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Study of the radiation damage induced by fast neutron and deuterium ions in graphite and zircaloy-4

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Abstract content
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In order to reliably predict the service lifetime of nuclear power reactors, nuclear materials damage response to energetic projectiles needs to be thoroughly evaluated and understood. Currently, within the nuclear industry, efforts are greatly focussed on investigating the pivotal role of nuclear materials, as their interaction with highly energetic particles can lead to their non-performance within the nuclear reactor environment. Critical for the optimal performance of these materials is that they maintain their structural integrity when they are under irradiation by energetic particles. One way of investigating their performance is by exposing them to highly energetic particles at pre-determined fluences within an accelerator environment.
In our case, 3.5 MeV fast neutrons and 4 MeV deuterium ions at fluences of 10ˆ16 n/cm2 and up to10ˆ20 ions/cm2, respectively, were made to interact with graphite and zircaloy-4 in a radio frequency quadropole (RFQ) accelerator at Necsa. Graphite and zircaloy-4 are in-core reactor materials that are used for neutron moderation and fuel cladding purposes, which are critical functions within the reactor. Failure of these materials in adequately performing their functions can have a disastrous effect on the safe operation of the reactor and its immediate environment.

The departure of these materials from their innate structural stability can be inferred from the changes observed in their microstructure after irradiation. To observe these changes, microstructural and crystal structural characterization techniques such as Optical Microscopy (OM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), and X-Ray Diffraction (XRD) were used.
The changes observed in the irradiated materials' microstructure are the formation of interstitial dislocation loops and the increase in the density of voids. Graphite presents mostly basal and prismatic dislocation loops after irradiation, while zircaloy-4 reveals the formation of hydrides in the microstructure. Both cases would eventually lead to changes in the physical and mechanical properties of these materials. The preliminaty results of the characterization of these materials after irradiation are reported in this study.

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