**Raman Spectroscopic Characterization of Petrologic Type in Chondrite Chips and Thin Sections and Potential Applications for Meteorite Pairing.** R. S. Jakubek[1], K. Righter[2], and M. D. Fries[3], [1]Jacobs, NASA Johnson Space Center, Houston, Texas, USA, [2]NASA Johnson Space Center, Mailcode XI2, 2101 NASA Parkway, Houston, TX, 77058, USA, [3]NASA Astromaterials Acquisition and Curation Office, NASA Johnson Space Center, Houston, Texas, USA

**Introduction:** Carbonaceous chondrites are the most primitive of meteorites. They experienced no melting or differentiation on their parent body preserving information from the solar nebula. However, secondary processes including aqueous alteration, thermal alteration, and shock metamorphism skews their geologic record of the solar nebula [1]. To differentiate between nebular and secondary process features, one needs to understand the magnitude and effects of secondary processes. Chondrites can experience a wide range and magnitude of secondary processes. The least altered specimens are designated petrologic type 3. Petrologic types <3 indicate increasing aqueous alteration while petrologic types >3 indicate increasing thermal alteration [2]. Petrologic type 3 is further broken down into sub-categories 3.0-3.9 each indicating increased thermal alteration less severe than type 4 [3].

Previously, it has been shown that the Raman spectra of the macromolecular carbon (MMC) within low grade (Type 3) chondrites can be used to determine their degree of thermal alteration, and thus petrologic sub-types 3.0-3.9 in the CV carbonaceous chondrites [4]. Increased thermal alteration decreases the MMC D band full width at half height (FWHH) and increases the intensity of the D band with respect to the G band ($I_D/I_G$) with 515 nm excitation. This occurs because heating of MMC causes it to anneal and order, and structural changes are reflected in Raman spectra [4].

Previous work used raw sample chips for Raman spectral acquisition, however, it was indicated that thin sections could potentially be used. Thin section preparation is known to effect MMC structure but only for MMC with structural ordering higher than that observed in type 3 chondrites [4,5]. Thus, there is potential for this technique to be used on thin section samples expanding the utility of this technique. In this work, we have examined the MMC Raman spectrum of carbonaceous chondrite chips and thin sections prepared from the same samples. We find that measuring the $FWHH_D$ vs $I_D/I_G$ for both chips and thin sections allow for estimation of petrologic type.

In addition, we are interested in using this technique to aid in pairing of CV chondrites from the US Antarctic meteorite collection. Due to atmospheric entry and terrestrial weathering meteorites fragment [6]. Meteorite pairing is the procedure of determining whether recovered meteorite fragments correspond to a single meteoritic mass that fragmented in the atmosphere or in the terrestrial environment. By including Raman measured petrographic type with the pairing criteria data set, we hope to further confirm or refute proposed meteorite pairings. The US Antarctic meteorite collection includes 119 CV chondrites, including 71 from the Miller Range (MIL), 78 from Larkman Nunatak (LAR), and 7 from Queen Alexandra Range (QUE). Because these dense collection areas were visited multiple times over several decades, the pairing assessment must periodically be revisited. This study includes all CVs in the collection, but focuses on these larger groups that need to be re-assessed.

**Experimental Methods:** Raman spectra were collected using Ratatoskr, an α300R Raman microscope. A 20x objective was used to focus a 532 nm incident laser beam into a 3um spot size on the sample. Low incident laser power of ~72 uW was used to reduce photodegradation of the samples.

Raman spectra were collected on both chips and thin sections of meteorites GRA06101, MIL07671, MIL091010, and RBT04133. Spectra from thin sections of Leoville and Vigarano were also collected. For each sample, 10 Raman spectra were collected each of a different spot on the sample surface. Raman spectra were baselined to remove any background and the D and G bands were fit to Lorentzian and Breit-Wigner-Fano functions, respectively, following [4]. Average G and D band parameters were calculated from the 10 spectra. The samples were plotted with FWHH of the D band as the ordinate and $I_D/I_G$ as the abscissa. The position of a chondrite on this plot was previously shown to be correlated to its petrographic type.

