Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PPS24-02 Room:415 Time:May 1 14:30-14:45

3-D observation of GEMS by electron tomography

MATSUNO, Junya[1*] ; MIYAKE, Akira[1] ; TSUCHIYAMA, Akira[1] ; NAKAMURA-MESSENGER, Keiko[2] ; MESSENGER, Scott[2]

[1]Dep. of Geology and Mineralogy, Kyoto Univ., [2]NASA Johnson Space Center

Amorphous silicates in chondritic porous interplanetary dust particles (CP-IDPs) coming from comets are dominated by glass with embedded metal and sulfides (GEMS). GEMS grains are submicron-sized rounded objects (typically 100-500 nm in diameter) with nanometer-sized (10-50 nm) Fe-Ni metal and sulfide grains embedded in an amorphous silicate matrix. Several formation processes for GEMS grains have been proposed so far, but these models are still being debated [2-5].

Bradley et al. proposed that GEMS grains are interstellar silicate dust that survived various metamorphism or alteration processes in the protoplanetary disk and that they are amorphization products of crystalline silicates in the interstellar medium by sputter?deposition of cosmic ray irradiation, similar to space weathering [2,4]. This consideration is based on the observation of nano-sized crystals (~10 nm) called relict grains in GEMS grains and their shapes are pseudomorphs to the host GEMS grains.

On the other hand, Keller and Messenger proposed that most GEMS grains formed in the protoplanetary disk as condensates from high temperature gas [3,5]. This model is based on the fact that most GEMS grains have solar isotopic compositions and have extremely heterogeneous and non-solar elemental compositions. Keller & Messenger (2011) also reported that amorphous silicates in GEMS grains are surrounded by sulfide grains, which formed as sulfidization of metallic iron grains located on the GEMS surface.

The previous studies were performed with 2D observation by using transmission electron microscopy (TEM) or scanning TEM (STEM). In order to understand the structure of GEMS grains described above more clearly, we observed 3D structure of GEMS grains by electron tomography using a TEM/STEM (JEM-2100F, JEOL) at Kyoto University. Electron tomography gives not only 3D structures but also gives higher spatial resolution (~a few nm) than that in conventional 2D image, which is restricted by the sample thickness (~>50 nm). Three cluster IDPs (L2036AA5 cluster4, L2009O8 cluster13 and W7262A2) were used for the observations. IDP W7262A2 was collected without silicon oil, which is ordinary used to collect IDPs, so this sample has no possibility of contaminations caused by silicon oil or solvent to rinse it [6].

The samples were embedded in epoxy resin and sliced into ultrathin sections (50-300 nm) using an ultramicrotome. The sections were observed by BF-TEM (bright field-TEM) and HAADF-STEM (high angle annular dark field-scanning TEM) modes. Images were obtained by rotating the sample tilt angle over a range of $\pm$65 degree in 1 degree steps. The obtained images were reconstructed to slice images. Mineral phases in the slice images were estimated by comparing with a 2D elemental map obtained by an EDS (energy dispersive X-ray spectroscopy) system equipped in the TEM/STEM.

Careful examination of the slice images confirmed that iron grains are embedded in the amorphous silicate matrix of the GEMS grains, but sulfide grains were mainly present on the surface of the amorphous silicate. These results are consistent with the model that GEMS grains formed as condensates [3,5], although more data are needed to conclude the origin of GEMS grains. The present study is the first successful example adapting the electron tomography to the IDPs. This type of analysis will be important for planetary material sciences in the future.

[1] Bradley et al. (1999) Science, 285, 1716
[2] Bradley and Dai (2004) ApJ, 617, 650
[3] Keller and Messenger (2011) GCA, 75, 5336
[4] Bradley (2013) GCA, 107, 336
[5] Keller and Messenger (2013) GCA, 107, 341
[6] Messenger et al. (2012) 43rd LPSC, 2696 (abstr.)

Keywords: IDP, GEMS, TEM, tomography