Investigation of structural transformations in high pressure shocked silicates from in-situ x-ray diffraction

A.Ravasio[1]*, J.-A. Hernandez[1], G. Morard[2], M. Guarguaglini[1], R. Alonso-Mori[3], D. Andrault[4], M. A. Baron[2], A. Benuzzi-Mounaix[1], R. Bolis[1], G. Fiquet[2], E. Galtier[3], G. Garbarino[5], A. E. Gleason[6], S. Glenzer[3], F. Guyot[2], B. Ko[7], H. J. Lee[3], W. L. Mao[6], M. Mezouar[5], B. Nagler[3], N. Ozaki[8], A. K. Schuster[9], S. H. Shim[7], T. Vinci[1]

[1]*Laboratoire pour l'Utilisation des Lasers Intenses (LULI), Ecole Polytechnique, CNRS, CEA, UPMC, 91128 Palaiseau, France*
[2]*Sorbonne Université, Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie, IMPMC, Museum National d'Histoire Naturelle, UMR CNRS 7590, IRD, 4 Place Jussieu, 75005 Paris, France*
[3]*SLAC National Accelerator Laboratory, 2575 Sand Hill Rd., Menlo Park, CA 94025, USA*
[4] *Université Clermont Auvergne, CNRS, IRD, OPGC, LMV, Clermont-Ferrand, France*
[5]*European Synchrotron Radiation Facility, ESRF, Grenoble, France*
[6]*Stanford Institute for Materials and Energy Sciences, SLAC, Menlo Park, CA, 94025, USA*
[7]*School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, USA*
[8]*Graduate School of Engineering, Osaka University, Suita, Osaka 565-0871, Japan and Institute of Laser Engineering, Osaka*
[9]*Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, D-01328 Dresden, Germany*

*e-mail: alessandra.ravasio@polytechnique.fr

Accurate models of the Earth, of Earth-Type exoplanets and of putative differentiated cores of giants planets require, among other compounds, an improved description of the physical properties of silicates under extreme conditions. In the most current description, Earth-like planets are assumed to be fully differentiated and constituted of a metallic core surrounded by a silicate mantle. This model is currently used to predict mass-radius relationship for planets up to 100 earth masses. Of overall importance are olivine $(Mg,Fe)_2SiO_4$ and orthopyroxene $(Mg,Fe)SiO_3$ minerals, with enstatite ($MgSiO_3$) and forsterite (Mg_2SiO_4) as the pure Mg end-members. The determination of their phase diagram at high pressures and temperatures both in solid and liquid phases is crucial for planetology. Previous measurements allowed to associate the solid-solid phase transitions that olivine undergoes at high pressure to the major seismic discontinuity detected in the Earth's mantle. Establishing the stability of these phases with pressure and temperature is necessary for super Earth studies and meteorites impacts as well as for high pressure physics. Similarly, the knowledge of properties of liquid silicates under high pressures and high temperatures are requested for modelling the dynamics and solidification mechanisms of the Magma Ocean in the early Earth, constraining the presence of partial melting at the present day core-mantle boundary.

Reaching pressure over 300 GPa simultaneously with temperature over 4000 K in DAC is as today a real challenge. Complications arise because of the high temperatures involved. Further issues are associated to the difficulties in maintaining the compounds under liquid state in the diamond cell because liquids tend to be displaced in thermo-mechanical gradients. This is the reason why experimental data are still very limited at lower mantle conditions and melt structural information is almost nonexistent beyond few tens of GPa. This situation leaves numerous doubts in the explanation of the observed large low shear velocity provinces (LLSVPs) area and ultra-low velocity zones (ULVZs) above the Core Mantle Boundary (CMB). To overcome these difficulties, both $MgSiO_3$ and Mg_2SiO_4 glasses under high pressures are often studied as liquid analogs. This approximation, though, has never been validated.

In this context, shock compression schemes can help in widening the characterised phase diagram region. This research has so far been impeded by the absence of a structural probe able to directly determine phase transformations along shocked states. The advent of extremely brillant and temporally short x-ray sources from XFEL has opened new exciting perspectives in this context, allowing *in-situ* x-ray diffraction (XRD) measurements. Obtaining XRD measurement on shocked samples also contributes to shed light into the kinetics of phase transitions at the nanosecond temporal scales, which is useful for understanding kinetic aspects and meteoritical impacts. In addition, the occurrence of metastable states along the shock path as a function of the duration of peak conditions is a major issue for better understanding the general relevance of dynamic compression studies for geophysics and planetology.

In this talk we will present recent results we obtained on in-situ XRD from shock compressed SiO_2, $MgSiO_3$, Mg_2SiO_4 cristalline and glass samples. The experiment was carried on at the MEC end-station of LCLS, in Stanford. Main shocked induced structural changes will be reported, comprising first observation of shock-induced metastable amorphous phases as well as unexpected high pressure polymorphs. Direct XRD data of liquid states could also be achieved and will also be discussed. A particular attention will be placed in the comparison between melts and high pressure glass we obtained in both static and dynamic compressions.

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