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High-Pressure Platform for Swift Heavy Ion Irradiations: Probing Structural Transformations in Extreme Radiation Environments

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Exploring the structural response and property transformations of materials under combined extreme conditions holds enormous importance across diverse, multidisciplinary, and fundamental research domains. The application of extreme pressures can induce novel phases and structures with distinctive properties. In this project, we explore the effects of exposing materials to high pressures combined with radiation conditions provided by swift heavy ions, which locally deposit extremely high energy densities (~eV/atom) on timescales as short as sub-femtoseconds, an effect that cannot be achieved by any other method.
We present an innovative experimental platform designed to simultaneously apply high-energy ion irradiation and high static pressures. This setup operates at the large-scale accelerator facility at the GSI Helmholtz Centre for Heavy Ion Research (Darmstadt, Germany). The ion accelerator provides beams of relativistic projectiles with ranges sufficient to reach samples pressurized inside diamond anvil cells (DACs). Previous work has demonstrated that the combination of pressure and ion irradiation induces structural modifications that are not observed when both extremes are applied separately [1,2]. For the irradiation experiments, the ion beam is collimated and injected through the gasket of the DAC, enabling monitoring of structural changes with increasing irradiation dose using in situ Raman spectroscopy. This presentation details the technical aspects of the experimental setup, outlines future plans, and showcases recent findings, including ion-induced phase transitions in various materials and compounds. These examples highlight the unique opportunity this approach offers to investigate materials far from equilibrium conditions and to provide new routes for achieving and stabilizing unconventional structural transformations.

References
[1] Glasmacher, U.A. et al., Phys. Rev. Lett., 96 (2006) 195701.
[2] Lang, M. et al., Nat. Mat., 8 (2009) 793.

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