Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS22-P02 Room:Convention Hall Time:May 27 18:15-19:30

Development of precise in-situ U-Th-Pb dating of phosphate using LA-MC-ICP-MS

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Phosphates in meteorites have high concentration of U and Th (<10 ug/g) and therefore, time-resolved history for planetesimal formation has been constrained based on U-Pb systematics using phosphates in chondrites[1),2)]. To establish a reliable chronological scenario, in-situ dating with high spatial resolution is important because these target material could possibly experience the gain or loss of Pb through the thermal effect or shock metamorphism by impacts among meteorites[3)] and interaction with water. To clarify the time interval for the formation of the chondritic parent bodies, required time resolution is a few million years at least[1)]. However, it is difficult to achieve the enough precision to discuss the planetesimal history using in-situ dating technique. Laser ablation method (LA) is flexible sampling technique in aspects that the spatial resolution can be readily changed and the various sampling protocols are possible. Recently, the highly-precise age determination has been reported by multiple collector ICP mass spectrometry couple with LA sample introducing technique (LA-MC-ICP-MS)[4)]. In this study, the development of precise in-situ U-Th-Pb dating method of phosphate using LA-MC-ICP-MS is carried out for the purpose of establishment of the time-resolved story for the thermal and accretion history of the chondritic parent bodies.

Problematic points which limit the analytical precision in in-situ U-Th-Pb age determination of phosphate using laser ablation ICP mass spectrometry (LA-ICP-MS) are as followed: (1)error associated with large counting statistics derived from deficit of amount of sampling, (2)absence of age-homogeneous standard reference material of phosphate desired for precise measurement, (3)heterogeneity of Pb isotopic composition in standard reference material caused by non-radiogenic Pb which might be initially distributed in the material, (4)matrix effect associated with the difference of volatility between measured elements, (5) the isobaric interference on ^{204}Pb from ^{204}Hg. To overcome these problems, in this study, we tested the following approaches listed below: (a)enhancement of the total sensitivity through the improvement of interface region of ICP mass spectrometer and the integration of target material using multiple-spot ablation method[5)], (b)evaluation of the age homogeneity of Madagascar apatite[6)], (c)evaluation of the common-Pb correction for the standard reference material based on ^{207}Pb method, (d)reduction of the matrix effect by utilizing the femtosecond laser ablation system and development of the method to evaluate the system closure using three isotope diagram for Pb, (e)test of isochron method based on normalization by ^{208}Pb. To identify the suitable phase for analysis, in addition, imaging mass spectrometry for U, Th and Pb isotopes in large area (cm x cm order) by LA-ICP-MS is also tested, and the possibility of age determination using laser ablation in liquid method[7)] is estimated as well.

References
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Keywords: Parent body, Phosphate, U-Th-Pb geochronology, LA-ICP-MS