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## Simulating auto-irradiation of glass using external irradiation beams: impact on glasses structure and properties

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In the current context of nuclear waste management, the fission products and minor actinides are vitrified in a borosilicate matrix and intended for long-term disposal in a deep geological repository. After several thousands of years, groundwater is expected to resaturate the clay host, then corrode the metallic canister and encounter the glass packages. The long-term behavior of glass under these conditions needs to be studied to guarantee the efficient containment of radionuclides. Glass self-irradiation is a key parameter because it impacts the glass properties and thereby its behavior<sup>1</sup>. Alteration experiments conducted on radioactive glasses are cumbersome to carry out, as they have to take place in hot environments (glove boxes or shielded cells). Therefore, external irradiations are used to simulate the impact of self-irradiations on the glass structure and properties<sup>2</sup>. Nuclear glasses will suffer from both electronic and nuclear damages, due to alpha and beta disintegrations, and to gamma transitions.

In this work, the structural changes induced by different irradiation scenarios of a complex SON68 type glass as well as its equivalent simple glass ISG are studied. The effect of various couplings between nuclear and electronic interactions using different electronic stopping power  $S_e$  are simulated by Au and He ions and electron irradiations. 2.5 MeV electron irradiations simulate the damage of beta and gamma radiations at saturation of the damage effects. 7 MeV Au irradiations and 1.7 MeV He simulate the damage of the recoil nuclei of alpha decays and alpha particles respectively. Au irradiations induce mainly nuclear interactions with matter while the electron and He irradiations lead to electronic interactions, except at the end of the path for He, but correspond to different stopping powers (higher for He than for electrons). Sequential irradiations are performed to reproduce the coupling effect of these different interactions to mimic the case of self-irradiation in nuclear glasses, leading to 8 to 12 irradiation scenarios (Figure 1). This work compares the structural damage induced by the various irradiation scenarios to help to understand the coupling effects between nuclear and electronic interactions.

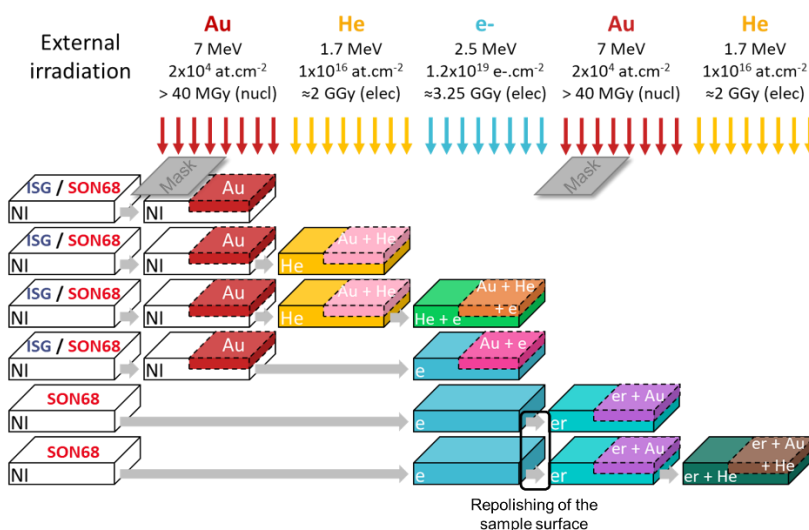


Figure 1: Scheme of the irradiation scenarios performed on the glass coupons.

The modifications on the structure and properties of the glass (swelling, hardness) are determined by several characterization technics like Raman spectrometry, Fourier Transform Infrared Spectroscopy, micro-indentation and optical interferometry<sup>3</sup>.

- 1 Gin, S., Jollivet, P., Tribet, M., Peugeot, S. & Schuller, S. Radionuclides containment in nuclear glasses: an overview. *Radiochim. Acta* **105**, 927-959, doi:10.1515/ract-2016-2658 (2017).
- 2 Mir, A. H. & Peugeot, S. Using external ion irradiations for simulating self-irradiation damage in nuclear waste glasses: State of the art, recommendations and prospects. *J. Nucl. Mater.* **539**, 152246, doi:https://doi.org/10.1016/j.jnucmat.2020.152246 (2020).
- 3 Gillet, C. *et al.* Impact of complex irradiation scenarios on the structure and the properties of the International Simple Glass. *J. Nucl. Mater.* **572**, doi:10.1016/j.jnucmat.2022.154079 (2022).