Dynamic compression response of SiO$_2$ at different strain rates

Karen Appel

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DFG Research Unit „Matter Under Planetary Interior Conditions“
The HED science within planets and exoplanets

➢ Phase relations
➢ Crystal chemistry
➢ Physical properties (viscosity, density, heat transport, plasticity..)
➢ Reactions of phases at relevant conditions
➢ Evolution of the Earth and planets
Structural properties and phase stabilities of rock-forming minerals at PT regime relevant for deep planetary interiors

- Dynamic optical laser compression experiments (quartz, fused silica, stishovite, cristobalite, GeO$_2$)
- Target design and experimental condition control with hydrodynamic simulations
- Obtain EoS data, identification of phase boundaries, derive melt structure
Set-up dynamic compression at MEC, LCLS, LS84

- Optical drive lasers: 527 nm, 10 ns, 300 μm focal spot, up to 4 x 15 J, ramped pulse
- X-ray diffraction detector (CSPAD)
- VISAR line imaging
- Materials: Al (250 nm), Ta (150 nm), Polyimide, SiO₂, LiF
- X-rays from XFEL (11 keV)
- Experimental and simulated results
Set-up dynamic compression at EH3, SACLA

Strain rates and duration of experimental HP techniques

- Optical laser shocks ($P_{\text{max}} \sim$ few TPa)
- Gas gun ($P_{\text{max}} = 300$ GPa)
- dDAC ($P_{\text{max}} = 165$ GPa)
- D-DIA ($P_{\text{max}} = 10$ GPa)
Set-up dynamic compression in a DAC at P02.2

- Up to 160 GPa
- Up to 160 TPa/sec
- 4 kHz repetition rate

H$_2$O

Schoelmerich, PhD thesis, 2020
Dynamic compression pathways in a dDAC
Results

Optical laser induced dynamic compression
$\alpha$-cristobalite during optical laser induced dynamic compression
Response of stishovite during dynamic compression

Schoelmerich et al., 2020

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Karen Appel, 14th of January 2021
Relative volume change of shock compressed stishovite vs pressure and comparison to other polymorphs
DFT-MD simulation for stishovite
Pressure – density data of stishovite

Schoelmerich et al., 2020
Effect of hydrostacity on the structural transition pathway
Summary on structural transformation pathways in SiO$_2$ polymorphs
Interest in experiments at dynamic compression facility at ESRF

FeO

- Further development of dynamic compression technique
  - Sample preparation
  - Data analysis
  - X-ray techniques
- Study well-known rock-forming systems at ultrahigh pressures and high temperatures
- Apply XANES to study phase relations, electronic and thermo-elastic properties of phases in the binary system Fe-O, to prepare ternary systems (Fe-Mg-O), and quaternary (Fe-Mg-Si-O).
- XRD experiments planned within a DFG funded project at HED (PhD student starts in mid-Feb)

Ozawa et al, 2011