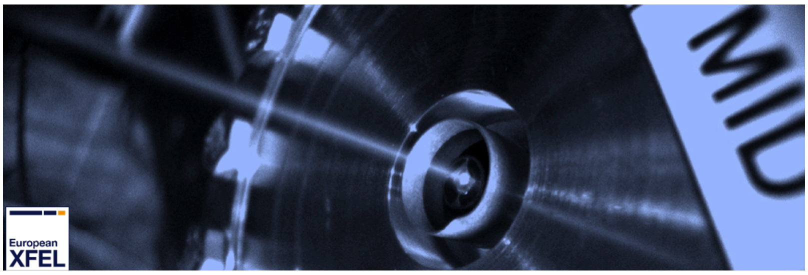

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Structure, properties and phase transitions of melts and glasses at in-situ conditions within Earth and rocky planets

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Silicate and Fe compound melts are major constituents of the interior of the Earth and rocky planets and have a strong impact on their evolution and properties. Despite this importance, information on properties of such melts at in-situ conditions are still scarce. Main reasons for this are, that these melts are not directly accessible and that experiments at in-situ conditions are extremely challenging, especially if flux hungry techniques will be applied. In addition, the properties change widely with pressure, temperature and the chemical composition opening up a wide parameter range.
Most high-quality actual information on structure of amorphous silicates is obtained with X-ray Raman (XRS) and total scattering analysis (PDF) on SiO2 glass or GeO2 as analogue for SiO2 (Prescher et al., 2017, Spiekermann et al., 2019, Petitgirard et al., 2019, Morard et al., 2020) at room temperature during static compression in a diamond anvil cell (DAC) and additionally X-ray emission spectroscopy (XES) in case of Fe-bearing systems. More recent studies expanded the temperature range to in-situ conditions by the application of either laser or X-ray heating within the DAC (Liermann et al., 2021; Kaa et al., 2022; Morard et al., 2022).
Another emerging way to study melts at in-situ conditions is the use of optical long pulse laser dynamic compression techniques that allow to achieve the most extreme pressure-temperature (P-T) states in the laboratory. The extreme states are only very short lived (nanosecond scale) and nowadays can be probed either with hard synchrotron or X-ray free electron laser (FEL) radiation. The short pulse length of the FEL radiation allows to obtain fs long snapshots of the material while it is excited to extreme temperatures and pressures. By the application of pump-probe techniques, the evolution of the sample during dynamic compression can be studied with great time-resolution and short-lived states of extreme conditions can be accessed (Briggs et al., 2019; Schoelmerich 2020; Armstrong et al., 2021). Most importantly, studies by dynamic compression have the advantage that the sample does not need to be constrained in a sample container that might mask the signal or react with the sample while the measurement is performed. However, all studies that were performed so far at FELs are limited in the accessible Qmax of 7. Since detector geometries have been optimized already, this limitation mainly originates from the restriction in the availability of higher photon energies. This maximum Q is considerably lower to what has been achieved at synchrotron sources (e.g. 10 in Prescher et al., 2017) and poses limitations to push forward the scientific knowledge.
Higher photon energies at an FEL source have the unique potential to overcome the present limitations at in-situ conditions by significantly increasing the Q range and thus strongly improving the quality of structural data that can be obtained from melts and glasses at in-situ conditions. For Earth science applications this will result in significantly better models for melt properties and planet evolution and add key input to a long lasting scientific question. Besides the application to systems which are relevant for Earth sciences, the method will certainly also be applied to study glasses of industrial and everyday relevance like mobile phone displays (Panzerglas) or window glasses.

Prescher, C. et al. (2017) PNAS 114, 10041; Spiekermann, G. et al. (2019) Phys. Rev. X 9, 011025; Petitgirard et al. (2019) Geochem. Persp. Let. 9, 32; Morard, G. et al. (2020) PNAS 117, 1198; Liermann et al. (202) JSR, 28 ; Kaa et al. (2022) PRR 4; Morard et al. (2022) JGR 127; Briggs et al. (2019) APL, 115; Schoelmerich (2020) PhD thesis, University of Rostock; Armstrong et al (2021) JOM, 73.

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