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Fe-rich silicate melt densities to 150 GPa

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Abstract

In order to constrain the density contrast between solid and melt at high pressure, we measured the density of amorphous $Mg_{0.7}Fe_{0.3}SiO_3$ glass as a potential composition for deep magmas up to 150 GPa. We found that a densification through an electronic transition takes place at about 100 GPa supported by Mössbauer spectroscopy and optical measurements. Enriched Fe-melts can thus densify through electronic transition at pressure of deep terrestrial mantle.

1. Introduction

Density contrast in the Earth's lower mantle is the main parameter that controls the entrainment and settlement of matter. During the early Earth's formation, tremendous amounts of melts could have been generated due to large planetary impacts such as the Moon-forming impact and accumulated on top of the core-mantle boundary facilitating the formation of a deep basal magma ocean [1]. The key parameter that controls potential density crossover is the iron content of the melt and its influence on melt density at high pressure. However, to date there are no data on melt densities at pressures of the lower mantle with composition relevant for a deep magma ocean and data on Fe partitioning remain debated with scattered values.

2. Results and implications

In order to measure the density of amorphous silicate to such conditions, we have developed a unique technique using the X-ray absorption method in the diamond anvil cell (DAC). The method enables to retrieve directly the density in situ at high pressure of amorphous or liquid materials. Prior to this study and using the same method, we discovered that the densities of $MgSiO_3$ [2] and SiO_2 [3] glasses could be similar to their crystalline phases at pressures of the deep lower mantle. Recently we have extended our dataset by measuring an iron-bearing $Mg_{0.7}Fe_{0.3}SiO_3$ glass up to 150 GPa (Fig.1) and fit an equation of state to model such composition. Using our data, we can compute the density of glass and liquid in the SiO-MgO-FeO system. Further, we found that an increase in density takes place at about 100 GPa linked to an electronic transition in Fe as evidence by Mössbauer spectroscopy and optical measurements (light absorption and visual observation).

3. Figures

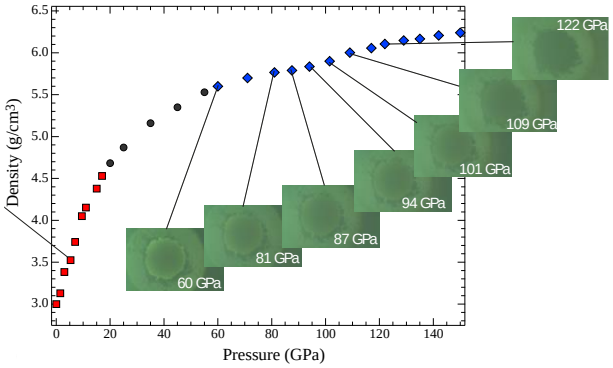

Figure 1: High pressure densities of $Mg_{0.7}Fe_{0.3}SiO_3$, in Methanol-Ethanol (M:E) pressure medium or without medium as a powder. At ~100 GPa the density shows an increase of ~5 per cent and the sample becomes opaque, as evidenced by the pictures of the sample on the figure.

4. Summary and Conclusions

We measured the density of an iron-rich silicate glass as an analogue of a melt with a composition equivalent to deep magmas up to 150 GPa. Such composition becomes denser than residual solids for any experimental value of Fe partitioning available. Further, Fe-rich melts can densify at high pressure through an electronic spin transition and thus can

accumulate at the top of the core-mantle boundary to form a basal magma ocean.

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