The research I've been working on during PhD consists of mainly three parts: 1) experimental study on Cu diffusion in silicate melts; 2) melt inclusion study on volatiles in the lunar interior; and 3) XANES study on iron redox change of silicate melts in graphite capsule experiments. The first two parts are the focuses of my PhD work, while the third part is a project developed as a side interest. Each of the three parts will be briefly described below.

Cu diffusion in silicate melts

As a transition metal element, Cu shows strongly chalcophile and moderately volatile behaviors in geochemical processes. The compatibility of Cu in sulfides, and its ability to form soluble complexes (e.g. CuCl, $NaCuCl_2$) in fluid phases are the key properties that lead to the enrichment of Cu in magmatic sulfide deposits and porphyry-type ore deposits. Magmatic sulfide deposits typically form in a mafic or ultramafic magma. Possible sulfur saturation during cooling lead to the formation and separation of sulfide drops from the silicate magma. Since the sulfide drops are denser than the silicate magma, they sink through the magma chamber, at the same time scavenging chalcophile elements (e.g. Cu, Au, Pt) from the surrounding melt. During this process, the enrichment of metals into the sulfide phase is a balance between their diffusivities in the silicate magma, and the sinking and growth of the sulfide drops. In that case, metal elements with high diffusivities might be more efficiently enriched into the sulfide drops than those with low diffusivities, resulting in a fractionation of metal ratios in the final deposit. A similar scenario occurs during porphyry-type deposit formation, where a saturated fluid phase scavenges and transports metals (e.g. Cu, Au, Mo) from the silicate magma to the shallower crust, forming economically valuable deposits. Recent studies suggest that, if the fluid phase upwells rapidly in fluid channels, diffusivities of these metal elements in the silicate melt might control the efficiency in their enrichment and transport by the fluid phase. Despite the potential role of kinetics in various geological processes, diffusivities of chalcophile elements are poorly determined. One important goal of my PhD study was to experimentally constrain Cu diffusivity in silicate melts. Copper diffusivity in basaltic melt was determined by diffusion couple experiments using synthetic basalts. While Cu diffusivities in anhydrous and hydrous rhyolitic melts were studied through chalcocite (Cu_2S) dissolution experiments.

Melt inclusion study on volatiles in the lunar interior

The most widely accepted model for Moon formation is that the Moon formed in a giant impact between a Mars-sized planetary body and the proto-earth. Studies on lunar volcanic rocks suggest the Moon to be more severely depleted in volatiles, which is in accordance with the high temperature caused by the giant impact. However, recent studies on lunar volcanic glass beads and olivine-hosted melt inclusions detected high concentrations of water (up to

1410 ppm), which indicates hundreds of ppm of H_2O in the primitive lunar mantle. The detection of high H_2O concentrations in the primitive lunar mantle brings challenge to the giant impact theory. However, the limited number of studies on lunar olivine-hosted melt inclusions are hardly conclusive about the H_2O content in the lunar mantle, due to at least the following two issues: 1) Lunar melt inclusion studies often involve re-homogenization because most of the lunar olivine-hosted melt inclusions are crystalized. In order to use these melt inclusion data for interpretation of volatile content in their source mantle, it's crucial to understand H_2O loss from melt inclusions during homogenization experiments; 2) Currently high H_2O concentrations detected in natural glassy melt inclusions are from 74220 only. To avoid sampling bias, investigation on a larger collection of lunar samples is necessary to understand volatiles in the lunar mantle from a broader scale. Part of my PhD research is trying to tackle the above two problems. Specifically, I experimentally studied volatile loss from lunar olivine-hosted melt inclusions during homogenization experiments, and used the results to discuss previous data and new data on homogenized melt inclusions. On the other hand, I studied six lunar samples for natural or homogenized melt inclusions to have a broader understanding of volatiles in the lunar mantle.

Mechanics and kinetics of iron reduction in basaltic melt

For experimental petrologists, oxidation state in the experimental charge is usually an important factor to control during experiments. An understanding of how and how fast equilibrium can be reached in the experiments is fundamental in designing experiments and interpretation of experimental outcomes. Iron oxidation state change is also a critical issue in igneous petrology, because it affects the physical properties of the silicate magma (e.g. color, viscosity), and controls precipitation of redox-sensitive mineral phases, such as magnetite. In this study, basaltic glasses quenched from piston cylinder experiments using graphite capsules were analyzed by μXANES to understand the oxidation change during the experiments. The measured Fe^{3+}/Fe^{2+} profiles suggest a rapid reduction mechanism that's controlled by diffusion of molecular hydrogen:

$$Fe_2O_3(melt)+H_2(gas)=FeO(melt)+H_2O(melt)$$

Profiles of H_2O concentration increase in the basaltic glasses after experiment are also in accordance with the above mechanism. The results suggest the possibility of a rapid equilibrium in graphite capsules during high temperature experiment, which might be good for various experimental studies. On the other hand, these results also suggest a possible way to quantitatively study the solubility and diffusivity of molecular hydrogen in silicate melts, which are poorly understood due to the complicated interactions between molecular hydrogen and iron species in the silicate melt.