Post-perovskite Phase Transition in Earth's Deep Mantle

The recent discovery of the post-perovskite phase suggests that $MgSiO_3$-rich perovskite, a predominant mineral in the Earth's lower mantle, undergoes a phase transformation near the bottom of the mantle, called the D" layer [1] (Fig. 1). The first publication on the $MgSiO_3$ post-perovskite phase transition [2] showed that it occurs at approximately 125 GPa and 2500 K, corresponding to a 2700 km depth in the mantle, using Pt as pressure standard. This closely matches the general depth at which the D" seismic-wave velocity discontinuity is observed (2600 to 2700 km depth), suggesting that this seismic boundary is a phase transformation origin. However, recently there has been an extensive debate on the accuracy of the *P-V-T* equation of state (pressure scale) of the internal pressure standard used in these high-pressure experiments. Moreover, the effects of chemical impurities such as FeO and Al_2O_3 found in the Earth's mantle need to be examined.

We have experimentally determined the post-perovskite phase transition in $MgSiO_3$ using multiple pressure standards of Pt, Au, and MgO [2,3]. The high-pressure and high-temperature conditions were generated in a laser-heated diamond-anvil cell (LHDAC). They were compressed with Re gasket and beveled diamond anvils with 200-μm culet. Heating was carried out using the TEM_{01}-mode Nd:YLF laser or a multi-mode Nd:YAG laser for 2 to 41 min. Angle-dispersive X-ray diffraction spectra were collected on the CCD detector and imaging plate (IP) at beamline **BL10XU**. The results of two separate sets of experiments on $MgSiO_3$ based on the Au pressure marker are shown in Fig. 2. The stabilities of perovskite and post-perovskite phases were determined by the changes in relative X-ray intensities. The coexistence was judged by the significant growth of both the phases with similar intensities. These results indicate that post-perovskite phase transition occurs at 113 GPa and 2400 K with a positive Clapeyron slope of +4.7±0.5 MPa/K. However, the results strongly depend on the pressure scale. All experimental data on the post-perovskite phase transition in $MgSiO_3$ are shown in Fig. 3 [2-4], which demonstrates that the transition pressure changes by as much as 15 GPa depending on the pressure standard and its *P-V-T* equation of state.

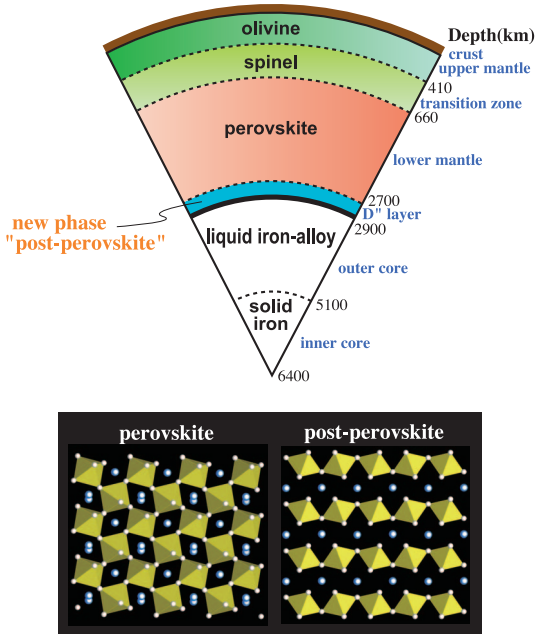

Fig. 1. **(a)** Schematic illustration of the Earth's interior. The main constituent mineral changes between layers; olivine in the upper mantle, spinel phase in the transition zone, perovskite phase in the lower mantle, and post-perovskite phase in D" layer. **(b)** Crystal structures of perovskite and post-perovskite. The yellow octahedra and white balls represent SiO_6 polyhedra, and the blue balls indicate Mg ions in both images.

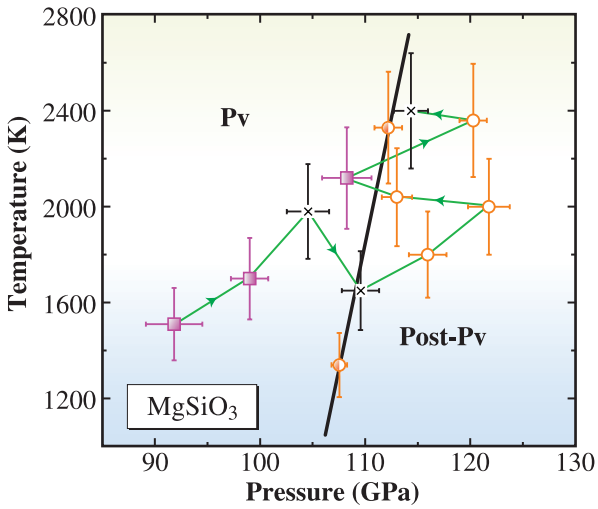

Fig. 2. Phase diagram of $MgSiO_3$ based on the Au pressure scale. Solid squares, perovskite; open circles, post-perovskite; half-filled circles, coexistence of perovskite and post-perovskite. Crosses show that the pattern did not change at these conditions. The sequential change in the *P-T* conditions in the first run is illustrated by arrows.