**Results:** Figure 1 shows the plot of $I_D/I_G$ vs $FWHH_D$ for all samples measured. In figure 1 we can see that the chip and thin section samples of the same meteorite are found in the same area of the plot resulting in being identified as the same petrologic classification. We qualitatively observe that the G band FWHH is decreased by ~2-5 $cm^{-1}$ in the thin sections compared to the chips. However, we observe no consistent difference in D band parameters or $I_D/I_G$ between thin sections and chips preserving the use of $FWHH_D$ vs $I_D/I_G$ as a measure of petrologic type. This result is in contrast to Beyssac et al. [5] and Bonal et al. [4] who states that thin section preparation should not effect MMC structure for the ordered MMC found in type 3 chondrites. Ammar et al. [7] investigated the effects of polishing on MMC in the Acapulco meteorite. They found that in the polished sample the $I_D/I_G$ ratio varies greatly with the spot on the sample while the G band width does not. From this they conclude that $I_D/I_G$ is affected by polishing but G band width is not. However, they do not compare their polished sample to an equivalent unpolished sample making it difficult to assess the effect of polishing. In our work we also observe that $I_D/I_G$ varies with sample spot, however, this variation is observed to be similar in both chips and thin sections and the average values are observed to be similar for thin sections and chips. The difference between our observation and that of Ammar et al. may be due to the fact that they are looking at more ordered carbon with $I_D/I_G$ of ~0.3-0.8, which has been shown to be more sensitive to polishing [5].

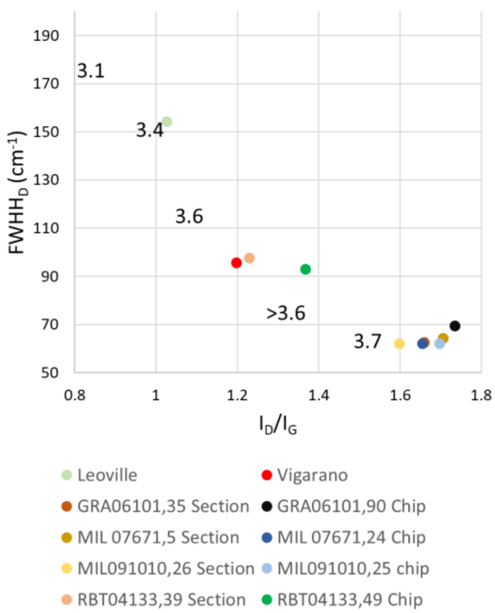


Figure 1: Meteorite chips and thin sections plotted as $FWHM_D$ vs $I_D/I_G$. Each data point is the average band parameter from 8-10 Raman spectra. The numbers 3.1-3.7 show where the different petrographic types lie on the plot as determined by Bonal et al. [4].

Figure 1 shows the $I_D/I_G$ vs $FWHH_D$ plot for all samples examined. Both thin sections and chips of GRA06101, RBT04133, and MIL091010 are found in the type 3.6-3.7 area of the plot. This is in agreement with previously determined petrologic types [4] and indicates that thin section preparation does not interfere with the Raman spectroscopic determination of petrologic type. Leoville is found in the ~3.1 type section of the plot in agreement with its assigned petrologic type [4,8]. The thin section and chip of MIL07671 yielded $FWHH_G$ vs $I_D/I_G$, values consistent with type 3.7, which is a higher petrologic type than reported by [4]; this might be due to brecciation that has preserved both 3.1 and 3.7 material within MIL 07671. Vigarano is ~3.6 type, intermediate between Leoville and most of the US Antarctic CVs, but at a slightly higher petrologic grade than reported by previous work [4,8]. These results show that $FWHH_G$ vs $I_D/I_G$ is a good method of estimating petrologic type for CV3 using both raw chip and thin section samples.

**Conclusion:** In this work we examine the structure of MMC in meteorite chips and thin sections to determine their petrologic type. Our results thus far suggest that both raw sample chips and thin sections can be used to find petrologic type by plotting the parameters $FWHH_G$ vs $I_D/I_G$.

**Future Work:** Future work on this projects includes collecting Raman spectra and plotting the $FWHH_G$ vs $I_D/I_G$ MMC band parameters for a large number of CV3 and perhaps other carbonaceous chondrites in the US Antarctic meteorite collection. We will include our work in the dataset used to assess potential meteorite pairings to further support or refute proposed pairings.

**Acknowledgments:** Funding for this work was provided as an Advanced Curation project run by the NASA Astromaterials Acquisition and Curation Office, Johnson Space Center. Thanks to Mike Zolensky for loaning sections of Leoville and Vigarano.

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