Formation age of mesosiderites

Makiko K. Haba1, Jörn-Frederik Wotzlow2, Akira Yamaguchi, Yi-Jen Lai, and Maria Schönäbächler2

1 Department of Earth and Planetary Sciences, Tokyo Institute of Technology, Tokyo 152-8551, Japan
2 Institute of Geochemistry and Petrology, ETH Zürich, 8092 Zürich, Switzerland
3 National Institute of Polar Research, Tachikawa, Tokyo 190-8518, Japan

Mesosiderites are composed of roughly equal amounts of silicates and Fe-Ni metal. This meteorite group has been thought to have formed by mixing of crustal and core materials without including much of the mantle materials. Although several scenarios for the formation of mesosiderites have been proposed, the mechanism and timing of the metal-silicate mixing are still open questions. In the previous works, the Sm–Nd and Mn–Cr ages of mesosiderites have indicated that the metal-silicate mixing likely occurred 20–150 Ma after solar system formation (Stewart et al., 1994; Wadhwa et al., 2003). However, the ages still have a large range more than 100 million years. In order to determine a more precise age of the metal-silicate mixing event, it is necessary to analyze the minerals which formed during the mixing event and have remained closed systems for chronometers throughout the later impact events. Rutile and zircon have strong resistance to mechanical and chemical breakdown over long periods and suitable for 92Nb-92Zr and U-Pb dating, respectively. In addition, the previous works have suggested that these minerals formed during the mixing event (e.g., Haba et al., 2017). In this study, we will report the new 92Nb-92Zr and U-Pb ages of mesosideritic rutiles and zircons, respectively, to determine the age of the metal-silicate mixing event.

Four mesosiderites having different metamorphic grades, Vaca Muerta (1A), NWA 1242 (2A), A 882023 (2/3A), and Estherville (3/4A), were used in this study. Rutiles and zircons were separated from residual samples after dissolving the Fe-Ni metal and silicate parts with concentrated acids. Subsequently, a few hundred of rutile grains which were handpicked from residual samples were dissolved in HNO3-HF using Parr® bombs. The Nb/Zr ratio and Zr isotope measurements were performed using a quadrupole ICPMS and a Neptune Plus MC-ICPMS, respectively, at ETH Zurich. 16 individual zircons from Vaca Muerta, NWA 1242, and Estherville (40–200 μm in diameter) were spiked with 3–5 mg of EARTHTIME 202Pb-208Pb,233U,237U tracer solution and dissolved in concentrated HF using Parr® bombs. U and Pb were separated using a HCl-based column chemistry and measured using a TRITON Plus TIMS at ETH Zurich.

Three zircon grains from Vaca Muerta and Estherville yielded a weighted mean 207Pb-206Pb age of 4558.5 ± 1.6 Ma (2σ). Other four grains from Vaca Muerta, four grains from NWA 1242, and five grains from Estherville yielded weighted mean 207Pb-206Pb ages of 4528.0 ± 1.4 Ma (2σ), 4525.1 ± 2.5 Ma (2σ), and 4526.8 ± 2.7 Ma (2σ), respectively. The younger ages from three mesosiderite samples show an overlapping within the errors. The weighted mean 207Pb-206Pb age of all younger zircons is 4527.2 ± 1.1 Ma (2σ). According to Haba et al. (2017), mesosiderites have two kinds of zircons: (I) magmatic zircons that crystallized before the metal-silicate mixing event, and (II) secondary zircons that formed through the mixing event. The older age is in good agreement but significantly more precise than the previously reported age for the magmatic zircon from Vaca Muerta, whose age is 4563 ± 15 Ma (Ireland and Wlotzka, 1992). Therefore, these zircons are considered to be relict zircons that formed in the silicate parts before the metal-silicate mixing event.

The Nb-Zr data of rutiles from four mesosiderites are plotted on a single line in the Nb-Zr isochron diagram. The 92Nb/93Nb ratio obtained from the rutile data is (7.5 ± 0.7) × 10−6, which is in good agreement with the 92Nb/93Nb ratio for mesosiderites reported in Schönäbächler et al. (2002). The data plotted on the single line indicate that the 92Nb-92Zr decay system of mesosideritic rutiles has not been disturbed by later impacts after they formed. Since the rutiles in mesosiderites have been considered to form during the metal-silicate mixing under reducing condition (e.g., Yamaguchi et al., 2001), the 92Nb-92Zr age of rutiles should correspond to the timing of the mixing event. Using the initial 92Nb/93Nb ratio of rutiles and the solar system initial 92Nb/93Nb ratio ((1.7 ± 0.6) × 10−5, Izuka et al., 2016), the 92Nb-92Zr age of rutiles was calculated to be 41 ±
15 Myr after CAI formation. This age corresponds to the absolute age of 4527 Ma, which is consistent with the $^{207}\text{Pb}-^{206}\text{Pb}$ age of secondary zircons of mesosiderites. The $^{92}\text{Nb}-^{92}\text{Zr}$ age of rutiles strongly supports that the metal-silicate mixing that formed mesosiderites occurred at 4527.2 ± 1.1 Ma.

References


