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Recent Advances in Hardware and Software for Determining Mineral Elasticity under Extreme Conditions

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The single-crystal elasticity is a fundamental property of crystalline materials that describes the macroscopic response of crystals to external forces. It is directly linked to the mechanical properties, elastic wave propagation, lattice dynamics, and anisotropy of minerals and materials. Brillouin scattering and single-crystal X-ray diffraction (XRD) techniques are instrumental in determining the elasticity of minerals under high-pressure and high-temperature (*P-T*) conditions, providing key parameters essential for interpreting seismic observations and deciphering the internal structure and dynamics of planetary bodies. Simulating high *P-T* conditions in laboratory is crucial for studying planetary materials and processes in planetary interiors, including phase transitions, melting behaviors, elastic behaviors, and thermodynamic properties. For this purpose, we have developed the Externally-Heated Diamond Anvil Cell Experimentation (EH-DANCE) system, which utilizes a resistive micro-heater with Pt-Rh or W metal wires surrounding the gasket containing samples in an externally-heated diamond anvil cell (EHDAC). With bi-directional fine-tuning pressure-control capabilities, the EH-DANCE system facilitates the investigation of planetary materials and processes under simultaneous high *P-T* conditions reaching high temperatures above 1400 K. It can be combined with in-situ techniques such as X-ray diffraction and Brillouin scattering, providing a robust platform for experimentally determining the elasticity of minerals and materials under extreme conditions. Moreover, we have developed a tool called "Brillouin View" based on the Python programming language, as part of the "Integrated Mineral Physics Research and Education Software Suite" (IMPRESS). The "Brillouin View" software offers robust capabilities for Brillouin scattering data processing and forward/reverse modeling of elastic constants from the acoustic velocity results obtained through single-crystal Brillouin scattering and XRD measurements. The tool streamlines data analysis, ensuring result reproducibility and promoting collaboration through shared code repositories. The development of the EH-DANCE extreme environment system, along with the "Brillouin View" software within the IMPRESS suite, paves the way for exploring new avenues in determining and modeling the single-crystal elasticity of minerals and materials. These advancements offer enhanced capabilities for studying the mechanical properties and behaviors of minerals under extreme conditions, providing valuable insights into the elastic characteristics of materials in geological and planetary contexts.