American Mineralogist, Volume 104, pages 94–99, 2019

Phase transition boundary between fcc and hcp structures in Fe-Si alloy and its implications for terrestrial planetary cores

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Abstract

The phase transition between a face-centered cubic (fcc) and hexagonal close-packed (hcp) structures in Fe-4wt% Si alloy was examined in an internally resistive heated diamond-anvil cell (DAC) under high-pressure (P) and high-temperature (T) conditions to 71 GPa and 2000 K by in situ synchrotron X-ray diffraction. Complementary laser-heated DAC experiments were performed in Fe-6.5wt% Si. The fcc-hcp phase transition boundaries in the Fe-Si alloys are located at higher temperatures than that in pure Fe, indicating that the addition of Si expands the hcp stability field. The dP/dT slope of the boundary of the entrant fcc phase in Fe-4wt% Si is similar to that of pure Fe, but the two-phases region is observed over a temperature range increasing with pressure, going from 50 K at 15 GPa to 150 K at 40 GPa. The triple point, where the fcc, hcp, and liquid phases coexist in Fe-4wt% Si, is placed at 90–105 GPa and 3300–3600 K with the melting curve same as in Fe is assumed. This supports the idea that the hcp phase is stable at Earth's inner core conditions. The stable structures of the inner cores of the other terrestrial planets are also discussed based on their P-T conditions relative to the triple point. In view of the reduced P-T conditions of the core of Mercury (well below the triple point), an Fe-Si alloy with a Si content up to 6.5 wt% would likely crystallize an inner core with an fcc structure. Both cores from Venus and Mars are currently believed to be totally molten. Upon secular cooling, Venus is expected to crystallize an inner core with an hcp structure, as the pressures are similar to those of the Earth's core (far beyond the triple point). Martian inner core will take an hcp or fcc structure depending on the actual Si content and temperature.

Keywords: Earth's core, high-pressure, diamond-anvil cell, internal resistive heating, Fe-Si alloy