INL/CON-24-78302-Revision-0

TRISO PARTICLE FUEL POLISHING PROCESS COMPARISON

June 2024

Changing the World's Energy Future

Zuzanna Maria Krajewska

Idaho National Laboratory

INL/CON-24-78302-Revision-0

TRISO PARTICLE FUEL POLISHING PROCESS COMPARISON

Zuzanna Maria Krajewska

June 2024

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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

Mechanical Polishing vs. Ion Polishing Methods

TRISO Particle Fuel Polishing Process Comparison

Zuzanna Krajewska*, Ph.D.
Idaho National Laboratory, USA

contact: Zuzanna.Krajewska@inl.gov

Mechanical Polishing

○ TRISO mounts were fabricated for each compact that would give the result of a cross-section of the compact at the level of the mount surface.

○ After the initial cut with the low-speed saw, the mount was backpotted with epoxy, ground, and polished and imaged via the Leica optical microscope.

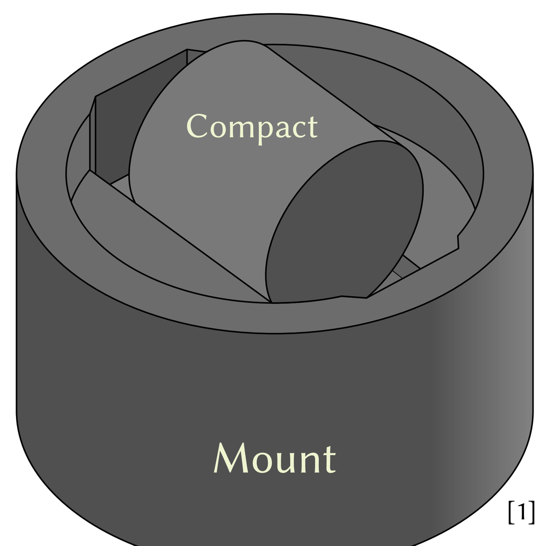
○ Grinding was performed using a 1200 grit grinding pad with ~20N of force during more aggressive grinding operations to rapidly remove material.

○ After each round of grinding, the mounts were inspected via the Containment Box (Window 2M) periscope.

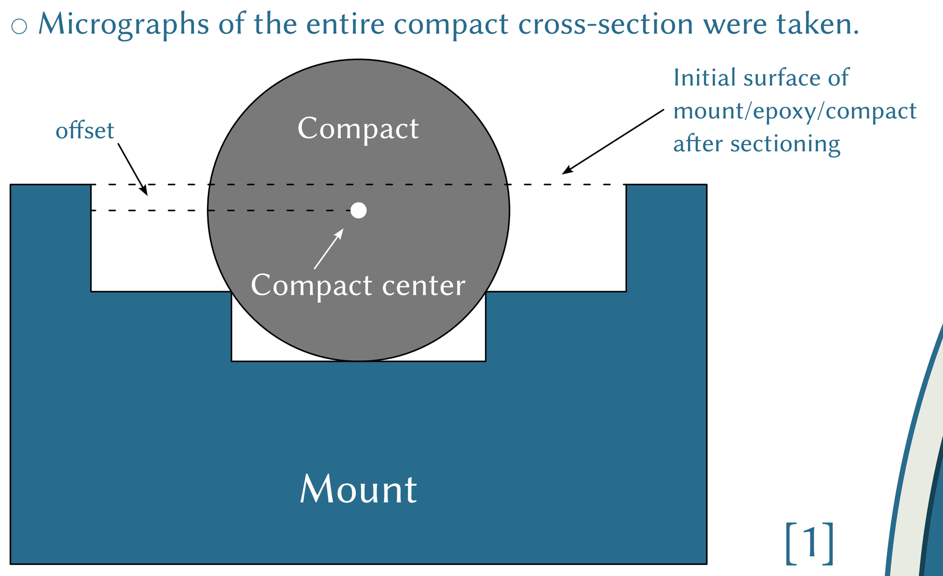
○ Frequent vacuum backpotting was performed to fill voids made accessible via grinding and polishing and to aid in preservation of the fuel kernels, specifically the pyrolytic carbon layer.

○ Once an adequate amount of material was removed, polishing was performed using a Struers MD-Mol pad and a 3-μm diamond suspension followed by a Struers MD-Nap pad and a 1-μm diamond suspension.

○ Micrographs of the entire compact cross-section were taken.



[1]



[1]

Ion Polishing

○ The surrogate TRISO samples were precisely positioned on the aluminum holder and fixed by the application of several drops of silver conducting glue.

