In situ studies at Extreme Conditions: the Large Volume Press at PETRA III beamline P61

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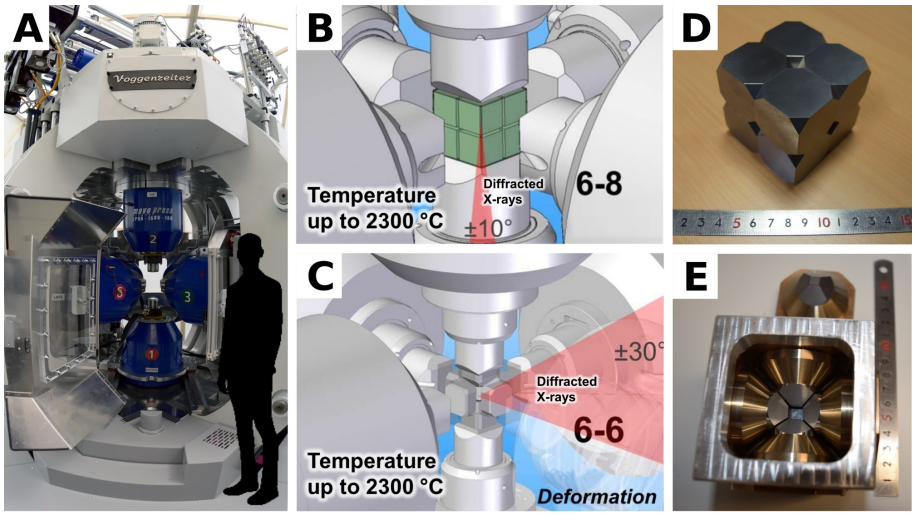
The study of the structure and properties of materials at extreme conditions of high pressures and temperatures is a rapidly advancing field of research, particularly in Earth and materials sciences. Extreme conditions of 24 GPa and 2300 °C can be routinely reached using a conventional large volume multi-anvil press (LVP). However, only few LVP, such as the 6-ram press, can achieve the most impressive targets (currently up to 65 GPa and > 2000 °C) while keeping a relatively large sample volume ($\sim$1 mm^3). The 6-ram LVP was chosen for the P61 wiggler beamline at PETRA III (DESY, Hamburg, Germany) for energy-dispersive X-ray diffraction techniques using high-energy polychromatic X-rays (40-200 keV). Although the beamline is still under construction, the LVP is operational since late 2015. Pressure in the LVP is generated with 6 independently controlled rams up to 15 MN (Figure). Ram displacement is extremely precise in the sub-micron range, enabling the maximum use of the crushing capacity of anvil materials such as cemented tungsten-carbide (WC) and sintered diamond anvils without frequent breakage. Furthermore, the LVP offers open access to the sample assembly for e.g. detector placement. Various compression setups are possible, such as Kawai-type 6-8 (Fig. B) and Cubic-type 6-6 geometries (Fig. C) using secondary WC anvils. In 6-6 geometry, the press is additionally capable of generating deviatoric stresses at constant displacement rates at high pressures. The LVP at beamline P61 is therefore well-suited for innovative extreme conditions research. In Earth Sciences it can simulate conditions in the Earth down to and beyond 1500 km depth (60 GPa) for phase relations and rheological studies of planetary mantle behaviour and evolution. In materials science, in addition to phase relations studies, novel pre-cursor materials with exotic properties (e.g. bandgap tuning, superconducting, piezoelectric or super-hard) can be synthesized and studied in situ at extreme conditions. X-rays at P61 are expected from early 2019. An outlook of the beamline will also be presented.



Extreme conditions science at P61. (A) the 6-ram LVP. (B,C) compression geometries and windows for diffracted X-rays. (D,E) anvils for the 6-8 and 6-6 compression geometries, respectively.