Design and optimization of a rotating sample holder for high-temperature ion implantation

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Accident Tolerant Fuels (ATF) are being developed to enhance the safety and resilience of nuclear fuel systems under severe accident conditions. These materials aim to overcome the limitations of conventional zirconium-based cladding, as highlighted by incidents such as the Fukushima Daiichi accident. Many ATF concepts involve modified cladding materials, such as surface coatings, composite structures, or alternative alloys.

Ion irradiation studies are commonly performed on flat samples due to experimental simplicity, however, this geometry fails to replicate the cylindrical structure, stress states, and thermal characteristics of actual fuel cladding. To enable more representative testing, we developed a rotating sample holder system for controlled ion implantation into tubular cladding samples at elevated temperatures.

A beam-shaping aperture was integrated into the design to prevent sputtering and change of the penetration depth at the sample edges. This aperture selectively masks portions of the ion beam, limiting sample exposure to the effective implantation area while covering the sample edges.

SRIM (The Stopping and Range of Ions in Matter) [1] and TRIDYN simulations were performed to model the ion implantation process and optimize the system parameters. The simulations provided data on the ion range distribution and at the selected energy to ensure penetration of the ions to the desired depth. We also obtained sputtering and strain information used to determine the aperture slit size.

[1] Ziegler, J. F., Ziegler, M. D., & Biersack, J. P. (2010). SRIM – The stopping and range of ions in matter (2010). Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 268(11–12), 1818–1823. https://doi.org/10.1016/j.nimb.2010.02.091