High precision trace element analysis of chondrule olivine by EPMA

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Chondrules from primitive chondrites are classified into type I (mg# > 0.9) and type II (mg# < 0.9) chondrules. Olivine grains in type I and II chondrules show different chemical zoning of major and trace elements so that olivine is a key phase to understand the formation mechanisms of chondrules. Recent study of Mg-rich olivines from type I chondrules in primitive chondrites using high-resolution cathodoluminescence (CL) showed that internal zoning structures in the olivines record high-temperature gas-melt interaction and epitaxial overgrowth (Libourel & Portail, 2018). The CL zoning well corelates with Al distribution. Where olivines of type II chondrules often show P and Cr zoning (McCanta et al., 2016), which is not observed in Mg-rich olivines of type I chondrules. To further investigate trace element distribution in the chondrule olivines, we developed a high precision trace element analysis of olivine by electron probe microanalyzer (EPMA).

High precision chemical analyses were performed by a field-emission EPMA (JEOL JXA-8530F) at KOPRI with a primary beam of 500 nA and 15 kV accelerating voltage. Si and Mg were measured with an energy dispersive x-ray spectrometer (EDS) and Ti, Al, Cr, Fe, Mn, Ni, Ca, Na, K, P, and Zn were measured with wavelength dispersive x-ray spectrometer (WDS), simultaneously. Detection limits of Ti, Al, Cr, Mn, Ni, Ca, Na, K, P, and Zn are 10, 6, 9, 15, 15, 3, 7, 3, 5, and 22 ppm, respectively. San Carlos olivine (SCol) was analyzed to test the accuracy and precision. Trace element abundances of SCol measured by KOPRI EPMA are 21 ± 12 (2SD), 172 ± 7, 101 ± 6, 1074 ± 12, 2897 ± 12, 679 ± 10, 68 ± 10, 3 ± 5, 12 ± 4, and 51 ± 28 ppm for Ti, Al, Cr, Mn, Ni, Ca, Na, K, P, and Zn, respectively, which are comparable with values obtained by LA-ICP-MS (De Hoog et al., 2010).

High precision trace element analysis by EPMA was applied to olivines of type I and II chondrules from a primitive ordinary chondrite (Elephant Moraine 14017; LL3). Refractory elements such as Ti, Al, and Ca are more abundant in type I chondrule olivines (Fo>99) than type II chodrule olivines (Fo75–90). Volatile elements such as Na, K, P are more abundant in type II chondrule olivine but below detection limits in type I chondrule olivines. Ti in the olivines shows a positive correlation with Al and Ca in type I chondrule, while it tends to have the same trend with Fe and Ca in type II chondrule. Since Ti diffusivities in olivines with variable compositions are considerably slower than those of Cr, Ca, and Fe-Mg (Cherniak and Liang, 2014), Ti zoning in the olivines probably preserve igneous processes of type I and II chondrules. A positive correlation between Al and Ti in the type I chondrule olivines may have resulted from dilution by introduction of Mg and Si from nebular gas into Ca, Al, and Ti-bearing chondrule melts (Marrocchi et al., 2018). Instead, Ti in olivine from type II chondrule has not been precisely measured and discussed. To understand Ti distribution in chondrule olivines we will conduct high precision quantitative mapping on chondrule olivines. With more data by quantitative point analyses and mapping on the olivines, gas-melt interaction in the nebula and fluid-rock interaction on the parent body will be discussed at the conference.