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Phase relation of C-Mg-Fe-Si-O system under various oxygen fugacity conditions: Implication for planetary interior

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Many exoplanets have been found recently based on the spectroscopic observation. A carbon-rich circumstellar gas was reported to exist around "beta-Pictoris", which has an exoplanet (Roberge et al., 2006). In such gas, carbon-enriched planet, "carbon-planet" may be formed. Carbon-bearing phase, such as carbide, carbonate, graphite and diamond are likely to compose the carbon-planet interior. Therefore, it is important to investigate phase relations of carbon-rich systems under high pressure conditions. In this study, C-enriched Mg-Si-Fe-O-C system was investigated at high pressure and temperature in order to understand the internal structure of the carbon-planet.

Phase relations were studied based on 2 series of experiments; (I)textural observation and chemical analysis of the recovered sample from 4 GPa and 1873K and (II)in situ X-ray diffraction experiments under high pressure and temperature. For the starting materials, we used several different oxide/metal components, as shown below: (i) MgCO3 + Fe + Si + C, (ii) (Mg1.8,Fe0.2)SiO4 + Fe + SiO2 + C, (iii) (Mg1.8,Fe0.2)SiO4 + Fe + Si + C, (iv) MgO + Fe + SiO2 + C, (v) MgO + Fe + Si + C. Oxygen fugacity (fO2) of the sample vaies depending on these assembleges due to different O amount in the starting materials. The sample was enclosed in graphite or MgO capsule. MgO capsule enables us to estimate fO2 in the sample based on the FeO content of the capsule contacting with the samples. Chemical analyses of the recovered samples were performed using an electron microprobe. In situ X-ray diffraction experiments were conducted at 4 and 15 GPa, and up to 1873 K at BL04B1 beamline, SPring-8 synchrotron facility.

Observed mineral/metal assemblages and their compositions vary depending on the redox condition of the sample. The compositions of metallic melt phases changes from Fe-C composition (C = 6.9~8.2 wt.%) in oxidizing conditions (deltaIW = -2.4 ~ -1.7) to Fe-Si composition (Si = 18 wt.%) in the more reducing condition (deltaIW $<$ -4.8). SiC grains were also found in the most reducing condition. The solubility of C into the Fe-melt phase increases with fO2, whereas the solubility of Si decreases with increasing fO2. Based on in situ X-ray diffraction experiments at 4 GPa, Fe3C was formed at 1073 K in the all samples. Fe3C peak disappeared and FeSi and SiC peaks appeared at 1373 K in the most reducing sample (v), whereas Fe3C remained in the other samples. Metallic phases in all samples were melted at 1673 K. In the experiment at 15 GPa, FeSi was formed at 1573 K and SiC was also observed at 1673 K in the sample (v). This is indicated that FeSi is stable at high pressure and reducing condition despite carbon-saturated condition. No carbonates was observed under the present experimental conditions. Therefore, carbon-bearing phases correspond to graphite/diamond, SiC and Fe-C alloy or Fe-Si-C alloy in the present redox conditions at 4~15 GPa. The present results may suggest that these carbon?bearing phases consist of carbon-planets interiors.

Keywords: Carbon-planet, Carbide, Silicon carbide, Oxygen fugacity