Core-Mantle Interaction-The Formation, Elasticity, Rheology, and Dynamics of Iron-Rich Silicate in Earth's D Layer

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Introduction

The D" boundary layer, the lowermost portion of the mantle where crystalline silicate and oxide meets molten iron core displays the largest contrast in physical and chemical properties of all the regions in the Earth, and undoubtedly plays a pivotal role in global dynamics and evolution. Where observations have been possible, seismic results have revealed a region with an intriguingly complex seismic signature. Recent high *P-T* experiments [1,2] and *ab-initio* theoretical calculations [2-4] indicate that the pure end-member $MgSiO_3$ perovskite (pv) transforms to a post-perovskite (ppv) phase with the $CaIrO_3$ structure at D" conditions. The ultimated relevance of this new phase to the Earth's interior depends upon its stability and properties within the physical-chemical boundary conditions of the D" layer.

Methods and Materials

The starting oxide mixtures were prepared by weighing MgO, Fe_2O_3 and SiO_2, in pyroxene stoichiometry with different Fe contents and using a gas-mixing furnace at a temperature to reduce all Fe^{3+} to Fe^{2+}. The treated mixtures were reground and sealed in Au capsules, which were then compressed in a piston-cylinder apparatus. The orthopyrozene starting materials were loaded into Re or x-ray transparent Be gaskets into a diamond anvil cell to generate pressure up to 170 GPa. A double-sided YLF laser system was used for heating the sample to temperatures up to 2500 K. A monochromatic x-ray beam was used for x-ray diffraction at beamlines 13-IDD and 16-IDB of the Advanced Photon Source. Nuclear resonant inelastic x-ray scattering measurements were carried out at 3-ID of the Advanced Photon Source. The delayed Fe K-fluorescence signal due to relaxation of the excited ^{57}Fe Mössbauer nuclei was collected by three avalanche photodiodes around the diamond cell axis. By removing the elastic line, the signal represents inelastically scattered phonons, and the phonon DOS is obtain with the previously developed data-processing procedures [5, 6].

Results

We observed that a large amount of Fe can be incorporated into the post-perovskite (ppv) silicate phase, and that this can significantly change its properties relative to the pure $MgSiO_3$ endmember [7, 8]. We determined the aggregate compressional and shear wave velocities of this Fe-rich silicate at high pressure and found that ppv with up to 40 mol % $FeSiO_3$ can explain the properties seismically observed in ultra-low velocity zones in Earth's D" layer [9].

Discussion

The vast reservoirs of Fe and silicates at the CMB provides favorable chemical-physical conditions for the formation of Fe-rich ppv silicate which holds the key to understanding the geophysical and geochemical properties of the D" layer. Contrary to the previous thinking that the mantle composition was essentially unchanged by contact with the core – *i.e.*, the composition of the mantle silicate remains within its Fe-poor solubility limit – our new scenario calls for a reaction layer of denser silicates with much higher Fe content. In regions of downward or horizontal movement at the CMB, the thickness of the Fe-rich layer is limited by solid reaction and diffusivity. In upwelling regions, the Fe-rich layer is too heavy to rise, and will be pile up under plumes (Fig. 1), resulting in the observed ULVZ. Although comprehensive studies of the equation of state, elastic anisotropy, diffusivity, rheology, magnetism, and reversible phase relation of ppv as a function of temperature and Fe concentration are still needed for developing the new paradigm for this most enigmatic layer in the solid Earth, this study provides an exciting new direction into the dominating role Fe-rich ppv may play in D"**.**

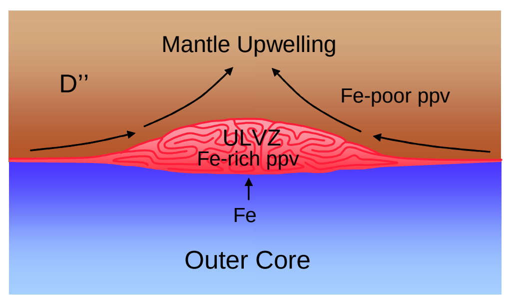

FIGURE 1. Schematic diagram of the reaction boundary between a Fe-poor mantle and Fe-rich core and the accumulation of Fe-rich ppv in ULVZ.

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