6.3.P01

3D-microtomographic determination of chondrule/matrix ratios in carbonaceous chondrites

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Measurements of chondrule-matrix ratios in different pieces of the Allende CV3 chondrite, combined with chemical analyses of chondrules and matrix indicate that their chemical compositions are complementary in terms of major and trace elements [1]. Furthermore, chondrules and matrix appear to always have the relative abundances needed to produce the canonical Allende bulk composition in different pieces of the meteorite. Other meteorites tell a similar story. This suggests that a strictly localized process produced chondrules and matrix in the same environment with uniform bulk composition. It precludes astrophysical models that require the formation of chondrules and matrix in different places with subsequent mixing of these components [e.g. 2].

The most critical evidence in this reasoning is the proportion of chondrules, matrix, CAI and other components in meteorites, which was previously determined from polished thin sections with electron microscopy. Here we obtained these proportions using 3D tomography combined with petrographic and chemical analyses in serial sections.

Tomographic images of a ~6x6x12mm Allende sample were collected using 50 KeV x-rays on the GEOCARS computer-aided microtomography beamline of the Advanced Photon Source (APS) at Argonne National Laboratory in Illinois [3]. To obtain the volumes of chondrules and matrix we applied the IDL program BLOB3D [4]. Then we cut the Allende sample in serial ~300µm slices for additional electron microprobe analyses of chondrules, CAIs and matrix to refine the tomographic data.

First results show that 3D microtomography can yield precise quantitative volumetric data. Hence it is possible to investigate the formation history of meteoritic components in a 3D context and to gain constraints on their astrophysical formation environment.

References

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6.3.P02

Stability of a melted iron inclusion on the surface of a melted chondrule

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Chondrules have a distinctive feature that they are depleted in siderophile elements relative to the solar abundance. Several processes, such as physical separation of iron inclusions by high speed rotation of chondrules during the formation and elemental fractionation of the precursor materials during the condensation from hot nebular gas, are considered to be possible reasons for the depletion of the siderophile elements.

Kinetic stability of the state where an iron inclusion is "on" the surface of a melted chondrule is important for determination of the efficiency of the physical separation of iron inclusions from chondrules. We formulated and calculated the lowest energy and shape of the iron inclusion and chondrule for the "on" state, and obtained the energy difference from the state where the iron inclusion is "outside" of the chondrule. The energy difference, equal to the energy required for leaving the iron inclusion from surface of the chondrule, can be transformed into the velocity of the iron inclusion by simple formula, $v_{\mathrm{crit}} = (2\delta E/m)^{1/2}$, where δE is energy difference and m is mass of the relevant iron inclusion. We obtained the critical velocity v_{crit} as around 120 cm s^{-1}, in the case that radii of the chondrule and iron inclusion (assumed as troilite) are 300 µm and 60 µm, respectively. Recent study reported that the nebular shock wave heating can induce the high speed rotational flow [1], but velocity of the flow is around 10 cm s^{-1} for typical nebular shock wave velocity (~9 km s^{-1}) and is much lower than the critical velocity. From the critical velocity, critical rotation frequency for the ejection of iron inclusions can be also estimated as around 640 s^{-1}. The rotation frequency of natural chondrules estimated from their three dimensional shape is 50 to 500 s^{-1} [2], and is again lower than the critical rotation frequency.

These results indicate a "troilite" inclusion with "on" state is stable and would not be ejected from chondrules efficiently. Our microscopic observations show, however, metal-iron inclusions of chondrules are rarely on the surface of chondrules with their equilibrium shape. This may indicate the "on" state for "metal-iron" is weakly stable or even unstable. Though further investigations are needed for clarifying the stability of "on" state for metal-iron inclusions, this issue will provide us the important information concerning the depletion of siderophile elements of chondrules.

References

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