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Structural Phase Transition in Fe_2SiO_4

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1 Introduction

Olivine, $(Mg,Fe)_2SiO_4$, is the most abundant mineral in the upper mantle. Its polymorphic transitions from olivine to wadsleyite and from wadsleyite to ringwoodite are believed to be responsible for the seismic discontinuities at 410 and 520 km depths. Determination of the phase diagram for olivine is therefore of particular interest to the study of the physical state and the chemical composition of this region of the earth's interior. Fayalite (Fe_2SiO_4,), the end-member of the solid-solution of olivine, has the *Pnma* symmetry. Therefore, the physical properties associated with the phase transitions of fayalite play an important role in understanding the composition, structure, and dynamics of the earth's mantle.

2 Experiment

The starting material was Fe_2SiO_4, fayalite, synthesized from a starting mixture composed of finely powdered Fe_2O_3 and SiO_2. The mixture was heated at 1273 K for 24 h at an oxygen fugacity (fO2) of one log unit lower than the wüstite-magnetite (WM) buffer. High-pressure X-ray diffraction experiments were performed using a multi-anvil high-pressure apparatus. The cubic anvil assembly was compressed using a "Max III" high-pressure apparatus, and was combined with a synchrotron radiation source located at the KEK in Japan. The diffracted X-rays were detected using a germanium solid-state detector at an angle of $2\theta = 6.0°$. A cylindrical graphite heater was inserted into the octahedral pressure medium and enclosed within a ZrO_2 sleeve for thermal insulation [1]. The powdered sample and gold, which was used as pressure calibrant, were loaded directly into the graphite heater, which also served as a sample capsule. The pressure was determined from the unit cell volume of gold using the equation of state for gold. After reaching the required temperature, we performed in situ measurements using the synchrotron X-rays. The duration of heating was 1-3 hours. Determination of the stable phase in each experimental run was carried out by observing the X-ray diffraction pattern of the sample. To check the identification of each phase in the in situ experiments, the recovered samples were also examined using micro Raman spectroscopy.

3 Results and Discussion

We performed approximately 25 experimental runs, and the boundary determined in this study is in general agreement with that reported in previous high-pressure experiments. However, the value of our dP/dT slope [1] was more positive than that in previous in situ experiments. It is likely that the discrepancy between previous and our high-pressure experiments dues to the kinetics of the structural phase transition. In previous in situ experiments, the P-T condition was changed several times during each run while observing the transition from the fayalite to the spinel structure. It is known that a metastable overshoot (ΔP or ΔT) is required to provide a sufficiently large energy driving force to overcome a nucleation and/or growth barrier for the transition. To avoid any influence of the kinetic effect, we used the same heating cycle as that used in conventional quench experiments.

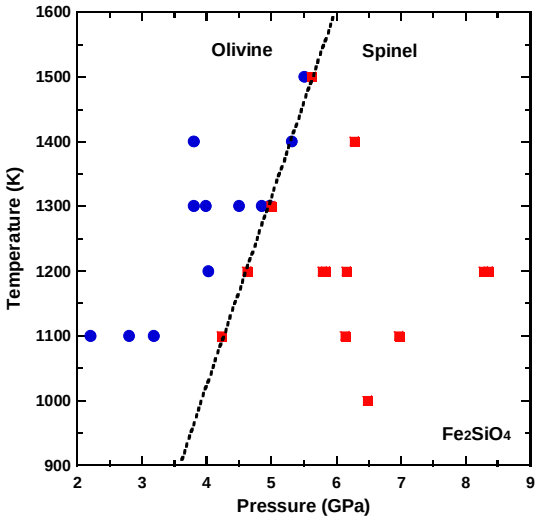

Fig. 1: Experimental results and phase boundary of the fayalite-spinel transition in Fe_2SiO_4. The solid circles and squares denote the conditions where the fayalite and spinel phases were stable, respectively. The dashed line shows the inferred phase boundary between the fayalite and spinel phases.

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References

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