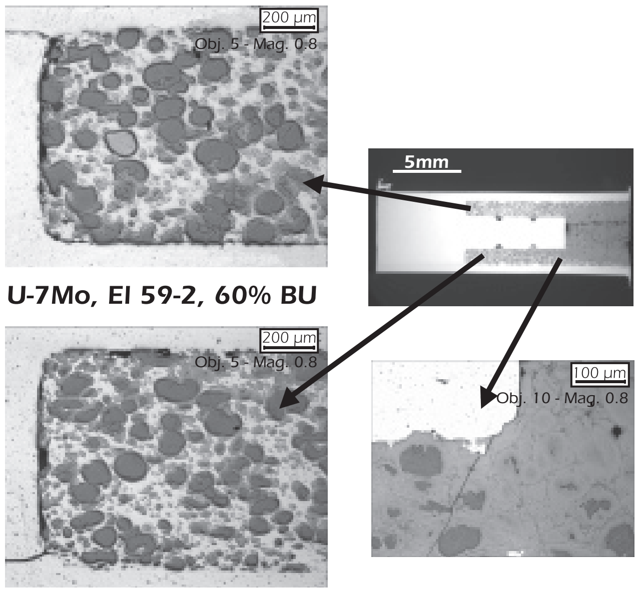

Fig. 1 Morphology of Irradiated Al-UMo fuel core following 60 atom % burnup. Fuel core in the annular region (at left) exhibits intact UMo particles, residual aluminium and an interaction product at the particle-matrix interface. The fuel core towards the midplane (at right) exhibits a fully reacted microstructure, an absence of residual aluminium and an absence of residual UMo fuel particles.

References

[1] K. Conlon and D. Sears (2006). Neutron Powder Diffraction of Irradiated Low Enriched Uranium-Molybdenum Dispersion Fuel. 10th Topical Meeting on Research Reactor Fuel Management (European Nuclear Society), Sofia, Bulgaria.

[2] K. Conlon and D.F. Sears, (2007). Neutron Powder Diffraction of UMo Fuel Irradiated to 60 Percent Burnup. 11th Topical Meeting on Research Reactor Fuel Management (European Nuclear Society), Lyon France.