INL/EXP-21-64120-Revision-0

Probing Microstructure-induced Swelling & Thermal Property Changes in Ion-Irradiated Oxide Fuels using Laser-generated Surface Acoustic Waves

September 2021

Amey Rajendra Khanolkar, Zilong Hua, David H Hurley, J. Matthew Mann

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Idaho National Laboratory

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Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

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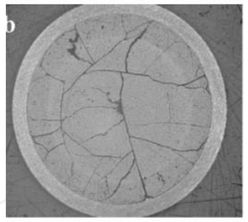
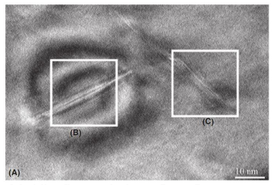
Radiation Effects on Microstructure & Thermo-physical Properties of *Oxide Fuels*

Optical Micrograph of Irradiated UO_2 pellet



C. Degueldre, Progress in Nuclear Energy, 92, 242-253 (2016).

High Resolution TEM image of dislocation loops in H^+ irradiated CeO_2



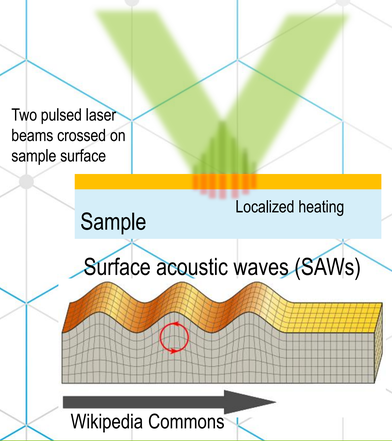
M. Khafizov, J. Am. Cer. Soc., 102(12), 7533-7542 (2019).

- Point defects
- Voids, loops
- Cracks

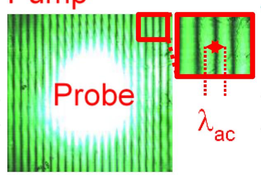
- Post Irradiation Examination (PIE) techniques:
  - Optical & electron microscopy
  - Extensive sample preparation with local effects
  - Insufficient structure-property relationships

Laser-based Materials Diagnostic Tools

Transient Grating Spectroscopy (TGS)



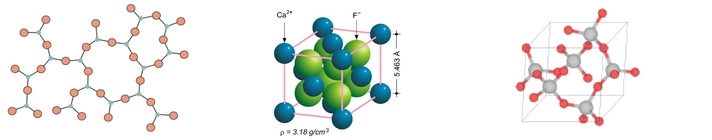
Interference Pattern projected on sample



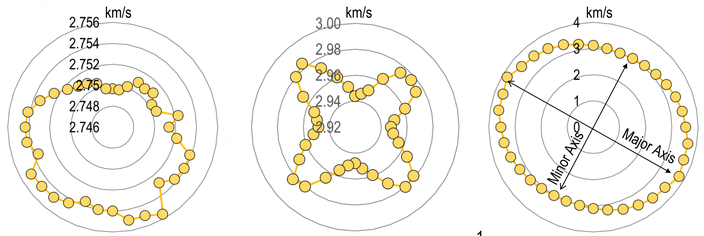
- Enables simultaneous mapping of elastic & thermal properties
- Confined to surface-confined micrometer length-scales

Simultaneous Mapping of Elastic & Thermal Anisotropy in *Insulators*

Fused Silica | Calcium Fluoride | Quartz

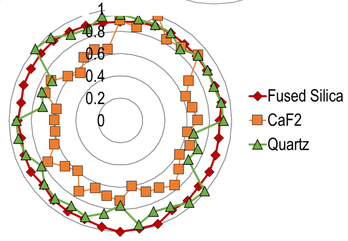


Direction-dependent SAW velocity

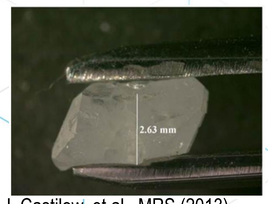


Direction-dependent Normalized Thermal Diffusivity

Circular symmetry indicates thermal isotropy



Thorium Dioxide (ThO_2) Fuel



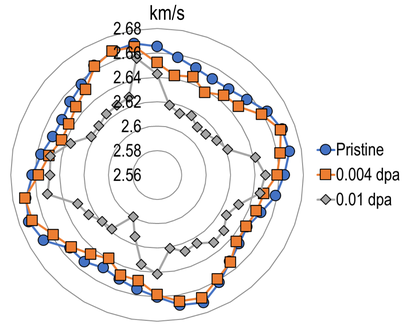
J. Castilow, et al., MRS (2013)

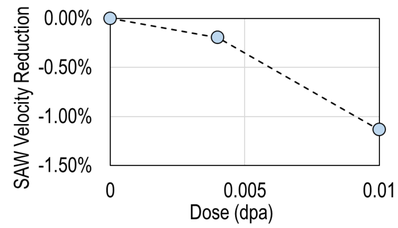
- Alternative to traditional UO_2 for advanced reactor concepts
- Very limited experimental data available for single crystal ThO_2

ThO_2 single crystals synthesized using hydrothermal growth at the Air Force Research Laboratory (AFRL)

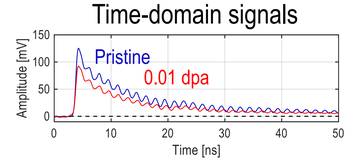
Radiation-induced Elastic & Thermal Property Changes in *Thorium Dioxide*

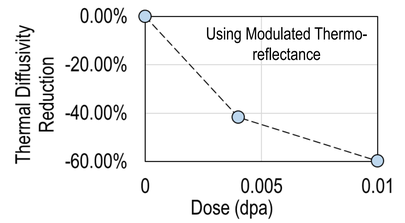
- ThO_2 single crystals irradiated with 2 MeV H^+ ions at room temp.
- TGS enables measurements in micrometer-thick damage regions





Time-domain signals





Research Output

A. Khanolkar, Z. Hua, C.A. Dennett, M. Khafizov, J.M. Mann, D.H. Hurley, "The influence of radiation-induced microstructural defects on the optical and elastic properties of ceramic nuclear fuels", TMS 2022 (accepted)

Harvest Strategy

- ***INL LDRD in Condensed Matter Physics***: Property evolution in ThN under high pressure & low temperature
- ***INL Seed LDRD***: Utilizing Laser ultrasonics for rapid screening of complex alloys → Materials for extreme environments

www.inl.gov Project Tracking #: 19P43-012FP

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