Structural transformations under coupled extremes of pressure and swift heavy ion irradiation

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Abstract

The response of materials to the simultaneous application of high pressure and intense ionizing radiation remains largely unexplored, despite its relevance for functionality in extreme environments and for non-equilibrium materials synthesis [1]. This unique combination of extremes is accessible using the high-pressure irradiation platform installed in Cave A at the heavy-ion synchrotron SIS18 (GSI, Darmstadt, Germany) [2].

Micrometer-sized samples are compressed in diamond anvil cells (DACs) and irradiated with 200–480 MeV/u uranium ions. In-situ Raman spectroscopy and optical microscopy enable real-time tracking of structural and optical modifications as a function of accumulated fluence.

In this contribution, we present recent results on ion-induced transformations in various materials under high pressure, including molecular compounds such as carbon monoxide (CO) and sulfur (S), the inorganic compound sodium azide (NaN_3), and selected nanomaterials [3]. Effects identified by Raman spectroscopy and synchrotron X-ray diffraction include polymerisation, decomposition, bond rearrangement, and phase transformations, highlighting the rich landscape of radiation–pressure–coupled processes.

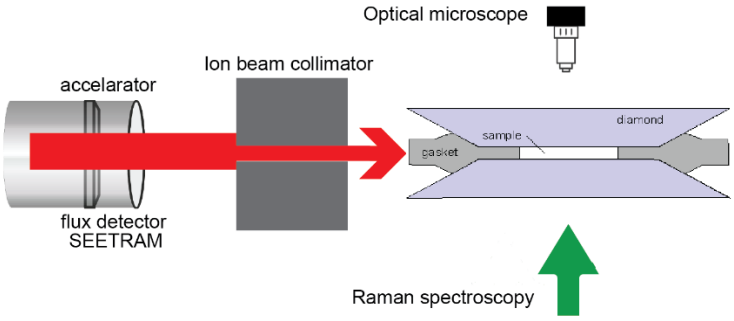

Figure 1. Schematic (not to scale) of the high-pressure irradiation platform at GSI. A pulsed ion beam exits the vacuum beamline through an Al window, is collimated, and passes through the gasket of a diamond anvil cell to reach the chamber.

[1] Lang M. et al. Nanoscale manipulation of the properties of solids at high pressure with relativistic heavy ions Nat. Mater. 8(10), 793–797 (2009).

[2] Tzifas, I., et al. Experimental platform for combining high pressure and swift heavy ion irradiations. Phys. Rev. Res. 8.2 (2026): 023054.

[3] Liang, J., et al. "Structural and optical responses of molecular solids to swift heavy ion irradiation under high pressures." Physical Chemistry Chemical Physics 28.13 (2026): 7835-7839.