Melting of Olivine $(Mg, Fe)_2SiO_4$ Under High Pressure

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Introduction

The melting behavior of these assemblages is important for determining the temperature of the mantle and the origin of the seismically-imaged structures at the core-mantle boundary. Transformations in the Earth materials induced by pressure, as well as the combined effects of pressures and temperature, are the key to interpreting the composition of the lower mantle.

The interpretation and understanding of the geochemical differentiation of the Earth, geodynamics, rheology, and seismic tomography data hinge upon the melting temperatures of the lower mantle constituents. For example, differentiation strongly depends on the evolution of Earth's history, viscosity and anelasticity scaled with the ratio of actual temperature over melting temperature, and the melting temperature limits lateral temperature variations and the temperature contrast between the bottom of the mantle and the core.

Campbell et al. (1992) concluded that perovskite $(Mg,Fe)SiO_3$ is the liquidus phase, when melting olivine at lower mantle pressure between 30 to 40 GPa. Williams (1990) concluded that magnesiowustite (Mg,Fe)O is the liquidus phase at lower mantle pressure above 50 GPa.

Objectives

•Understand how the lower mantle melts.

•Which phase, silicate perovskite or magnesiowustite, co-exists with the liquid?

•Does this change with pressure?

Hypothesis

When melting of forsterite under lower mantle condition, the liquidus phase is silicate perovskite at 30 to 60 GPa.

Methodology

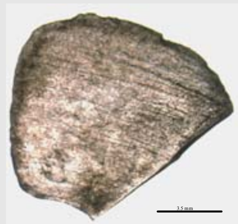
•Study $(Mg,Fe)_2SiO_4$ as a simplified model of lower mantle composition.

•Diamond anvil cell for generating high pressures.

•Laser heating for generating high temperatures.

•Electron probe of a linear scan through the melting spot for composition.

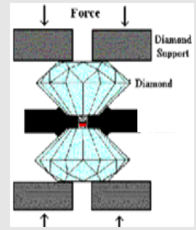
•Improvements in experimental design.



1. Polishing the Sample

•$(Mg_{0.9}Fe_{0.1}Ca_{0.001}Mn_{0.001})_2SiO_4$

•Sand paper 1200 grit

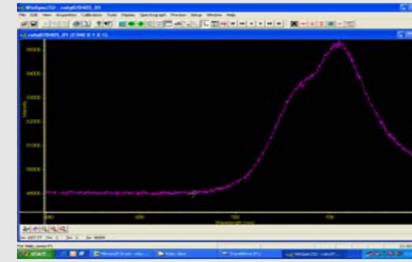


2. Loading the Sample

•Diamond culets: 300 µm across

•Sample chamber: 30 µm thick

• Diameter is 130 µm

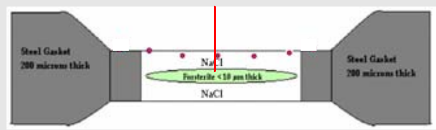


3. Measuring the Pressure

•Pressure is measured using ruby fluorescence.

•Pressure spectrum at 30 GPa.

•Standard deviation is 0.2 GPa

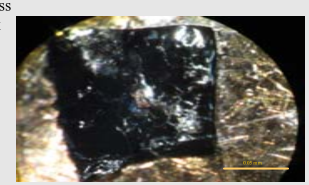


4. Laser Heating

•Laser beam size is 30 µm

•Red laser λ = 1.064 µm

•Temperature >3000 K



5. Recovering the Sample

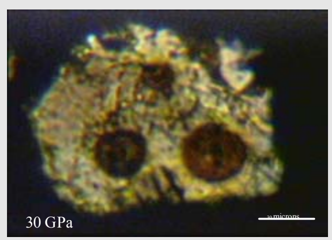
•Mounted on carbon tape

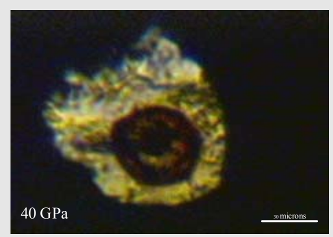
•Carbon coated

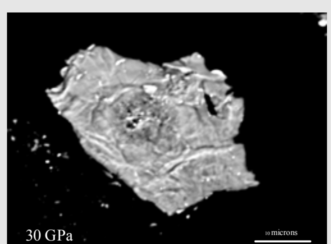
6. E-Probe Analysis

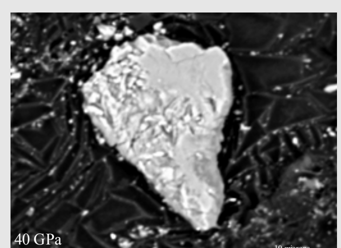
•EDS analyses

•Line running across the diameter









Preliminary Experiments

Electron microprobe analysis:

- Measurements along a line running across the diameter of the laser-heated spots.
- Because of the temperature gradient, the melt is concentrated in the center, and the solid phase on the liquidus forms a ring around the melted spot
- The main observation to be made is whether this solid phase is silica-rich (perovskite) or silica-poor (magnesiowüstite).
- EDS analyses is better for this type of sample instead of using the WDS because this method is less sensitive to variations in topography, which is very important in these small and thin samples.

References

- Boehler, R. High-Pressure Experiments and the Phase Diagram of Lower Mantle and Core Materials. Geophysics, vol. 38. May, 2000.
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