1. Enigma at the Bottom of the Earth’s Mantle

The Earth’s core-mantle boundary (CMB) between crystalline silicate rock and molten iron alloy is believed to be the interface with the largest contrast in physical properties (e.g., density, elastic moduli, electrical conductivity) within the Earth’s interior. The D” layer, the area just above the CMB, has therefore attracted a great deal of interest in seismology and mineral physics because this layer may play a key role in the dynamic and thermal evolution of the Earth’s mantle. Advances in seismology have provided some unusual and puzzling seismic characteristics of the D” region with, for example, a large discontinuity in seismic wave velocities and anomalous shear wave anisotropy. “The D” discontinuity”, which is characterized by a 2.5-4.0 % discontinuous increase of seismic shear wave velocity, occurs about 250 km above the CMB (at pressures of ~119-125 GPa). This rapid seismic velocity change is among the most enigmatic of seismic features and its origin is not fully established. A number of explanations for the D” discontinuity have been offered. However, there is, no consensus on how the phenomena of the D” layer can be explained (e.g., Wysession et al., 1998).

2. Discovery of Post-Perovskite Phase Transition

The recent experimental discovery of the perovskite to post-perovskite phase transition in MgSiO₃ (the major component in the lower mantle), which occurs under P-T conditions thought to exist at the bottom of the mantle (~125 GPa, 2500 K), provides significant insight into the properties of D” region (Murakami et al., 2004). The crystal structure of post-perovskite phase is completely different from that of perovskite, and the post-perovskite phase is thought to have large single-crystal elastic anisotropy because of its sheet-stacking structure of SiO₆-octahedra (Fig. 1). The computational calculations and interpretations of seismic data suggest that the perovskite to post-perovskite phase transition and the properties of this new phase could reasonably explain most of the seismic characteristics of the D” discontinuity. However, the magnitude of the velocity jump caused by the perovskite to post-perovskite phase transition has not been determined through direct experimental measurements, and it is essentially important to have those experimental data in order to interpret D” phenomena.
3. Direct Sound Wave Velocity Measurements across the Post-Perovskite Phase Transition

Accurate acoustic wave velocity data in the laboratory for the primary components in the lowermost mantle, MgSiO₃ in the perovskite and post-perovskite phases, at pressures corresponding to the D” region are essential to provide constraints on the nature of this boundary. Here we present the results of aggregate sound velocity measurements of the MgSiO₃ perovskite and post-perovskite phase by Brillouin spectroscopy in the diamond anvil cell (DAC) up to a pressure of 172 GPa, in combination with infrared laser heating of the sample. This technique allowed us to obtain high quality Brillouin spectra and to dramatically extend the upper limit of pressure for Brillouin measurements. Based on these results, the aggregate shear wave velocity contrast post-perovskite phase transition is at most 0.5 % (Fig. 2).

4. Implications for the D” discontinuity

This contrast is much smaller than typically observed across the D” discontinuity, indicating that the formation of an isotropic aggregate of the post-perovskite phase provides an insufficient velocity increase to explain the D” discontinuity. Alternatively, it is possible to explain the more typical larger seismic velocity contrast by crystal lattice preferred orientation (LPO) of the post-perovskite phase, which is strongly induced by its single-crystal elastic anisotropic feature. A strong preferred orientation could develop under shear flow although it is still under debate as to which slip plane is dominant for the MgSiO₃ post-perovskite phase. If we assume the presence of horizontal shear flow, which is believed to exist at the CMB (Fig. 3), then a reasonably large seismic velocity contrast (~ 7 %) may appear together with a signature of shear wave anisotropy as the computational works predicted (Iitaka et al., 2004). If this were the case, the velocity change as the D” discontinuity could be explained by the shear flow pattern at the base of mantel and a degree of preferred orientation of the post-perovskite phase.

References
