Mineralogical examination of carbonaceous matter in carbonaceous chondrites by TEM and Raman spectroscopy

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Introduction: Carbonaceous matter in chondritic meteorites has information of a complex history of the protoplanetary disk and/or meteorite parent bodies.

In this study, we have analyzed the carbonaceous matter extracted from 10 Antarctic carbonaceous chondrites (CM2, CM2 or Cl, CO3 types) and 6 Non-Anterctic carbonaceous chondrites (CM2, CV3, CO3 types) using Raman spectroscopy and transmission electron microscopy (TEM) to measure the degree of alternation.

Sample and methods: The samples used in this study are as follows.

Antarctic carbonaceous chondrites:

Yamato(Y)-86720 (CM2), Y-86789 (CM2), Y-80120 (CM2), Y-793321 (CM2), Y-74662 (CM2), Y-82054 (CM2), Asuka(A)-881655 (CM2), Y-790992 (CM2), Belgica(B)-7904 (CM2 or "CI"), Y-86751 (CV3), Y-790992 (CO3), A-882094 (CO3),

Non-Antarctic carbonaceous chondrites:

Acfer331(CM2), Murray(CM2), NWA 852, NWA 2086(CR2), Shişr 033(CR).

The meteorite samples were dissolved in HF/HCl. Then, the samples for Raman analysis are placed on a slide glass with ethanol. Samples for TEM observation were prepared on microgrids.

TEM observations were carried out using JEM-2010(JEOL) system that was operated at 200 kV with EDS attachment.

Raman spectroscopy detects the structural order of carbonaceous material, which is best parameterized by the relative intensities of the so-called D ("disordered") and G ("graphite") bands. The intensity ratio I_G/I_D increase in the case of graphite with the size of the domain. Mono-crystalline graphite shows only G band at ~1581 cm^{-1}. The second band, the D band at ~1355 cm^{-1} is caused by defect, polycrystallinity and small domain sizes, crystal boundary effects, and size reflects increasing disorder. The peak width of D band (Γ_D) generally decrease with increasing metamorphism.

Result: Raman analyses average of the signals from all constituents of the meteoritic carbonaceous material residues, which include highly interlinked macromotecular material, potentially amorphized C and small mineral grains embedded in the extracted carbonaceous matter, including presolar grains of SiC, graphite, and nano diamonds as well as oxides (e.g., chromite) of solar system origin.

The result of Raman analysis, the most primitive samples (CM, CI) show the largest values for Γ_D and D band position. CV and CO type chondrites shows smaller values than CM or CI. From this, crystallinity of carbonaceous matter differ with the meteorite types.

Using the ratio of Γ_D vs. D band position, the relative degree of crystallization of the carbonaceous matter in the meteorites becomes apparent. The peak metamorphic degrees and peak temperatures were calculated using the half bandwidth of D band [1]. Using these data, the peak metamorphic temperature of carbonaceous matter in the chondritic meteorites was estimated. The meteorite samples of B-7904, Y-793321, Y-86720 which have experienced strong thermal metamorphism [2] showed relatively low temperature for formation of carbonaceous matter: That is, 223ºC (B-7904), 227ºC (Y-793221), and 240ºC (Y-86720). This contradicts peak temperature of thermal metamorphism calculated from phyllosilicates: Y-793321 (200-259ºC), Y-86720 (700-750ºC), and B-7904 (<750ºC) [2]. It is suggested that carbonaceous matter in meteorites has experienced different thermal history from phyllosilicates.

In the TEM observation, we could find organic globules in the samples whose carbonaceous matter indicates low crystallinity. Organic globules show the hollow morphology. Measuring the thickness of outer envelope and radius of the organic globules observed in each sample, the ratios of the thickness of outer envelope vs. radius were similar for all organic globules even in different type carbonaceous chondrites. From this, it is not likely that there is a relationship between the type of meteorite and the size and thickness of outer envelope of organic globules.

On the other hand, in the carbonaceous matter of Allende (589ºC) and A-882094 (458ºC), which has well crystallized carbonaceous matter, we couldn't find organic globules. There may be a relationship between the presence of organic globules and degree of the organic material crystallization.

In addition, we conduct a carbon isotope measurement of carbonaceous material. discuss the relationship between degree of crystallinity of chondritic carbonaceous matter and abundance of organic globules.

References:

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