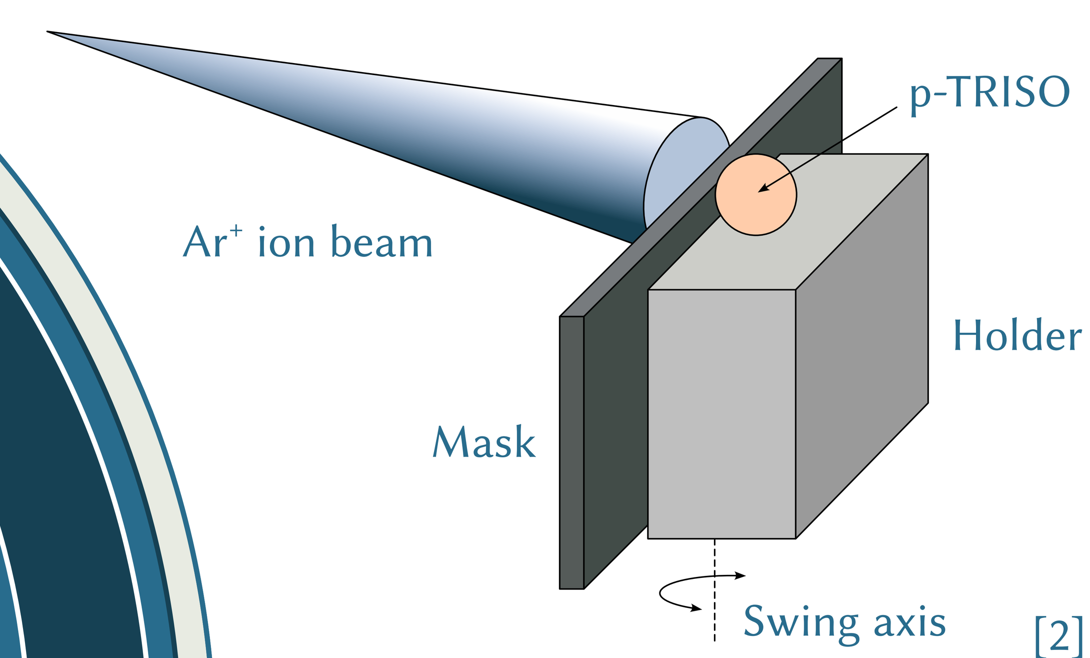
○ In the next step, the holder was attached to the mechanical positioning system allowing for precise alignment of the cutting mask and sample position with respect to the ion beam.

○ During ion milling, a divergent beam of ions is used allowing for effective removal of wide areas on the unmasked region of the sample.

○ The cutting mask was aligned to shadow approximately half of the TRISO sphere.

○ Milling was conducted using Ar+ ions accelerated in the potential of 6 keV. To decrease sample surface waviness, swing ±40° around an axis parallel to the mask surface was used.

○ The time for the complete cutting of the 0.5 mm TRISO sphere was approximately 6 hours. Ion cross-section milling was performed using the Hitachi IM4000Plus system.

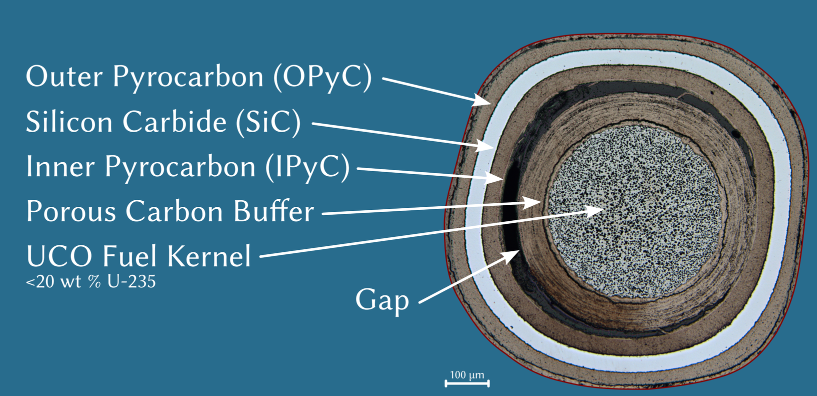


[2]

