Deformation of Fe-Nitrides Under Uniaxial Compression

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Seismic anisotropy observed in Earth's core has been attributed to the alignment of Fe-light element-alloys through crystallization or deformation during or after inner core formation. Light elements have been proposed to strengthen hcp-Fe or form new phases more resistant to deformation and affect the elastic properties of the core. One light element of interest is nitrogen, which alloys with iron to form phases including hexagonal ε-Fe_3N_x ($0.75 < x < 1.4$) at <51 GPa, cubic γ-Fe_4N at < 56 GPa, and hexagonal β-Fe_7N_3 at > 51 GPa. β-Fe_7N_3 has similar properties to Fe_7C_3 and has been proposed to be present within the inner core as an accessory phase or, more likely, as a solid solution with Fe_7C_3. Both of these phases have the potential to store carbon and nitrogen in the deep Earth.

In this study, we investigate the strength, elasticity, and deformation of ε-Fe_7N_3, γ-Fe_4N, and β-Fe_7N_3 under non-hydrostatic compression from 1 bar to pressures reaching ~90 GPa at ambient temperature. The β-Fe_7N_3 phase was synthesized by laser heating at 60 GPa. Radial x-ray diffraction was collected in a panoramic diamond anvil cell at the Advanced Photon Source beamlines 16-BMD, 16-IDB, and 13-IDD. Patterns were analyzed in the crystallographic software MAUD (Material Analysis Using Diffraction) using a full profile Rietveld refinement to solve for the preferred orientation texture, elastic moduli, and strength of the iron nitrides. Diffraction patterns of ε-Fe_7N_3 and γ-Fe_4N indicate that there is not a low-pressure strain-induced transition to β-Fe_7N_3. We observe that the non-hydrostatic strain values, Q(hkl), increase with pressure. For ε-Fe_7N_3, the slope of strain increases the greatest at <17 GPa, at >17 GPa the phase exhibits yielding. Our results are compared to hcp-Fe and Fe-carbides to quantify the variation in strength between different alloys at core formation conditions.