

Three-dimensional shapes of cosmic spherules: comparison with chondrules and shock wave model

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3-D structures of chondrules have been studied using X-ray microtomography (1). It has been proposed from their external shapes and internal structures on the distribution of metal/sulfide grains and voids that chondrules were rotated at high speed during melting. This high-speed rotation is consistent with a shock wave model for chondrule formation (2). Cosmic spherules are another type of spherulitic objects, which are formed by shock wave melting during their entry into the Earth's atmosphere. In the present study, we examined 3-D structures of cosmic spherules and compared them with those of chondrules to discuss chondrule formation process as well as cosmic spherule formation process.

Cosmic spherules collected from Antarctica (0.12-0.32 mm in size) were imaged by an x-ray microtomographic system at beamline BL47XU in SPring-8 (3) with monochromatic x-ray beams of 10 or 13 keV. The voxel size of the CT image is 0.5x0.5x0.5 micron, which gives the effective spatial resolution of about 1.5 micron (3). 3-D structures were reconstructed from about 300-600 slices.

3-D external shapes were approximated as three-axial ellipsoids with a-, b- and c-axes (axial radii are A, B and C, respectively). The aspect ratio, p , was defined as C/A . Prolate and oblate shapes are recognized. Cosmic spherules were plotted on a C/B vs. B/A diagram together with chondrules, which were removed from the Allende meteorite (1). For chondrule shapes, two groups can be recognized: oblate to prolate chondrules (mainly oblate shapes) with large p of 0.8-1 and prolate chondrules with small p of 0.6 to 0.8. The spherule shapes were also plotted onto the same regions as those of the chondrule shapes. In addition, some cosmic spherules have dumbbell shaped with p of about 0.3-0.4. Textures of the spherules were recognized from their CT (porphyritic, barred olivine and cryptocrystalline textures). Some spherules are porous with a large amount of voids. Cosmic spherules are characterized by porous porphyritic oblate and barred olivine prolate spherules. About 44 percents of spherules are compound.

The chondrule shape feature can be explained by high-speed rotation during melting (1). A melt droplet becomes oblate by rotation. If rotation rate exceeds a critical value, the shape instability occurs and the melt might become prolate. Oblate and prolate spherules can be also explained by rotation. Dumbbell shaped spherules can be regarded as shapes with higher rotation rates than those of prolate shapes. The rotation rates of chondrules (about 100-500 rps) were estimated by a balance between the centrifugal force and the surface tension of a melt (1). If the cosmic spherules were also rotating during melting, the rotation rates for the oblate spherules should be about 1000 rps or more.

Cosmic spherules are formed by shock wave melting during their entry into the Earth's atmosphere. The shock wave model has been also proposed for the chondrule formation (e.g., (4)). The similar shape features of spherules and chondrules might suggest that the both types of spherules, cosmic spherules and chondrules, are formed by shock wave melting with different shock conditions.

In contrast to the general shape features, some detailed textural and shape features of the cosmic spherules and chondrules are different. Dumbbell shaped chondrules are not known. Radial pyroxene spherules are not found. Porous porphyritic oblate and barred olivine oblate shapes are not characteristic of chondrules. At this moment, we do not know whether the above differences are due to difference of the shock conditions between chondrule and spherule formations or due to different origin of chondrule formation.

References: (1) Tsuchiyama A et al. (2003) LPS XXXIV, 1271. (2) Susa H. and Nakamoto T. (2002) *Astrophys. J.*, 564, L57-60. (3) Uesugi K. et al. (1999) *Proc. SPIE*, 3772, 214. (4) Connolly H. C. Jr. and Love S. G. (1998) *Science*, 280, 62-67.