Tristructural isotropic (TRISO) nuclear fuel

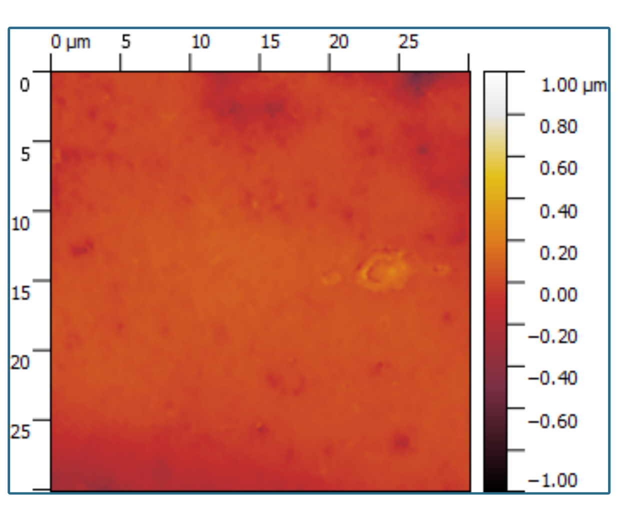
General

TRISO fuel is an encapsulates sub-millimeter uranium-carbide/uranium-oxide spheres embedded in the carbon-ceramic composites. TRISO fuel is mainly used in high-temperature gas-cooled reactors (HTGRs), where TRISO enables high thermal efficiencies and use of entirely passive heat rejection in off-normal conditions to prevent core damage. Before and after irradiation process, TRISO particles must be verified in terms of the quality of the coating layers.



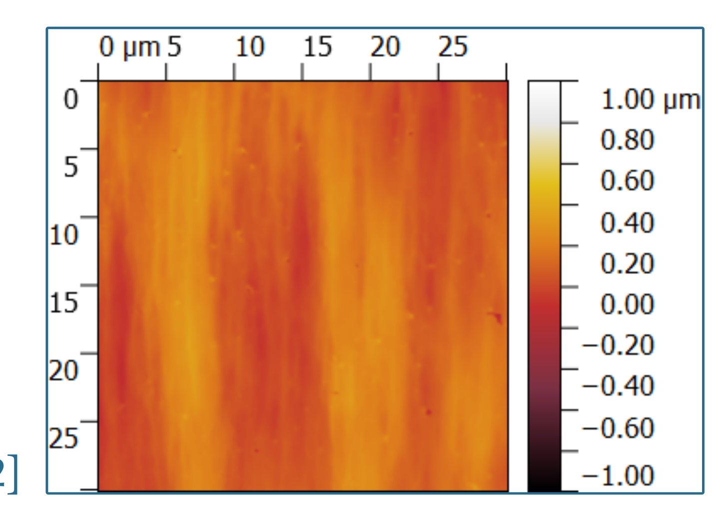
Preparing the TRISO samples for testing involves polishing the samples to obtain a cross-section. Two methods of polishing the TRISO sample were selected, the mechanical and ionic method.

IPyC Layer



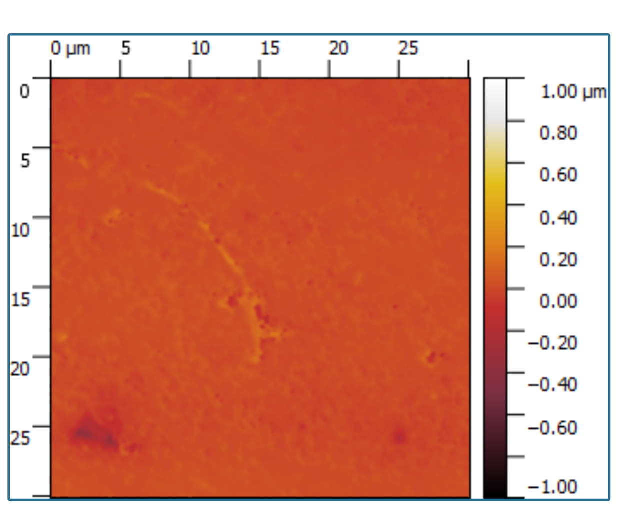
[2]