The MgO pressure scale may be the most practical at this moment, because it has been extensively studied and is least controversial, although the absolute pressure scale over 100 GPa is not available. Indeed, the post-spinel transformation boundary in Mg_2SiO_4 based on MgO pressure scale matches the depth of the 660-km seismic discontinuity [5]. Our results also indicate that the pressure of post-perovskite phase transition (119 GPa at the realistic mantle temperature of 2400 K) derived from the MgO scale is consistent with the location of the D" seismic discontinuity at around 2600 km depth in the Earth's mantle. Note that the MgO scale predicts a significantly large Clapeyron slope for this boundary (+11.5 MPa/K). Such a large Clapeyron slope suggests that the post-perovskite phase transformation will promote extensive upwelling of high-temperature plumes from the hot core-mantle boundary region.

In addition, all of our data on $MgSiO_3$, $(Mg_{0.9}Fe_{0.1})_2SiO_4$, natural pyrolitic mantle (KLB-1 peridotite), and basaltic oceanic crust (MORB) compositions are plotted together in Fig. 4 [3]. Only Au was used as pressure the standard for these experiments, because Pt and MgO readily react with the iron-bearing samples. These results indicate that the stabilities of perovskite and post-perovskite phases in these natural compositions are consistent with the phase transition boundary in pure $MgSiO_3$. The compositional variations from pure $MgSiO_3$ to natural mantle and crust materials have little effect on the post-perovskite phase transition.

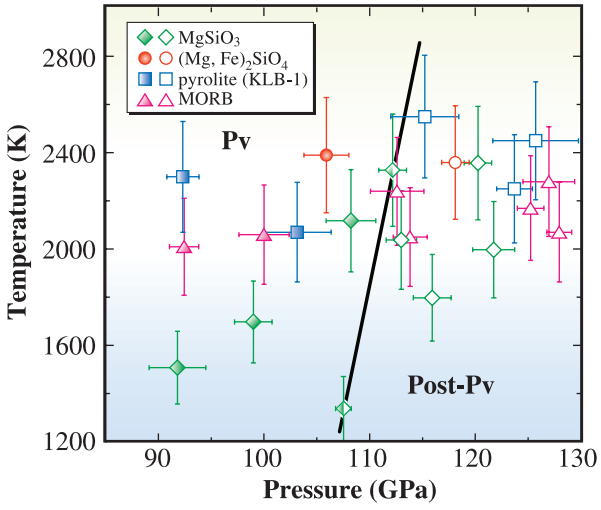

Fig. 4. Stabilities of perovskite (solid symbols) and post-perovskite (open), based on the Au pressure scale. All of these data are consistent with the phase transition boundary in pure $MgSiO_3$, as shown by the bold line.

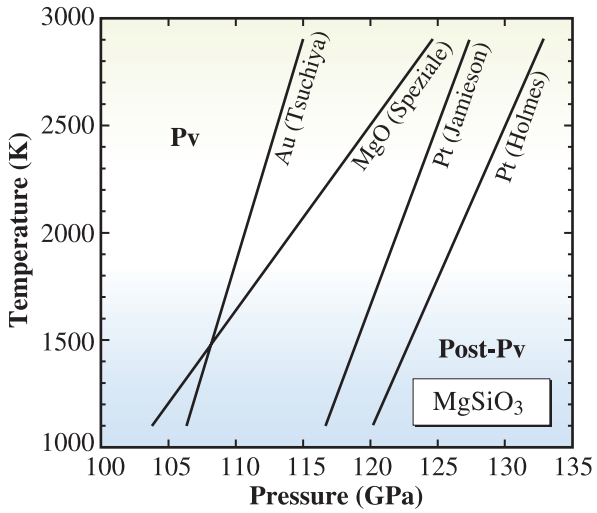

Fig. 3. Post-perovskite phase transition boundary in $MgSiO_3$ based on the Pt-scale [2,4] and the Au and MgO pressure scales [3]. The location and the Clapeyron slope are strongly dependent on the internal pressure standard and its *P-V-T* equation of state.

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