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

PPS25-08 Room:213 Time:May 2 11:00-11:15

Internal structure of chondrules and their possible origin

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In order to clarify 3D shapes and internal structure of chondrules in Allende chondrite, we have separated 180 chondrules grains and investigated them with X-ray CT apparatus (Scan Xmate-D180RSS270) recently installed at the Museum of Natural History, Tohoku University (Tsuda et al., JPGU 2013). We also developed an optical device to measure 3D shape of chondrules or other spherical objects (Nishida et al. JPGU 2013). Our results revealed that chondrules shapes show wide distribution consisting of true spheres, prolate-spheres and oblate-spheres. Chondrules with porphyritic textures distribute in all shape categories. Chondrules with barred olivine texture (quenched from super-heated melt) show a distribution between true sphere and oblate-shape. Implication of the 3D shapes and internal texture of chondrules are consistent with the shock-wave heating model (e.g., Miura & Nakamoto, 2002, 2008).

Due to the density contrast, textures of Fe-FeS phase are most easily observed by X-ray tomography. By melting, coagulation and growth of Fe-FeS phase occur in chondrules. In some chondrules, coagulation resulted in mini-core formation (driven by surface energy minimization, see Fig.1). It is suggested that duration of heating episodes could be estimated by coagulation textures of Fe-FeS. If chondrules were formed by shock heating mechanism (e.g., Miura & Nakamoto, 2002, 2008), separation of molten silicate and coagulated Fe-FeS droplets would have taken place during acceleration and slow down of chondrules. Accordingly, significant chemical fractionation took place by dynamic processes during chondrules formation.

In X-ray CT images, many chondrules are surrounded by 50-200 micron thick rims. Coagulation and growth of Fe-FeS grains are observed in chondrules-rims as well as inside of chondrules indicating that temperature may have exceeded ˜1000C (eutectic point in the Fe-FeS) in the chondrule-rims. The common appearance of growth texture of Fe-FeS grains supports high-temperature origin of chondrule-rims rather than metasomatic origin. Clear textural distinction between chondrules and their ambient rims may correspond with presence or absence of melting in silicates. Most abundant element that volatilized below 1000C is sulfur. It is suggested that sulfur would have acted as a glue to coagulate dust particles onto molten droplets (chondrules) during shock heating episodes.

Keywords: meteorite, chondrule, texture, origin, X-ray CT