Oxidation of iron sulfide in artificial micrometeorites

Hiroshi Isobe[1], Takaaki Gondo[2] and Kento Murozono[2]
[1]*Department of Earth and Environmental Science, Faculty of Advanced Science and Technology, Kumamoto University, Kumamoto 860-8555, Japan*
[2]*Graduate School of Science and Technology, Kumamoto University, Kumamoto 860-8555, Japan*
[3]*Faculty of Science, Kumamoto University, Kumamoto 860-8555, Japan*

Micrometeorites (MMs) have the most abundant flux in current accumulation of planetary materials to the Earth (Love and Brownlee, 1993). The MMs larger tham 70 μm in diameter show variously melted textures. In particular, completely melted MMs are known as cosmic spherules. Cosmic spherules have experienced large degrees of melting of primary phases during atmospheric entry, and form molten droplets (Love and Brownlee, 1991; Genge, 2008). Evaporation of meteoritic materials, especially sulfur species, may have environmental effect at upper atmosphere (Court and Sephton, 2011; Tomkins et al., 2016). Troilite is typical FeS phase in chondritic meteorites. In this study, we carried out rapid heating and quenching experiments on fine particles of meteoritic materials and FeS reagent. We used the fine particles free falling apparatus with controlled gas flow (Isobe and Gondo, 2013). Starting materials are particles of approximately 100 μm in diameter prepared from CV, CM and H chondrites and FeS reagent. FeS reagent is inhomogeneous mixture of troilite, iron oxide and iron metal. Oxygen fugacity was controlled to FMQ +1.5 log unit. Temperature of the particles was higher than 1400°C at maximum for approximately 0.5 seconds and quenched within a second. Run products are retrieved from the bottom of the furnace tube.

Run products from meteoritic materials show quite analogous textures to MMs including scoriaceous, porphyritic olivine and barred olivine. Almost molten particles show spherical shape due to surface tension of the silicate melt. The outside shape of the particles is various depending on melt fraction of the particle. On the surface of several molten spherules, melted Fe sulfide can be seen. Immiscibility between sulfide melt and silicate melt may induce sulfide melt discharge from silicate melt.

Run products from FeS reagent with rounded shape and smooth surface show the particles were completely melted. Chemical compositions of particles analyzed on cross sections are generally well homogenized from inhomogeneous starting materials by complete melting. Molar ratios of Fe in melted regions are close to 0.5, while compositions of S and O are various. Varieties of S and O compositions show various degree of oxidation and evaporation of sulfur. Distribution of compositions of melted regions in Fe-S-O system is plotted in liquidus compositions of FeO and FeS saturated melt (Ueda et al., 2008).

Troilite in MMs is melted and oxidized by atmospheric entry. Compositions of FeS melt in fine spherules are following Fe-S-O phase relations even in a few seconds. The surface deposition of iron sulfide on cosmic spherule has not been reported. Sulfide on MMs may be removed by abration in the upper atmosphere. This process may be constant source of sulfur species to the upper atmosphere other than terrestrial volcanic activity. Evaporation of sulfur from meteoritic materials in atmospheric entry heating may depend on oxygen fugacity of the upper atmosphere. Sulfur supply from meteoritic materials to atmosphere may be limited on planets with oxygen-free atmosphere.

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