FEI Yingwei, 2013. Experimental Insights into the Interior Processes and Chemical Compositions of the Deep Earth. *Acta Geologica Sinica* (English Edition), 87(supp.): 238.

Experimental Insights into the Interior Processes and Chemical Compositions of the Deep Earth

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High-pressure experiments provide crucial data necessary to understand deep Earth processes. Development of the piston-cylinder apparatus in the 60's allowed us to simulate conditions in Earth's upper mantle (to ~100km), leading to a better understanding of the deep crust and upper mantle. Popular use of the multi-anvil device since the 80's to extend that range to the shallow lower mantle (~750km), and further simulations of the deep mantle and core using laser-heated diamond-anvil cell techniques have provided essential data to understand the mineralogy, composition, and geochemical processes from the crust to the core. High-pressure phase equilibrium studies have provided insights into the origin of the ultra-high pressure rocks and mantle xenoliths and the nature of the observed seismic velocity discontinuities in the mantle. Element partitioning between crystal and melt and between metal and silicate has provided constraints on early mantle evolution, light elements in the core, and planet differentiation. In this talk, I will discuss recent advances in high-pressure research with emphasis on the chemistry of the core.

In order to determine the minimal temperature of a liquid core or the maximal temperature of a solid core, we have systematically investigated melting relations in the binary systems Fe-FeS, Fe-C, and Fe-FeSi, move toward unravelling the crystallization sequence and element partitioning between solid and liquid metal in the ternary and quaternary systems up to 25 GPa, using multi-anvil apparatus. We have developed new techniques to analyse the quenched samples recovered from laser-heating diamond-anvil cell experiments using combination of focus ion beam (FIB) milling, high-resolution SEM imaging, and quantitative chemical analysis with silicon drift detector EDS. With precision milling of the laser-heating spot, we determined melting using quenching texture criteria imaged with high-resolution SEM and the sulfur partitioning between solid and liquid at submicron spatial resolution. We have also re-constructed 3D image of the laser-heating spot at multi-megabar pressures to better constrain melting point and understanding melting process. The new techniques allow us to extend precise measurements of melting relations to core pressures in the laser-heating diamond-anvil cell. In addition to the static experiments, we also used shockwave compression to determine density, sound velocity, and melting of core materials up to liquid outer core conditions. The integration of the static and dynamic compression data provides an extensive dataset over a wide pressure and temperature range that is necessary for establishing a comprehensive model of the planetary cores, providing the best fit to the geophysical, cosmochemial, and geochemical observations.

Key words: high-pressure behavior, composition of deep Earth, interior process, phase transition

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