MINERALOGY AND CRYSTAL CHEMISTRY OF CP MICROMETEORITES

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CP (chondritic porous) interplanetary dust particles differ from other types of extraterrestrial materials in porosity, morphology and mineralogy. Their porous, fragile structures are consistent with the inferred properties of cometary meteors. If CP particles are indeed derived from comets then they may contain vapor phase condensates that were formed in the solar nebula or presolar interstellar environments. As part of an ongoing effort we have been utilizing a range of electron-beam methods to obtain detailed characterizations of the major mineral species found within CP particles.

Laboratory studies of both natural and synthetic vapor phase condensates have shown that such materials can exhibit crystallographic and morphological features that are diagnostic of vapor phase growth.[1-3] For example, two important aspects of gas-to-particle condensation are the presence of characteristic defects within growing crystals and unusual modes of crystal growth. Together these can lead to gross morphological perturbations, resulting in a variety of unusual crystals. We have recently identified pure enstatite grains within CP particles, whose unique characteristics strongly suggest that they formed by gas-to-particle condensation.[4,5] They occur as whiskers (e.g. rods and ribbons) and platelets. Rods contain axial screw dislocations and are grossly elongated along the crystallographic [100] direction. Ribbons are blade-shaped clinopyroxene crystals that are also elongated along [100]. (Terrestrial, lunar and meteoritic pyroxenes, when not equiaxial, tend to be elongated along [001]). Platelets consist of angular and disc-shaped ortho-clino crystals that can exhibit extreme flattening on any one of the three principle crystallographic axes, i.e. [100], [010] or [001]. These unusual crystal habits are consistent with material formed by gas-to-particle condensation. The results of our study of pyroxenes within CP particles have provided strong structural (crystallographic) evidence for the survival of primordial magnesian silicate condensates.

The results of the pyroxene studies underscore the need for a detailed mineralogical investigation of CP particles. Therefore, we have extended our efforts to characterize other mineral phases, including carbon, silicon carbide, olivine, sulfides and FeNi alloys. Analytical methods that we are utilizing include electron diffraction, high-resolution lattice fringe imaging, X-ray spectrometry, and electron energy-loss spectroscopy.

Intergrowths of carbon and silicon carbide are found within CP particles as isolated grains. They consist of microcrystals (< 250 Å diameter) of silicon carbide embedded in a matrix of amorphous carbon. Such grains are of special interest because they could represent pre-solar material derived from carbon-rich stars with C/O >1. However, silicon and carbon are both common particulate contaminants; they can be found in the collection medium (silicone oil), laboratory cleaning solvents (hexanes), and specimen support substrates (holey-carbon). Although we consider it unlikely that these grains are contaminants, we are carefully investigating the possibility that they could have been modified or even created either during collection and processing, or under electron irradiation. Studies we have done on pure carbon indicate that in spite of moderately high bulk carbon contents of CP particles, graphitic carbon is exceedingly rare. The rare occurrence of graphitic carbon in these materials may well be a result of contamination, since trace amounts of graphitic carbon occur on all of the holey-carbon support films upon which the samples are mounted. The possible lack of graphite in CP micrometeorites contrasts with its relatively high abundance in the smooth phyllosilicate containing chondritic micrometeorites (type CS) and in CI/CM matrix.

An interesting aspect of our mineralogical investigation is that nearly all the micron-sized grains with obvious whisker and platelet morphologies are almost pure (iron free) enstatite. Although olivine grains (with variable iron content) are very common, we have only identified a single olivine whisker, which like the pyroxenes is iron free. Most of the mass of CP particles is in the form of submicron polycrystalline grains. Preliminary evidence suggests that at least part of this polycrystalline material is simply aggregates of even smaller platelets. Two other mineral constituents of CP particles, pyrrhotite and FeNi alloy exhibit evidence of crystallographic superstructuring. Elucidation of their crystal structures may provide further information regarding the possible preservation of condensates in CP micrometeorites.

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