A new spin on understanding mineral physics of the Earths deep mantle

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Mineralogical models of the planet indicate that the lower mantle, the most voluminous layer of the Earth, consists of approximately 20% ferropericlase [(Mg,Fe)O] and approximately 80% silicate perovskite [(Mg, Fe)SiO_3], in addition to a small amount of calcium silicate perovskite ($CaSiO_3$). Silicate perovskite is recently observed to transform to post-perovskite at the lowermost mantle region. The ability of iron, the most abundant transition metal in the lower-mantle minerals, to adopt different electronic spin and valence states can affect a broad spectrum of physical and chemical properties of the Earth's interior. To the astonishment of mineral physicists, pressure-induced electronic spin-pairing transitions of iron and associated effects on the physical properties of host phases have been recently observed in lower-mantle minerals including ferropericlase, silicate perovskite, and post-perovskite at high pressures and temperatures. The spin transition zone (STZ) of iron in ferropericlase occurs over a wide pressure-temperature range extending from the middle part to the lower part of the lower mantle, whereas iron is found to be predominantly in the intermediate-spin state in perovskite and post-perovskite throughout most of the lower mantle. The spin transitions of iron in the lower-mantle phases significantly affect our understanding of the geophysics, geochemistry, geomagnetism, and geodynamics of the lower mantle. In particular, as the spin transitions of iron occur in the lower-mantle minerals at high pressures and temperatures, their properties such as density, sound velocities, thermal conductivity, and electrical conductivity can be continuously influenced by the ratio of the high-spin and low-spin/intermediate-spin states along the lower-mantle geotherm. Here I will discuss what is known about the nature of the spin transitions, focusing on the effects of the spin transitions on the properties of the deep mantle such as density, composition, seismic velocities, and transport properties. Future challenges and research opportunities in the studies of the spin transitions will also be addressed so as to stimulate deep-mantle scientists to explore this new frontier collaboratively.

References:
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Abs. No. **568**
Meeting: **DMG 2008**
submitted by: **Lin, Jung-Fu**
email: **afu@jsg.utexas.edu**
date: **2008-07-01**
Req. presentation: **Vortrag**
Req. session: **S08**