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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 on exposing materials to radiation conditions provided by swift heavy ions, which locally deposit extreme high energy densities (~eV/atom) on time scales as short as sub-fs, an effect that cannot be reached by any other approach. This highly localized and fast energy deposition drives the local atomic structure far from equilibrium and produces specific defect configurations and complex structural modifications.

We present an innovative experimental platform designed to simultaneously apply high-energy ion irradiation and extreme static pressures while enabling in-situ sample characterization. This set-up is operated 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 large enough to reach samples pressurized inside diamond anvil cells. Previous work has demonstrated that the combination of pressure and ion irradiation induces structural modifications, that are not observed if both extremes are applied separately [1-3]. For the irradiation experiment, the ion beam is collimated and injected through the gasket of the high-pressure cell enabling monitoring of structural changes with increasing irradiation dose by using in-situ Raman spectroscopy through the diamond anvil. All components are mounted on motorized high-precision stages operated by remote control to align the ion beam with the pressurized microscopic sample. This presentation details the technical aspects of the experimental setup along with future plans and showcases recent findings, including ion-induced phase transitions in rare earth sesquioxides (Gd2O3) and sodium azide (NaN_3). These examples highlight the unique opportunity of this approach to investigate materials far from equilibrium conditions and provide new routes for achieving and stabilizing unconventional structural transformations

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