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Ferromagnesite as a Potential Deep-Mantle Carbon Carrier
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Physical and chemical properties of the potential deep-carbon carriers such as carbonates can play a significant role in our understanding of the deep-carbon storage as well as the global carbon cycle of the planet. Iron-bearing magnesite, ferromagnesite [$(Mg,Fe)CO_3$], has been commonly proposed to be a major carbon carrier in the Earth's mantle. Studying its elasticity and phase diagram under relevant P-T conditions of the deep mantle is thus important for our understanding of the deep-carbon storage in the Earth's interior. Here I will discuss our recent research results on single-crystal elasticity, the spin transition, and the high-pressure structural transition in the $(Mg,Fe)CO_3$ carbonate system in the deep mantle [1-4]. Based on Brillouin experimental results and thermal elastic modelling, magnesite exhibits extremely high compressional wave (Vp) anisotropy of approximately approximately 48 percent and shear wave (Vs) splitting of approximately 40 percent along an expected geotherm of the cold subducting slab. These anisotropies are much larger than those of major constituent minerals in the Earth's upper mantle including olivine, pyroxene, and garnet. The modeled aggregate Vp and Vs velocities in moderately carbonated peridotite and eclogite containing approximately 10 wt. percent magnesite (approximately 5 wt. percent CO_2) show minimal effects of magnesite on the seismic profiles of these rock assemblages at upper mantle conditions, suggesting that the presence of magnesite is likely difficult to be detected seismically in the mantle. However, due to its unusually high Vp and Vs anisotropies, magnesite-rich rocks with strong preferred orientations may exhibit sufficient Vp and Vs anisotropies that can have significant influences on seismic anisotropies of the regionally carbonated upper mantle [2]. Using synchrotron X-ray diffraction and Raman spectroscopy coupled with a diamond anvil cell, we have also studied the phase stability and compressional behavior of ferromagnesite at lower-mantle P-T conditions. An electronic spin transition of iron in the $(Mg,Fe)CO_3$ system occurs at approximately 40 GPa and can significantly affect its elasticity, phase stability, and chemistry at high P-T [3-4]. Our high-pressure results further show that rhombohedral ferromagnesite transforms into an orthorhombic high-pressure phase following the spin transition of iron at mid-lower mantle P-T conditions [1]. The high-pressure orthorhombic phase is found to be in the low-spin state that can become a stable deep-carbon carrier at deeper parts of the lower mantle below 2000 km in depth. These findings suggest that deep-mantle carbonates can exhibit unique physical and chemical properties than that at shallower mantle conditions, affecting our understanding of the deep carbon cycle at extreme environments.

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