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Elucidating Radiation-Induced Degradation in Siliceous Minerals via Multi-modal Imaging

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Deteriorating nuclear infrastructure escalates the need for accurate characterization of radiation damage in various structural components of a nuclear power plant, including the concrete biological shield (CBS). Exposure of concrete in CBS to neutron radiation induces damage from cracking and residual stresses caused by radiation-induced volumetric expansion (RIVE). In the literature, most studies have investigated irradiation damage in pure and single-phase minerals, however, the RIVE behavior of multi-phase polycrystalline materials such as granite is not entirely understood. Here, we investigate granite samples with Si^{2+}ions to mimic neutron radiation and deploy a detailed multi-modal imaging approach to understand RIVE. Specifically, we use chemical (Raman imaging, laser spectroscopy, scanning electron microscopy) and mechanical (nano-indentation) techniques to create information-rich hypermaps of the pristine and irradiated surfaces of mineral phases. Using this multi-imaging dataset, we elucidate that the RIVE and associated mechanical properties of the siliceous minerals gradually deteriorate with increasing radiation exposure. These experimental results, in combination with simulations of RIVE, enhance our understanding of mineral-specific responses to nuclear radiation.