

Carbon dissolution mechanism in forsterite

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Introduction

Silicates are major and important minerals that constitute the Earth's crust and mantle. An enormous amount of carbon is also contained in the Earth's interior. Shcheka et al. (2006) studied about carbon solubility in mantle minerals by high temperature and high pressure experiments, and indicated that carbon solubility increases as a function of pressure to a maximum of ~12 ppm by weight in olivine at 11 GPa. In this case, carbon substitutes as C^{4+} for Si^{4+} and occupies SiO_4 tetrahedra as CO_4 tetrahedra. Sen et al. (2013) suggested that significant substitution of C^{2-} for O^{2-} could occur in geological silicate melts/glasses at moderate pressure and high temperature and might be thermodynamically far more accessible than C^{4+} for Si^{4+} substitution. Thus, it has not been perfectly obvious whether carbon substitutes for Si^{4+} and create CO_4 tetrahedra or substitutes for O^{2-} partially and create $Si(O,C)_4/SiC_4$ tetrahedra.

In this study, we determined the carbon dissolution mechanism in forsterite, which is the major minerals in the upper mantle.

Experimental method

Natural forsterite (San Carlos, California, USA) was used in carbon solubility experiments. Forsterite was mixed with either graphite as a crystalline solid or activated carbon as an amorphous form to be homogenized powder. Then, they were heated for 1000 °C, 2 days under ambient pressure. After that, the X-ray powder diffraction study was performed to analyze the change of lattice parameters of the reaction products. The FT-IR study was performed to indicate whether carbon dissolved in SiO_4 tetrahedra. The EPMA analysis was for quantitative analysis of carbon in the reaction products. Moreover, assumption of the reaction product structures was done by the first-principle calculation.

Result and discussion

The X-ray powder diffraction study showed that as increasing the carbon content, the lattice parameters were isotopically contracted. The FT-IR study showed that a C-O bond would be partially formed. Moreover, the EPMA analysis revealed that a small amount of carbon was dissolved in the forsterite with a negative correlation between Si and C. All of the experimental results obtained so far suggested that carbon was able to dissolve in the SiO_4 tetrahedra in forsterite as C^{4+} . The first-principle calculation supported the observed results and the proposed substitution model in the study.

However, the quantity of carbon dissolution in forsterite is low, so we have to repeat verification experiments carefully and lead the conclusion.

Keywords: silicate mineral, carbon dissolution, forsterite