

## LAMDA: Irradiated-Materials Microscopy at Oak Ridge National Laboratory

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Oak Ridge National Laboratory's Low Activation Materials Development and Analysis (LAMDA) laboratory is a dedicated facility containing specialized instruments for the study of irradiation-induced effects on materials properties. Located in the Materials Science and Technology Division, LAMDA consists of several interconnected contamination-zone and clean area suites. Originally created as a facility for plutonium studies and then thermophysical properties of graphite for high temperature gas cooled reactors in the 1960's, the role of LAMDA has changed with the emphasis placed on "low activation" materials. Currently, LAMDA is involved in both fundamental and applied research on radiation-induced changes in structural materials, reactor internals, diagnostic materials and sensor components for both current and advanced reactor designs for both fission and fusion systems. LAMDA allows for the examination of low activity radiological samples (< 100 mR/hr at 30 cm) without the need for remote manipulation. LAMDA typically utilizes small, compact samples to allow researchers to leverage cutting-edge characterization and test equipment to study materials phenomenon not possible at a hot cell facility. The LAMDA facility is maintained as a low alpha contamination facility, but certain equipment is available for fuel-related studies. LAMDA contains a strong electron microscopy sub-program, which we describe here.

A full complement of equipment and instruments are available for metallographic and microstructural analysis of materials. This includes X-ray tomography and three irradiated-materials-dedicated FEI DualBeam FIB-SEM instruments for 3D materials studies and the preparation of specimens for TEM. LAMDA contains a new 200kV Schottky JEOL JEM-2100F S/TEM with EDS and Gatan Quantum Image Filter, and leverages ORNL's other TEM tools as well as SEMs and atom probe.

The LAMDA lab works in conjunction with the Irradiated Materials Examination and Testing (IMET) and Irradiated Fuels Examination Laboratory (IFEL) hot-cell facilities at the laboratory to study materials irradiated at either the High Flux Isotope Reactor (HFIR) or other experimental and commercial reactors. The LAMDA, IMET, IFEL and HFIR facilities are all part of the National Science User Facility. LAMDA performs work supported by various Department of Energy (DOE) programs including the Fusion Materials, Light Water Reactor Sustainability, DOE-Naval prime contractors, as well as collaborations with other international research facilities, universities and companies.

Figure 1 shows the IMET facility, where irradiated capsules are opened and the specimens sorted and subjected to first-stage preparation (e.g., inspection, cutting, grinding). Figure 2 shows one of the FEI DualBeam instruments, which is located in a lead-shielded room and equipped for remote operation, and can be used to prepare TEM specimens of irradiated fuels. Figure 3 shows the newly installed JEOL 2100F TEM/STEM instrument. Figure 4 shows Re-rich precipitates in HFIR-irradiated tungsten that was prepared in LAMDA through FIB processing, showing that materials with relatively high induced levels of activation can be handled with appropriate safety controls for the researchers. [1]

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Facility.



Figure 1: Irradiated Materials Examination and Testing (IMET) hot cell facility.



Figure 2: FEI Quanta DualBeam FIB-SEM system. A second operator control station, separated from the instrument by a lead wall, protects the operator from strongly gamma-emitting specimens.



Figure 3: JEOL 2100F TEM/STEM instrument. Equipped with EDS and EELS+EFTEM, this tool is now available for irradiated materials and fuels work in LAMDA.

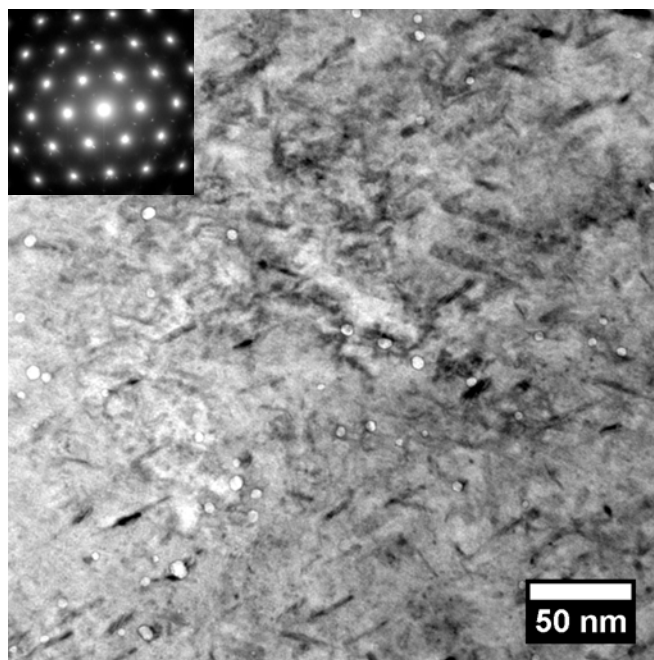


Figure 4: Tungsten irradiated at  $\sim 750^\circ\text{C}$  to  $7 \times 10^{25} \text{ n/m}^2$ ,  $\approx 2 \text{ dpa}$ ,  $\sim 6 \text{ at\% (Re+Os)}$  transmutation. Radiation-induced precipitation (perhaps  $\sigma$  or  $\chi$  phases) and voids are visible.