Fe-Mg partitioning between perovskite and ferropericlase in the lower mantle

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ABSTRACT

Fe-Mg partitioning between perovskite and ferropericlase in the MgO-FeO-SiO2 system has been studied up to about 100 GPa at around 2000 K using a laser-heated diamond anvil cell (LH DAC). The compositions of both phases were determined by using analytical transmission electron microscopy (ATEM) on the recovered samples. Present results reveal that the Fe-Mg apparent partition coefficient between perovskite and ferropericlase [Kp/fp = (Xp/Mp)/(Xf/Mf)] decreases with increasing pressure for a constant FeO of the system, and it decreases with increasing FeO content of ferropericlase. The gradual decrease of Kp/fp with increasing pressure is consistent with the spin transition in ferropericlase occurring in the broad pressure range from 50 to 100 GPa at around 2000 K.

Keywords: Perovskite, ferropericlase, Fe-Mg partitioning, LH DAC, FIB

INTRODUCTION

The partition coefficient between (Mg,Fe)SiO3 perovskite or post-perovskite and (Mg,Fe)O ferropericlase is important to understand the chemical and physical properties of the lower mantle, such as density and elastic velocities. The exchange partition coefficient of Fe and Mg between perovskite (Pv) and (Mg,Fe)O ferropericlase (Fp) can be expressed as Kp/fp = Xp/Mp/Xf/Mf, where X is the mole fraction of the component i (=Mg,Fe) in phase A (=Pv, Fp).

The partition coefficient between perovskite and ferropericlase (Kp/fp) has been investigated by various researchers using powder X-ray diffraction technique and/or analytical transmission electron microscope (ATEM), revealing the dependency of pressure and temperature and the effect of oxygen fugacity and trivalent cations (e.g., Guyot et al. 1988; Mao et al. 1997; Andrault 2001; Murakami et al. 2005; Kobayashi et al. 2005). Katsumura and Ito (1996) revealed that Kp/fp decreases with increasing Fe/Mg ratio of the system at 23 GPa. Tange (2006) determined the phase relation of an Fe-rich (Mg0.53,Fe0.47)SiO3 pyroxene up to 47 GPa using a Kawai-type multi-anvil apparatus with sintered diamond anvils. Although the compositional dependency on Kp/fp was reported up to 50 GPa using a laser-heated diamond anvil cell (LH DAC) (Mao et al. 1997), the effect under deeper lower mantle conditions is still unknown.

High-spin–low-spin (HS-LS) transitions of Fe in ferropericlase (Badro et al. 2003; Lin et al. 2005; 2007; Speciale et al. 2005) and perovskite (Badro et al. 2004; Li et al. 2004; Jackson et al. 2005) have been reported at lower mantle pressures. Badro et al. (2004) suggested that Fe may strongly prefer ferropericlase with low-spin Fe regardless of the spin state of perovskite. Theoretical calculations suggest that the HS-LS transition of ferropericlase occurs gradually under deep mantle conditions (Sturhahn et al. 2005; Tsuchiya et al. 2006), and this was experimentally confirmed by Lin et al. (2007) by X-ray inelastic scattering study at high temperature.

Auzende et al. (2005) reported that Kp/fp decreases above 70–80 GPa possibly due to the HS-LS transition of Fe in ferropericlase. On the other hand, the effect of HS-LS transition of Fe in ferropericlase on the partitioning behavior was not clear in Kobayashi et al. (2005).

In this study, we clarified the compositional effect on Kp/fp under deep lower mantle conditions and confirmed that the partitioning behavior of Fe between perovskite and ferropericlase may be affected by the gradual HS-LS transition of Fe in ferropericlase in the lower mantle.

EXPERIMENTAL METHODS

High-pressure and high-temperature partitioning experiments were performed up to 99 GPa and 2100 K using a LH DAC. A single crystal of San Carlos olivine with a thickness of 10–20 μm and a diameter of about 50 μm was embedded in sodium chloride for runs SCFe2 and SCFe6 and loaded into the sample hole in a pre-compressed Re gasket with the initial thickness of 30 μm. In run SCFe2 and SCFe6, Fe was coated to the surface of the olivine single crystal, using an RF sputtering machine, as an absorber of the laser, to generate a homogeneous temperature condition. Powdered San Carlos olivine was used for the other runs (SC40, 42, 44, 45) without the NaCl pressure medium. The chemical composition of San Carlos olivine, determined using an electron probe microanalyzer (JEOL JXA-8800M), is shown in Table 1. The samples were loaded into a sample chamber with a diameter of about 40 μm in a pre-compressed Re gasket.

Experimental pressures before and after laser heating were measured at room temperature by the ruby fluorescence method (Mao et al. 1978) and the Raman shift of the Ti2 mode from the culet surface of the diamond anvil (Akahama and Kawamura 2004). The mean values of pressure before and after laser heating

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