Electrical conductivity of a lowermost part of the mantle

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It is likely that measured changes of a few milliseconds in Earth's length of day on decadal timescales are attributed to the exchange of angular momentum between the solid mantle and fluid core. To explain the length-of-day type of variations on decadal timescales, the following mechanisms have been proposed: (1) gravitational coupling between changes in density and/or topographic inhomogeneities of the inner core and mantle, (2) topographic coupling from fluid pressure on the deformed core-mantle boundary, and (3) electromagnetic coupling between the core and a weakly conducting mantle. Although the third mechanism can reasonably explain the observed changes of a few milliseconds in Earth's length of day on decadal timescales, this mechanism requires a highly conductive layer at the base of the lower mantle. However, it is known that magnesium silicate perovskite, which is the dominant mineral in the lower mantle, does not have such a high electrical conductivity. Therefore, this electromagnetic coupling was considered unrealistic if the lowermost part of the lower mantle is composed only of magnesium silicate perovskite. Recently, the possibility of CaIrO3-type Al2O3 with high electrical conductivity has been reported [1]. Both theoretical and experimental results show that CaIrO3-type MgSiO3 phase, which is likely to have analogous high electrical conductivity, can exist at the base of the lower mantle [2]. The possibility of a highly conductive D" layer requires a reappraisal of the electromagnetic coupling mechanism to understand the observed changes in Earth's length of day.

We used a laser-heated diamond anvil cell and intense X-rays from a synchrotron radiation source to acquire precise data on Al2O3 under high pressure, and directly observed a phase transformation between Rh2O3(II)-type and CaIrO3-type Al2O3. The similarity in physical properties between CaIrO3-type Al2O3 and MgSiO3 was investigated using both experimental and theoretical method. This allowed us to estimate the profile of the electrical conductivity at the bottom of the lower mantle, which can explain Earth's rotation period changes of a few milliseconds in Earth's length of day on decadal timescales, if the exchange of angular momentum between the solid mantle and fluid core occurs by an electromagnetic coupling between the conducting core and mantle.

[1] Oganov and Ono, Proc. Natl. Acad. Sci., 102, 10828-10831 (2005).

[2] Ono and Oganov, Earth Planet. Sci. Lett., 236, 914-932 (2005).