Mesoscale Priority Research Direction

The potential of high energy x-ray diffraction and microtomography for the study of UO_2 under processing and operating conditions.

Opportunity

- Advances in >80 keV synchrotron X-Ray performance enable the application of High Energy x-ray Diffraction Microscopy (HEDM) and micro-tomography (μT) to high-Z materials.
- Measurements at APS by LANL researchers have demonstrated 3D non-destructive grain reconstructions (3μm res.) and tomography (1μm res.) on UO_2 nuclear fuel pellets approximately 0.75 mm in diameter.
- New light source based tools enable in-situ bulk time-resolved studies of nuclear fuels kinetics at the meso-scale under (extreme) fabrication or operating conditions (temperature or pressure).

Meso Challenge

- Thermal and mechanical properties are controlled by heterogeneities with inherent length scale ranging from 10's of nm to 100's of microns.
- In the case of UO_2, grain morphology, cracks and voids control the thermal conductivity and transport of fission gasses. HEDM and μT provide information at exactly this length scale.
- Non destructive monitoring of microstructural evolution at depth in engineering materials on the mesoscale.

Approach

- Develop temperature and pressure environments to enable HEDM and μT experiments under simulated operating or processing conditions.
- e.g. for UO_2, this means high temperature furnaces, gradient furnaces, etc.
- Replace expensive destructive serial sectioning studies with cheaper more representative time resolved studies.
- Growing the number of beam lines suitable for high energy X-rays studies and increasing the number of scientists familiar with the analysis will be crucial to expanding the impact of this arena .
- Hard X-rays are particularly appropriate for studies of radioactive materials because they remove the need for costly and hazardous sample preparation.

Impact

- HEDM and μT techniques used in-situ with environments can validate microstructural models in ways that were unimaginable just a few years ago – potentially offering insights on microstructure control that could affect a wide range of scientific arenas from radiation damage to light weigh structural materials to processing.
- The ability to inform fuel performance codes using HEDM , and UT microstructural data – will remove much empiricism and improve use margins in nuclear fuels.
- The impact to the nuclear energy materials community could be particularly profound if the techniques are applied to radioactive materials.

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Contact: Don Brown dbrown@lanl.gov or Mark Bourke bourke@lanl.gov

High Energy X-ray Diffraction and Tomography Used to Characterized Ceramic (UO2) Nuclear Fuels

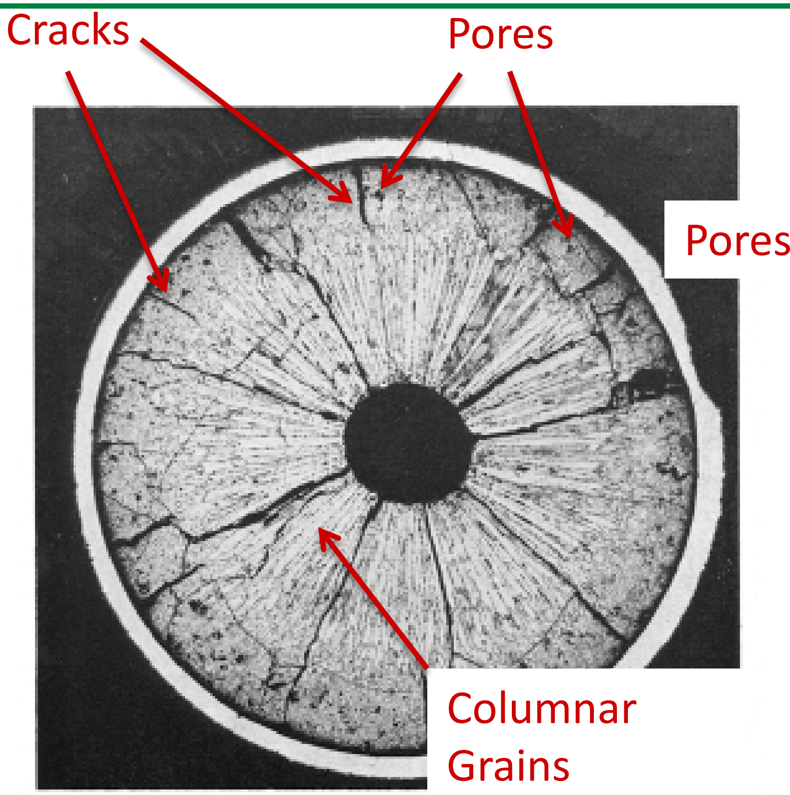
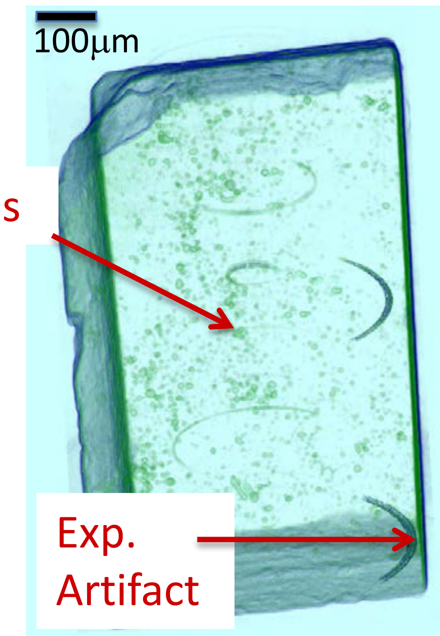
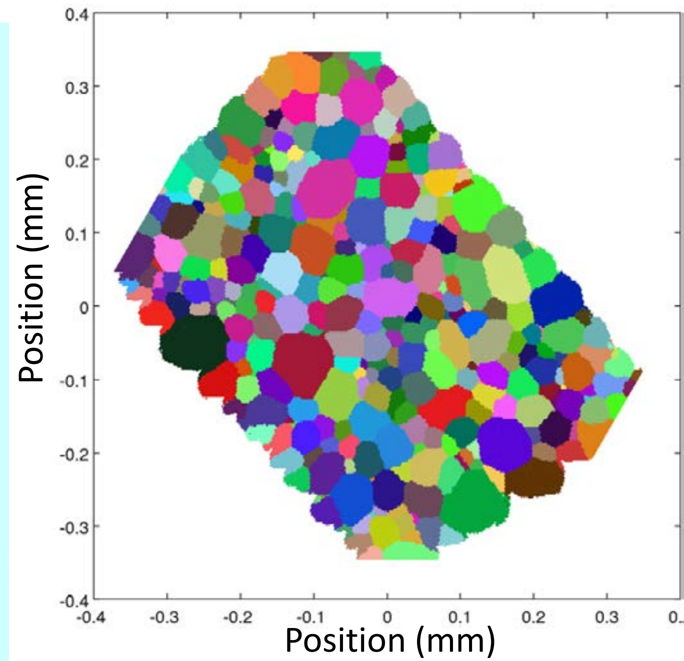


Fig. 1. Section through an irradiated fuel pin, showing columnar grains and collection of porosity as a central cavity. ×10





- Microstructure of UO2 nuclear fuels evolves during use.
- Pores and cracks larger than 2µm were imaged with high energy (80keV) x-ray tomography.
- Grains smaller than 10mm were imaged with high energy diffraction microscopy.
- These techniques can be utilized in-situ to study evolution under conditions simulating in-reactor conditions.

THE KINETICS OF PORE MOVEMENT IN UOz FUEL RODS
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