Geophysical Research Abstracts
Vol. 12, EGU2010-466-5, 2010
EGU General Assembly 2010

Possible primitive origin of carbonate in CAI of Murchison carbonaceous chondrite

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Astronomical observation identified existence of carbonate in nebula gas by spectrum analysis. However, all the carbonate minerals have been regarded as secondary product. We therefore tried to find primitive carbonate mineral in some chondrites. We have checked several carbonaceous chondrites using more than fifty thin sections. Extensive observation has been carried out on the CAIs. If CAIs include carbonate minerals, they could be most possible candidates of primitive carbonate condensed directly from nebula.

We discovered a unique spherical CAI consisting of calcite, spinel, diopside that is partly surrounded by PCP in Murchison meteorite for the first time. Calcite coexists with spinel and diopside in the CAI. A number of micron-sized vacancies were recognized in the calcite grains. One apparent calcite grain seems to be an aggregate of tiny calcite crystals. The calcite grain is mostly surrounded by thin film-like diopside and then by massive spinel. Their occurrence suggests evidence against in-situ formation of calcite as the secondary phase on the parent body. The textual characteristics of the CAI also imply that the replacement is unlikely to produce calcite on the parent body.

The oxygen isotopic compositions and REE were obtained by a Nano SIMS.

The primitive phases of spinel and diopside have low delta values of oxygen 17 and also low delta values of oxygen 18 (-30 to -50 per mill,) common to the primitive phases and they distribute on or near the CCAM line on the three isotopic diagram. In contrast the calcite has slightly high and wide delta values of oxygen 17 (-25 to 11 per mill,) and delta values of oxygen 18 (-20 to 30 per mill,). Oxygen isotopic compositions of spinel and diopside are similar to those of non-altered CAIs of CV chondrites and some other carbonaceous chondrites. Although the calcite has slightly high values of oxygen isotopic ratios, none of them plot on the TF line. Their data scatter between CCAM line and TF line. Our result indicates that calcite should have been formed initially in low delta oxygen 17 and 18 environments. The oxygen isotopic compositions of liquid water of Murchison are close to SMOW values on the three isotope plot. Therefore alteration or replacement caused by liquid water on the parental body should shift the oxygen isotopic compositions of the calcite toward the SMOW values. All the oxygen isotopic compositions of calcite by alteration are on the TF line including our results and the reported values in literatures. No alteration can be recognized in the CAI and oxygen isotopic compositions may demonstrate that neither of the alteration nor replacement processes should be the reason to produce isotopic shift of the calcite toward the crossing point of CCAM line and TF line. The calcite in the refractory CAI of Murchison meteorite should keep primitive isotopic compositions of oxygen formed in the early solar nebula.

The REE patterns of the calcite grains are characteristic: they are highly enriched in LREE but not so enriched in HREE relative to CI chondrite. The LREE abundances in the calcite are almost one hundred times more than CI chondrite but the HREE abundances are as small as ten times of CI chondrite. Such patterns are similar to those of spinel and diopside in the CAI. Such REE characteristics should suggest that the calcite has been formed while the nebula temperature slightly cooled and after most of HREE have condensed. In contrast, calcite formed by alteration in the matrix of Murchison is highly depleted in all REEs. Its REE abundances are too low to analyze and its pattern is almost flat. Some REE could not be analyzed due to low concentrations.

We admit that, however, it will be still difficult to explain how to mix high temperature products with low temperature products in space.