Structural Differences Between Insoluble Organic Matter in Matrix and Chondrules: Potential Insights into Pre-Parent Body Thermal Alteration

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Introduction: Carbon is a major molecular constituent of primitive chondrites of low petrologic grade.[1] A majority of the carbon (>70%) is in the insoluble organic matter (IOM) fraction that cannot be extracted from the meteorite sample using polar or nonpolar solvents.[1] The IOM is comprised of a kerogen-like macromolecular carbon (MMC) structure that consists of aromatic rings connected by highly branching aliphatic chains.[2] Raman spectroscopy is highly sensitive to IOM due to a strong resonance enhancement that occurs for all visible excitation wavelengths, making Raman a powerful in-situ probe of IOM.[3] The Raman spectrum of IOM consists of two primary bands, the G band originates from all carbon-carbon bonds in the MMC structure and the D band that originates from carbon 6-member ring breathing motions.[3] The peak position and width of the G and D bands probe the structure of the IOM.[3,4] Using Raman spectroscopy, the IOM structure has been shown to correlate with the thermal alteration history of the meteorite, allowing for petrologic grade classification to the tenths place in the 3.0-3.9 range.[5]. Here, we have collected Raman images of GRA 06100,41 (CR2) for the examination of the IOM spatial distribution and observe significant differences between the IOM in the matrix and chondrules.

Results: Figure 1 shows the Raman image results of GRA 06100,41. The average IOM Raman spectra for the matrix and chondrules significantly differ (Figure 1c). The D and G bands are upshifted (G matrix ~1600 cm^{-1}, G chondrule 1611 cm^{-1}, D matrix ~ 1338 cm^{-1}, D chondrule 1368 cm^{-1}) and more narrow (FWHH G matrix ~63 cm^{-1}, G chondrule ~50 cm^{-1}, D matrix ~260 cm^{-1}, D chondrule ~180 cm^{-1}) in the chondrule compared to the matrix indicating that the chondrule IOM is more ordered compared to that of the matrix with aromatic and aliphatic moieties that are smaller with a more limited size distribution.[3,4] In addition, the chondritic IOM has a larger D band intensity relative to the G band (D/G ratio, Matrix 0.60 ,Chondrule 0.85) indicating more aromatic moieties in the chondrite IOM.[3,4] Figure 1b shows a Raman image map of the D/G ratio of the IOM spectra showing an increased value within the chondrules compared to the matrix.

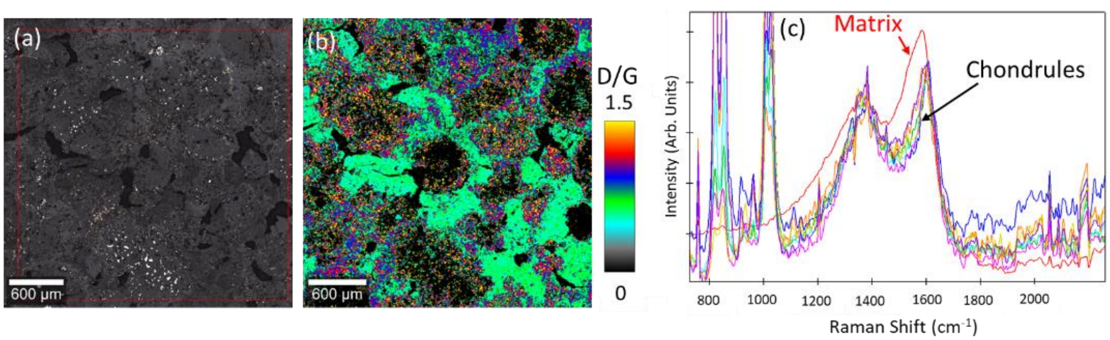

Figure 1: (a) Microscope image of GRA 06100,41. (b) Raman image plotting D/G values for IOM spectra. (c) Average Raman spectra of the matrix and select chondrules.

Discussion: Structural changes in the IOM are generally thought to be predominantly dependent on the peak thermal alteration experienced by the meteorite, with other effects like shock and aqueous alteration having a lesser effect.[5] With this assumption, the results above indicate a higher peak thermal alteration of chondritic IOM compared to matrix IOM, with the matrix IOM consistent with petrologic type 3.0 and the chondrule IOM consistent with petrologic type 3.1.[6] Hanon et al. (1997) showed evidence that both chondrule and matrix precursors possibly contained carbon-bearing grains[7] and each component experienced different thermal histories before accretion. Thus, it is possible that the differences in chondrule and matrix carbon structure in GRA 06100,41 record pre-parent body thermal alteration that was not overprinted by parent body heating.

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