Lattice-preferred-orientation of hcp metals studied by high-pressure deformation experiments

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Many hypotheses have been proposed for origin of seismic anisotropy in the Earth's inner core which consists of solid metal (e.g. Sumita and Bergmann, 2009). Plastic deformation of constituent material (most probably hexagonal-close-packed (hcp) iron) is one of the candidate processes to form the inner core anisotropy. Thus knowledge of deformation-induced lattice preferred orientation (LPO) of hcp-iron is important for understanding of nature of the inner core. In this study, we have carried out shear deformation experiments on hcp-iron and its analogue materials, hcp-Co and hcp-Zn, and determined its deformation induced LPO.
Shear deformation experiments were carried out using a deformation-DIA apparatus at high-pressure and high-temperature. Experimental conditions were 14–18 GPa and 723 K for Fe, 3 GPa and 673 K for Co, and 2 GPa and 573 K for Zn. Development of LPO in the deforming sample was observed in-situ based on two-dimensional X-ray diffraction using an imaging plate or X-ray CCD detector and monochromatized synchrotron X-ray. In shear deformation of Fe, <0001> and <112(_)0> axes gradually aligned to be sub-parallel to shear plane normal and shear direction, respectively, from the initial random orientation. In final LPO of Fe, <0001> and <112(_)0> axes are back-rotated from shear direction by ~30o. On the other hand, in the deformation experiments of Co and Zn, the <0001> was aligned to parallel to shear plane normal. The above results suggest basal slip <112(_)0>{0001} is the dominant slip system in these hcp metals under the studied deformation conditions. The deviation of LPO of Fe from ideal orientation is presumably due to friction on the bottom plane of piston under higher pressure conditions.
It has been shown that Earth’s inner core has an axisymmetric anisotropy with P-wave traveling ~3% faster along polar paths than along equatorial directions. Although elastic anisotropy of hcp-iron at the inner core conditions is still controversial, recent theoretical studies consistently shows that P-wave velocity of hcp-iron is fastest along <0001> direction at least at low-temperatures. Our experimental results could be suggesting that most part of the inner core deforms with shear plane sub-parallel to equatorial plane.

Keywords: hexagonal-close-packed metal, lattice preferred orientation, inner core

