MULTI-CHRONOLOGY OF METEORITIC ZIRCON AND THE INITIAL ABUNDANCE OF PLUTONIUM-244 IN THE SOLAR SYSTEM.

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Introduction: Zircon is very rare in asteroidal meteorites but has been found in basaltic eucrites, mesosiderites, H5, L5, and LL3–6 chondrites [e.g., 1–3]. Compared to other minerals in meteorites, zircon has strong resistance to thermal resetting and is suitable for U-Pb and ^{182}Hf-^{182}W dating. Furthermore, the trace element compositions, especially rare earth elements (REE), U, and Th, have been examined for understanding the formation conditions of meteoritic zircon [e.g., 1–3]. For these reasons, meteoritic zircon has been recognized as a powerful tool to elucidate the early crustal evolution of differentiated asteroids. However, meteoritic zircon has the potential to provide additional chronological information of processes that occurred after their formation. For example, (U-Th)/He thermochronology, which has been widely utilized for terrestrial zircon [e.g., 4], would constrain the cooling history of the parent bodies. Meteoritic zircon may further contain cosmogenic components including ^{81}Kr ($T_{1/2} = 0.229 \times 10^6$ years) because Zr is one of the main target elements producing ^{81}Kr by spallation reaction. Cosmogenic noble gases in meteoritic zircon would therefore yield a cosmic-ray exposure age without measuring a whole rock sample. Moreover, meteoritic zircon perhaps contains fissiogenic Xe derived from ^{244}Pu as observed in Hadean terrestrial zircons from Jack Hills, Western Australia [5]. Because zircons from asteroidal meteorites have much older crystallization ages (~4.52–4.56 Ga [e.g., 2, 6]) than even the oldest terrestrial zircons (4.1–4.2 Ga [5]), it might be possible to determine a precise initial ^{244}Pu/^{238}U ratio of the solar system using meteoritic zircon. In order to obtain these information, we performed high-precision U-Pb dating, trace element analysis, and noble gas analysis using zircon from the mesosiderite Northwest Africa (NWA) 8741.

Analytical Methods: Zircon grains were separated from 31.9 g of NWA 8741 by dissolving the metal parts in concentrated HCl and the silicate parts in concentrated HNO_3-HF mixture. Subsequently, zircon grains with sizes of ca. 70–200 μm in diameter were handpicked from the residues and prepared for U-Pb dating by ID-TIMS, trace element and noble gas analyses. Samples for U-Pb dating were spiked with 3–5 mg of EARTHTIME ^{202}Pb-^{205}Pb-^{233}U-^{235}U tracer solution and dissolved in concentrated HF using Parr® bombs. Uranium and Pb isotopes separated using a HCl-based column chemistry were measured using a TRITON Plus TIMS at ETH Zurich [7]. The REE, U, and Th concentrations of the zircons were measured using the Element XR sector field ICPMS with Nd:YAG 213 nm laser ablation system at the National Institute of Polar Research, Japan. Two zircon samples (0.000154 and 0.000143 g) were used for obtaining noble gas compositions (He, Ne, Ar, Kr, and Xe) including ^{81}Kr, which were extracted by total melting at 1800°C and measured using a modified-VG5400 (MS-3) mass spectrometer at the Korea Polar Research Institute.

Results and Discussion: Six zircons from NWA 8741 yielded a weighted mean ^{207}Pb-^{206}Pb age of 4525.0 ± 1.3 Ma (95% confidence level). Other mesosiderites contain two kinds of zircons: (I) relict zircons that crystallized during initial magmatism (4563 ± 15 Ma) [8], and (II) secondary zircons that formed during the metal-silicate mixing event (4528.4 ± 1.4 Ma) [2, 9]. The ^{207}Pb-^{206}Pb ages of zircons from NWA 8741 are in good agreement with those of the secondary zircons. The zircons from NWA 8741 have relatively homogeneous trace element compositions, and the average U and Th concentration of 11 zircons are 1.1 ± 0.3 ppm and 0.08 ± 0.06 ppm, respectively. The ^{4}He concentrations of two zircon samples are 4.8×10^{-4} and 4.5×10^{-4} cm^{3}STP/g. Using the average U, Th and ^{4}He concentrations, the (U-Th)/He age is estimated to 2.5–2.6 Ga. Noble gas analysis revealed that zircons from NWA 8741 contain a cosmogenic components. The ^{81}Kr-Kr exposure age of the zircons is estimated to 37 million years. The fissiogenic ^{136}Xe from one zircon sample is $(1.31 \pm 0.14) \times 10^{-10}$ cm^{3}STP/g. Assuming a ^{244}Pu branching ratio of 0.00125 and ^{136}Xe fission yield of 5.6%, the ^{244}Pu concentration is calculated to 0.020 ± 0.002 ppm at the time of zircon formation. Using the zircon ^{207}Pb-^{206}Pb age (4525.0 ± 1.3 Ma) and ^{238}U and ^{244}Pu concentrations, the ^{244}Pu/^{238}U ratio is estimated to 0.012 ± 0.004 at CAI formation (4567.3 Ma [10]). This initial ratio is slightly higher but within analytical uncertainty equivalent to a previous estimate from terrestrial zircons (~0.008) [5].

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