In Situ High *P-T* Experiments on Fe-C System: Implications for the Earth's Core

J. Li,[1] Y. Fei,[1] H. K. Mao,[1] T. Uchida,[2] Y. Wang,[2] M. Rivers,[2] S. Sutton[2]

[1] *Carnegie Institution of Washington, Washington, DC, U.S.A.*

[2] *Consortium for Advanced Radiation Sources, The University of Chicago, Chicago, IL, U.S.A.*

Introduction

Carbon is a possible component of the Earth's core. Wood[1] has argued that in the Fe-C system, the stability field of Fe_3C expands with pressure. As a result, the Earth's inner core may be a carbide compound. Furthermore, Wood showed that the estimated density of Fe_3C is in good agreement with that of the inner core at corresponding pressures and temperatures, thus supporting the hypothesis of an Fe_3C-dominant inner core. Critical testing of Wood's hypothesis requires knowledge of phase relations in the Fe-C system at high pressures and high temperatures, as well as the *P-V-T* equation of state of Fe_3C.

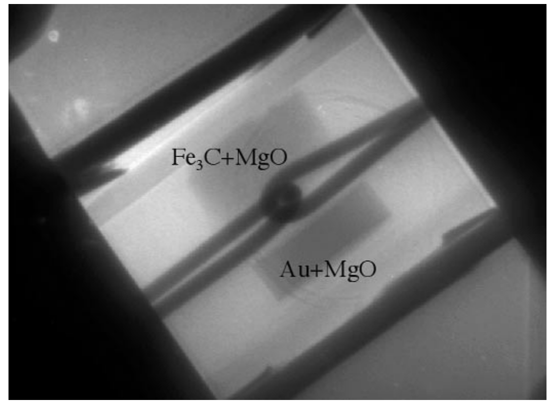

FIG. 1. This image shows a typical x-ray projection of the charge at ambient condition.

Materials and Methods

We conducted high *P-T* experiments on Fe-C systems, using the 250-ton press installed at the GSECARS 13-BM-D beamline at the Advanced Photon Source (APS), Argonne National Laboratory, with a double-stage split-cylinder "T-cup" multianvil apparatus. *In situ* measurements were carried out based on the energy dispersive method with an energy range of 20-100 keV. Incident x-ray beam size was 100 × 100 mm, and diffracted x-rays were detected by a Ge solid-state detector at a fixed angle.

Starting materials included powders of pure Fe, Fe_3C, and Fe-Fe_3C mixture with 4.5 wt% C. Fe_3C was synthesized at 2 GPa and 1000ºC using a piston-cylinder apparatus at the Geophysical Laboratory. Multiple samples were loaded in each run to provide an internal pressure standard (Au) and to allow direct comparison between pure Fe and Fe mixed with Fe_3C.

Results and Discussion

In situ x-ray diffraction spectra of Fe_3C were collected at pressures and temperatures up to 20 GPa and 1373 K. No phase transition was observed under these conditions. As the temperature increases, the peak positions shift continuously toward the lower energies, due to thermal expansion. From these data, the thermal expansivity of Fe_3C can be calculated and compared with the values Wood[1] assumed to estimate the density of Fe_3C at the inner core pressure and temperature.

After the experiments, quenched samples were analyzed using an electron microscope at the Geophysical Laboratory. We found that about 1.4 wt% C dissolved in the coexisting Fe phase at 17.5 GPa and 1273 K. This result is inconsistent with the calculated Fe-C phase diagram at a similar pressure[1], thus shedding doubts about the prediction that the stability field of Fe_3C expands with pressure. Combined with the x-ray diffraction data, we can estimate the density of Fe-C alloy, which is important for evaluating the possibility of C being present in the Earth's core.

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Reference

[1] B. Wood, Earth. Planet. Sci. Lett. **117**, 593-607, (1993).