Novel portable Paris-Edinburgh presses for synchrotron time-resolved 3-D micro-imagining under extreme conditions

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Synchrotron X-ray microtomography is a non-destructive 3D imaging/microanalysis method selective to a wide range of properties such as morphology, density, chemical composition, chemical states, structure, and crystallographic perfection with extremely high sensitivity and spatial resolution. To extend this technique to extreme conditions (high-pressure/high-temperature/high stress), we developed two new portable devices based on the Paris-Edinburgh press:

1/ the RoToPEc (Rotating tomography Paris–Edinburgh cell [1]), where two opposed conical anvils are used to pressurize a sample embedded in an X-ray transparent boron epoxy gasket. In our new system, both anvils can rotate independently under load, with no limitation in angle, through two sets of gear reducers and thrust bearings. The accurate and simultaneous rotation of the top and bottom anvils is achieved using stepper motors and optical encoders positioned precisely on the both anvils. The ability to fully rotate the sample chamber under extreme conditions (up to 15 GPa and 2200K), overcomes the usual limited angular aperture of ordinary high pressure set-ups, allowing complete sets of tomographic projections to be acquired, in both full-field imaging (where a large (approx. 2x2 mm^2) monochromatic (or pink) x-ray beam is used to collect 2D radiographs) or micro-diffraction modes (scanning with a pencil beam of FWHM 3 x 3 μm^2 at several projection angles). Additionally, independent and controlled rotation of each anvil enables operation in shearing (one anvil rotates while the other is stationary) or deformation modes (both anvils rotate in opposite directions) under high P,T conditions. Hence, our portable device can operate in four different modes: (i) tomography, (ii) shearing, (iii) deformation or (iv) combination of (iii) or (ii) and (i). Our portable device has been easily and successfully adapted to various multi-modal synchrotron experimental set-up at beamlines ID27 (**ESRF**), PSICHE (**SOLEIL**), and I12 (**DIAMOND**).

2/ the UtoPEc (Ultra-fast Tomography Paris-Edinburgh cell) is a new Paris-Edinburgh press optimised for high speed tomography (0.5 seconds per full tomogram) at high pressures and temperatures (up to 15 GPa and 1500 K). This press has been developed at PSICHE beamline (**SOLEIL**) and is compatible with performing tomography on millimetre-sized samples. Rotary couplings allow continuous rotation of the press for fast tomography time series. At the PSICHE beam line, a spatial resolution of a few microns can be obtained for a full 2k x 2k reconstruction in 0.5 seconds. *In situ* tomography can also be combined with diffraction to provide measurements of pressure, temperature, phase transitions or composition.

The potential of our new presses for *in situ* synchrotron experiments will be illustrated by preliminary results [1-3] recently obtained from these facilities on many scientific cases. To conclude, we will present the new scientific opportunities our portable devices allow for studies of phase transition, density, crystallization and deformation under extreme PT conditions.

References

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