Time-dependent spectroscopic and mineralogical changes by heating of Murray CM chondrite

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Many hydrous carbonaceous chondrites were found to be thermally metamorphosed after aqueous alteration. Spectroscopic observations of C-type asteroid Ryugu suggest that Ryugu is similar to parent bodies of heated hydrous carbonaceous chondrites (e.g. Kitazato et al., 2019). Three possible heat sources are proposed: decay heat of radionuclides, solar radiation, and shock-induced heat and the duration of heating decreases in this order. However, kinetics of thermal alteration of carbonaceous chondrite is poorly understood. In this study, long-duration heating experiments of Murray CM chondrite was performed to evaluate time-dependent changes of reflectance spectra and mineralogy.

A powder ($\phi < 155$ μm) and polished fragments of Murray meteorite (CM2.4–2.5; Rubin, 2007) were heated at 600˚C for the duration of 1, 10, 100, and 500 hours in vacuum at oxygen fugacity of around IW buffer. The heated samples were analyzed by conventional XRD, Synchrotron-XRD, FE-SEM/EDS, micro-Raman spectroscopy, FT-IR, and Karl-Fisher Titration method.

After 1-hour heating, the hydrous minerals (serpentine and tochilinite) were decomposed into amorphous phases and water was completely evaporated from the samples. After 10-hour heating, low crystalline secondary olivine and taenite newly formed. The amounts of these secondary minerals increased with heating duration. The absolute reflectance of the sample at 0.55 μm decreased after 1-hour heating, but continuously increased after 10-hour heating. The D and G bands in the Raman spectra, which reflect structures of amorphous carbon, of several chondrule rims did not change significantly and thus seem to be less sensitive to heating duration at 600˚C. Based on the classification of the heating stage defined by Nakamura (2005), the 1-hour heated sample corresponds to the weakly heated (stage II) chondrites and 10-hour, 100-hour, and 500-hour heated samples correspond to the moderately heated (stage III) chondrites.

We defined and quantified six parameters representing temporal changes of the spectroscopic and mineralogical features such as slope of reflectance spectra in the wavelength range from 0.38 to 0.55 μm, the absolute reflectance at 0.55 μm, the half widths and peak positions of diffractions from secondary olivine and taenite. These parameters will be used to estimate conditions of thermal alteration of naturally-heated carbonaceous chondrites and also returned samples from Ryugu.

