AGU Meeting – Fall 2003

Expanded Stability of the hcp Structure in Iron-Rich Alloys

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The Earth's core is composed of an Fe-rich alloy, with a solid inner core probably in the hcp structure. However, in pure Fe the hcp structure exists only at pressures too high, or temperatures too low, for many important geochemical measurements to be applied to the phase most relevant to the core, using standard multi-anvil apparatus. In the present work it is demonstrated that the stability of the hcp phase can be enhanced by alloying Fe with Ru or Os, permitting experimental investigation of Fe-rich hcp metal at lower pressures and/or higher temperatures than is possible in the pure Fe system. Pure metal starting materials were mixed with alumina to limit annealing and loaded in the 250 ton multi-anvil press at beamline 13-BMD at the Advanced Photon Source. The metal compositions were homogenized in situ at high P and T, and the phase diagram of the alloy composition was determined by synchrotron x-ray diffraction. Pressures were calibrated using the Au equation of state. At each P,T condition the sample was allowed to diffusively equilibrate; this was essential to obtaining reliable results. In the pressure range 5-15 GPa, it was found that 17 at% Ru, 26 at% Ru, and 29 at% Os in the alloy elevated the temperature limit of the hcp phase region by 250 K, 700 K, and 650 K, respectively, relative to pure Fe. At still higher T the hcp phase persists in fcc+hcp coexistence regions. An alloy containing only 10 at% Os had a fcc+hcp phase region extending 600 K above the hcp/fcc boundary of pure Fe, but the pure hcp phase region was not significantly expanded at this composition. The slopes of the phase boundaries are similar to that of the hcp/fcc boundary in Fe. The enhanced stability of the hcp structure demonstrated here is sufficient to permit investigation of chemical and physical properties of Fe-rich hcp alloys when the properties of pure hcp-Fe are inaccessible to experiment.