IPyC Layer

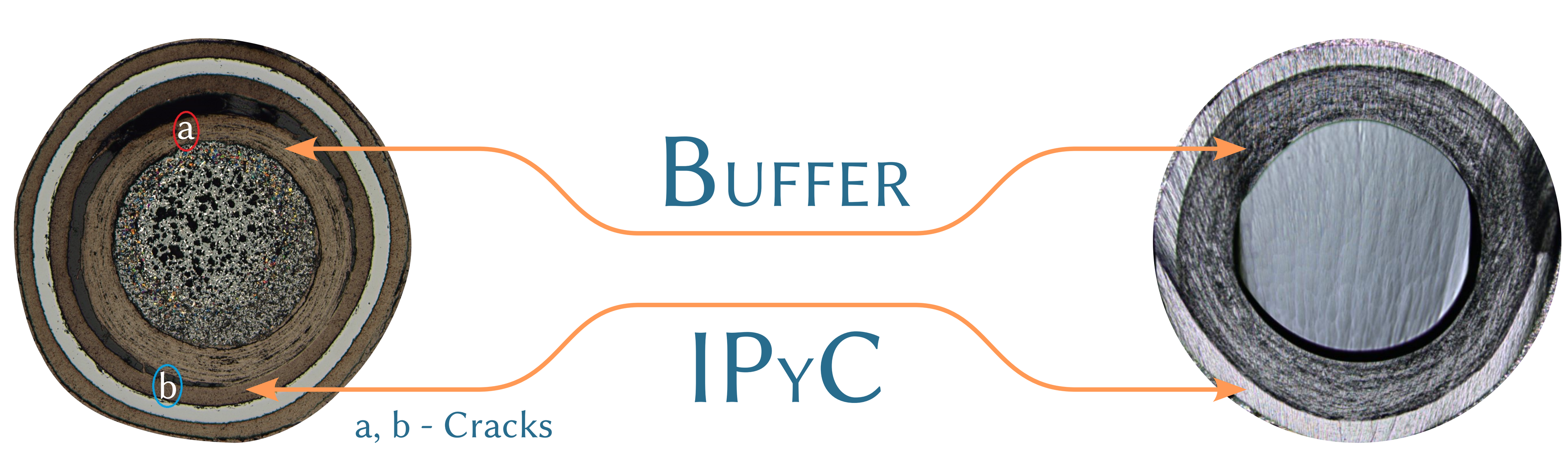


[2]

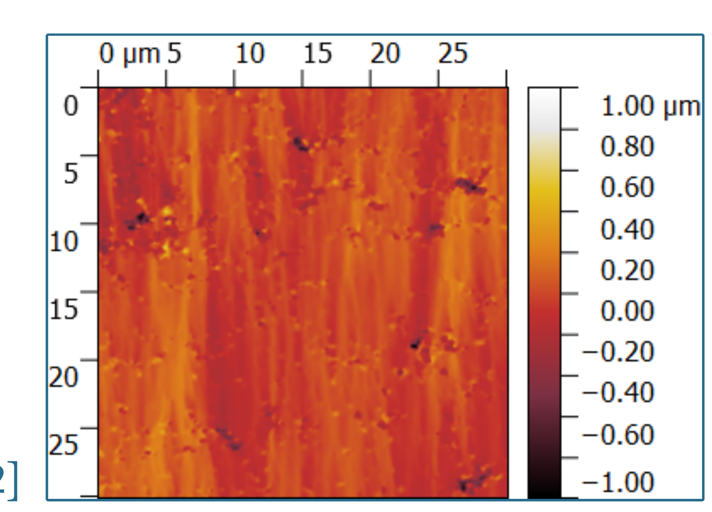
Buffer Layer



[2]



Buffer Layer



[2]

Conclusion

○ The purpose of the experiment was to determine which polishing method causes less damage during the polishing process itself.

○ Confocal laser scanning microscope (CLSM) was selected technique used to compare TRISO sample polishing methods. The roughness profiles of the buffer and IPyC layers were measured for the ion and mechanical polished TRISO samples.

○ The use of CLSM allowed to present that although for the IPyC layer the polishing method has no impact, a significant difference is noticed for the buffer layer.

○ Polishing the buffer layer with the mechanical method spreads the polished material on its surface, thereby smoothing the layer. The ionic polishing method keeps the porous structure of the buffer layer, so it is a less invasive polishing method. Since the porous buffer layer serves as a mechanical separation between the kernel and the coating layers it is important for further experiments to keep its structure unchanged.

○ Although each of these polishing methods can be used for sample preparation, additional arguments in favor of using an ion polishing method are the possibility of using constant parameters, repeatability (reliability) of results, and shorter lead time, which as such, interferes less with the structure of the tested material.

Literature

[1] J. Stempien, J. Schulthess, AGR-3/4 Fuel Compact Ceramography, Idaho National Laboratory, INL/EXT-20-57610 (2020)

[2] Z.M. Krajewska, T. Buchwald, T. Tokarski, W. Gudowski, Front-end investigations of the coated particles of nuclear fuel samples - ion polishing method, Nuclear Engineering and Technology 54 (6), p. 1935-1946 (2022)

INL