Electronic Spin Transition of Iron in the Earth's Lower Mantle

1. Intellectual Merit of the Proposed Study

This proposal aims to study the nature of electronic spin transitions of iron in the lower mantle mineral assemblage with emphasis on associated properties influencing the chemical and physical dynamics of the lower mantle. Using a combination of laboratory and synchrotron-based facilities with high pressure-temperature diamond anvil cells, the proposal builds upon the PI's recent findings on the spin transition in ferropericlase to explore the nature and consequences of spin transitions in perovskite and post-perovskite. Experiments will probe physical properties most relevant to modelling the structure and geodynamics of the lower mantle including thermal equations of state, deformation and strength, sound velocities, and transport properties. Multidisciplinary efforts are required to evaluate the implications of spin transitions on understanding of the state of Earth's lower mantle, principally involving theoretical and experimental mineral physics, seismology, geophysics, and geodynamics. Here the effects of spin transitions on the properties of lower-mantle minerals under relevant lower-mantle conditions will be determined through two broad, prioritized classes of activities: 1) determining the nature and pressure-temperature (i.e. depth) interval of spin–state transitions of iron in lower-mantle perovskite and post-perovskite using X-ray emission spectroscopy, X-ray diffraction, and Mössbauer spectroscopy; 2) determining the effects of the spin transitions on thermal equation of state, deformation and strength, sound velocities, and transport properties of these minerals using axial and radial X-ray diffraction, nuclear inelastic scattering, and impulsive stimulated light scattering in externally-heated and laser-heated diamond cells. With an emphasis on the spin transitions, these studies aim broadly to understand properties of the lower-mantle minerals at various pressure-temperature-composition conditions, providing direct mineral physics results for input into understanding the state of the lower-mantle at a time when tomographic images and geophysical models of the lower mantle are rapidly advancing.

2. Broader Impacts

This is the PI's first NSF proposal and the requested support would constitute the primary source of funding for the proposed research. The requested support will allow the PI to exploit this frontier research collaboratively with co-workers. The proposed projects take advantage of the PI's unique research capabilities with the diamond cell techniques and recently-developed in-house and synchrotron facilities. Techniques developed in this proposal will further enhance synchrotron user facilities and become more widely available to users as they become optimized. The expected results are fundamental to geophysics and geodynamics of the Earth and will provide new aspects of information to modelling satisfactorily the seismic, mineralogical, and geodynamic behaviour of the lower mantle. The proposed studies will likely result in many visible, high-profile scientific publications as evidenced from the PI's recent relevant publications in Science, Nature, AGU Eos, among other journals. The proposed research will be a significant part of the PI's graduate students' theses, and involve the training of graduate and undergraduate students and postdocs. They will have unique opportunities to be trained to use innovative techniques and involved in conducting cutting-edge experiments. The outcome of the proposed research will be incorporated into undergraduate and graduate courses currently under development by the PI to begin at the University of Texas Austin in the Spring of 2009.