Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS024-24 Room:103 Time:May 23 12:30-12:45

Constraints on FeO and refractory element contents of lunar Magma Ocean from conditions of crust formation

Risa Sakai[1*], Ikuo Kushiro[1], Hiroko Nagahara[1], Kazuhito Ozawa[1], Shogo Tachibana[1]

[1]Earth and Planet. Sci., Univ. of Tokyo

The lunar highland crust is composed of purely anorthosite with tens of kilometers thick, and would be formed by the crystallization and flotation of anorthite from a global lunar magma ocean (LMO). The chemical composition, depth, and the actual differentiation mechanisms of LMO are still debated, although there are many previous studies. The FeO and refractory element (Al_2O_3 and CaO) contents of LMO are especially important due to the strong influence on the composition and the physical properties of the melt, and the amount of anorthite and other minerals crystallized in the cooling LMO. The purpose of this study is to constrain on the FeO and refractory element contents of the initial LMO consistent with the conditions of lunar crust formation.

At first, we assumed the bulk composition of the initial LMO varying FeO and refractory element contents and the differentiation mode varying the efficiency of crystal separation. Then we determined the composition of the LMO at the anorthite appearance by thermo dynamical calculations with MELTS/pMELTS. Finally, it is evaluated whether these results satisfy the following conditions: (1) the amount of crystallized anorthite enough to form the crust with the average thickness (~45 km), (2) the observed pyroxene composition of lunar highland crust, and (3) anorthite flotation in turbulent LMO at time of the anorthite appearance.

In present study, the compositional range considered was the FeO content by 0.5-2.5 times of BSE and the refractory element (Al2O3 and CaO) contents by 1.0-2.5 times of BSE. The mass balance evaluation of the amount of crystallized anorthite concluded that the crust with current thickness of the Moon could be formed from the FeO-enrichment of <2.3x and refractory element-enrichment of <2.0x composition. The mineralogical evaluation on pyroxene concluded that, if the refractory element contents are low (~1.0x), the extremely FeO-rich (>1.5x) initial composition does not reproduce pyroxene of which composition is consistent with that of lunar crustal samples. The fluid dynamic evaluation of anorthite flotation in turbulent LMO concluded that an anorthite crystal could float and separate in the initial composition with FeO-enrichment (>1.5x) due to the high density and the low viscosity of melt, regardless of the refractory element contents and the differentiation mode.

The present study shows the important conclusion that the FeO content of the initial LMO was comparable or higher than the BSE. This conclusion suggested the several possibilities: (1) the impactor object for the giant impact event of the Earth and Moon system originally had higher FeO content than BSE and/or (2) the oxygen fugacity of the LMO was higher than BSE for some reasons. More rigorous model with the detailed consideration on physics and chemistry of magma ocean processes of the cooling LMO based on the present study may give implication for the origin and evolution of the Moon.

Keywords: bulk composition of Moon, lunar magma ocean, anorthosite crust, differentiation, physical properties of magma, piston-cylinder experiments