The Effect of Mantle Pyrope on the Kinetics of the Phase Transformation between Olivine and Ringwoodite

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Introduction

The concept of olivine metastability has attracted great interest in the last 30 years, largely due to its geophysical and geodynamic implications. The extent of metastable olivine in subducted slab critically depends on the mechanism and the kinetics of phase transformation of olivine to its high-pressure polymorphs. Numerous studies have demonstrated previously that the transformation mechanism and the kinetics are stress-dependent.[1-5] Pyrope has the highest strength among minerals in the Earth's upper mantle. Adding pyrope in olivine powder will likely result in higher stress in olivine upon cold compression and hence affect the kinetics of olivine phase transformations. This study was done to examine this effect. In addition, garnet reaches more than 20 vol% in the normal mantle above the 410 km discontinuity. Any effect on the olivine transformation kinetics would have important implications as to the nature of this discontinuity.

Materials and Methods

Experiments were carried out at beamline 13-BM. The starting materials included San Carlos olivine and natural mantle pyrope from the Four Corners area on the Colorado Plateau. Pyrope crystals were brought up from the upper mantle by explosive eruption of ultramafic diatremes. The starting pyrope crystal has a composition close to $Py_{71}Alm_{16}Gr_{13}$ with about 4 wt% of Cr_2O_3. The powdered samples were dried in a vacuum oven at 160°C for several hours prior to sample loading. Pure olivine powder and a mixture of olivine and pyrope (~ 4:1 volume ratio) were loaded in the same high-pressure cell. Two sample layers were separated by powder NaCl (mixed with BN), which was used as the pressure standard. After the sample was compressed to the target pressure (P) using the 250-ton LVP coupled with a T-Cup device, the temperature (T) was increased stepwise. The phase transformations were monitored by x-ray diffraction while the sample assembly remained under the desired P, T conditions. The pressure was calculated based on the Decker's EOS of NaCl, and the temperature was measured by a W-3%Re/W-25%Re thermocouple.

Results and Discussion

The phase transformation of olivine to ringwoodite was slowed down by the inclusion of natural mantle pyrope in the experimental charge (Fig. 1). The olivine-ringwoodite transformation has clearly occurred in the pure olivine sample after 10 min at 16.1 GPa and 550°C, whereas ringwoodite did not appear in the mixture of olivine and pyrope even after 20 min at the same conditions.

The above observation suggests that the addition of pyrope failed to provide a significant amount of additional stress to speed up the phase transformation. The differential stress is limited by the yield strength of olivine. Olivine might be well beyond the yield point at the experimental conditions. In this case, when compared to the pure olivine sample, the presence of pyrope would reduce the olivine diffraction signal as the sample was diluted. In addition, the pyrope grain may block the reaction front and disrupt the propagation of phase transformation propelled by the propagation of differential stress and hence slow down the transformation.

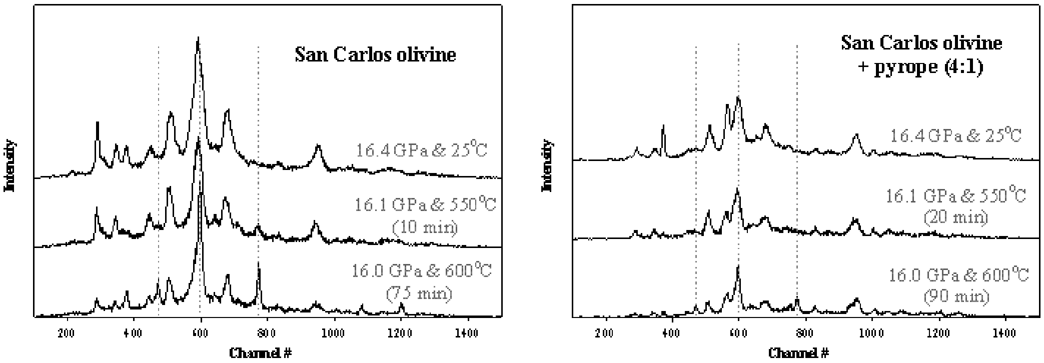

FIG. 1. Diffraction patterns for both pure olivine and the mixture samples. Dotted vertical lines are guidelines for ringwoodite diffraction peaks. Please note the time differential between two samples.

Acknowledgments

This work was supported by the Center for High Pressure Research (EAR8917563) and NSF grant EAR-0001217. Use of the Advanced Photon Source was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38. We wish to thank the GSECARS team for assisting us during the course of this study.

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