

EXTRA-TERRESTRIAL CARBON AND WATER MOLECULE IN MUKUNDPURA CARBONACEOUS CHONDRITE (CM2).

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Introduction: The Mukundpura meteorite, whose fall was witnessed on June 6, 2017, represents a carbonaceous (CM) chondrite of petrologic type-II. Detailed morphometric, petrographic, mineral chemical, whole rock geochemical and Laser Raman Spectroscopic (LRS) analyses of the Mukundpura meteorite have been attempted by several workers [1, 2, 3, 4, 5]. In the present study, Laser Raman Spectroscopy (LRS) and the Fourier Transform InfraRed (FTIR) spectroscopy has been carried out to determine qualitative and semi-quantitative features and/or parameters of organic or inorganic molecules in carbonaceous component (like aliphatic/aromatic with ordered/disordered structures), carbonates, Si-O stretching and structural (OH) stretching bonds from phyllosilicates and matrices. Several amino acids were reported from Mukundpura carbonaceous chondrite (CM2) by [4].

Methodology: Laser Raman Spectroscopy (LRS) is a fast and non-destructive method of spectral analysis, and generally permits significantly better spatial resolution than X-ray diffraction (XRD). Raman spectra were obtained using a Renishaw In-Via Reflex Micro-Raman instrument at GSI, NCEGR Kolkata. The data were obtained using a 514 nm edge Ar⁺ laser (gratings: 2400 lines/mm) and a 785 nm edge diode laser (gratings: 1200 lines/mm), having ~ 0.84 – 1.2 μm spot beam diameter and focus energy varies from 12 – 15 mW to acquire the Raman signal. Accumulations time of Raman spectra lasted for 10 – 100 s. A charge coupled device (CCD) detector is attached with an automated confocal microscope (Leica made) having objective lenses of 5X (N.A = 0.12), 20X (N.A = 0.40), 50X (N.A = 0.75) and 100X (N.A = 0.85; N.A – Numerical Aperture). The room temperature was maintained at 22 ± 1°C. The peak positions of Raman spectra were determined by the Wire program (Version 3.4). The spectral resolution for each Raman vibrational mode is on the order of ± 1-2 cm⁻¹. The Thermo-Nicolet iS10 Fourier Transformed InfraRed (FTIR) Spectrometer is a research grade FTIR instrument with transmission and attenuated total reflectance (ATR) accessories located at GSI, NCEGR Bangalore. The detector used is deuterated triglycine sulfate KBr (DTGS-KBr) detector and the source is Mid infrared Ever-Glo (Silicon carbide). The source voltage is 10.6V and 1.4A respec-

tively. The Beam splitter is KBr with mid infrared range. Smart OMNI-Transmission accessory is used for collection and absorption of spectrum. The data spacing is 1.929 cm⁻¹ with a resolution of 4 cm⁻¹. The optical velocity is chosen 0.6329 cm s⁻¹ and the collection range is from wave number 400 to 4000. The experiments are performed after collection of proper background. The infrared beam from the source passes through an interferometer. This interferometer performs an optical inverse of Fourier transform on the IR radiation. Infrared spectroscopy using KBr pellet is one of the reliable analytical technique for the quantitative and qualitative analysis of various geological samples but unlike LRS its a destructive method. Small amount (mg) of meteorite sample (0.60 g) was mixed with 0.25 to 0.50 g (approx) spatula of KBr in an agate mortar. Sufficient amount of sample was poured to cover bottom of pellet dice, and pressure was applied using hydraulic press at ~5000-10000 psi. The pressed disc shaped sample pellet (mixed with KBr pellet) was removed carefully from dice, and placed in the FTIR sample holder prior to the analysis. The pressed sample disc was nearly transparent.

Results: Raman spectra were acquired from matrix, chondrules and clasts. The Raman spectral data of olivine with known molar fractions (⁰¹X_{Mg}) were obtained based on the doublet peak positions (819-823 cm⁻¹ peak and 843-858 cm⁻¹ peak), corresponding to its compositional variation. In the matrix part, the peak positions of the two first order Raman bands, namely D and G bands were observed to vary from 1302-1334 cm⁻¹ and 1578-1597 cm⁻¹ respectively. These wide D and G bands might correspond to a highly disordered carbonaceous material likely to be present in the matrix. Aggregates of irregular shaped carbonate (CaCO₃) grains are present within the matrix, confirmed by Raman spectroscopy having characteristic peak positions of 152 cm⁻¹, 280 cm⁻¹, 713 cm⁻¹ and 1088 cm⁻¹ (Figure 1). Most importantly it also contains water-bearing mineral phases (phyllosilicates like serpentine and tochilinite) which is the direct evidence of presence of water (OH) molecule in the solar system [1, 5].

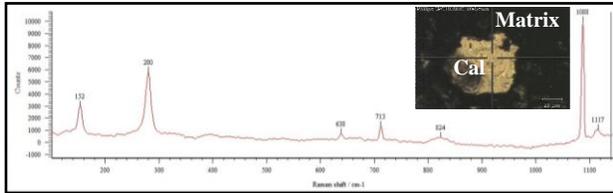


Figure 1: Aggregates of carbonate (CaCO_3) grains from matrix

The data obtained from FTIR and Laser Raman micro-spectroscopic studies of the Mukundpura carbonaceous chondrite suggest that it belongs to carbonate-rich assemblage (Figure 2), where highly disordered carbonaceous organic component is observed. The results of FTIR analysis show that part of the organic material present in Mukundpura carbonaceous chondrite (CM2) is aliphatic in nature. The aliphatic hydrocarbon peaks are confirmed between $2800\text{--}3000\text{ cm}^{-1}$ (part of a spectral range in Figure 2). The peak values at 2851 cm^{-1} , 2922 cm^{-1} and 2960 cm^{-1} may be correlated to stretching symmetric CH_2 band (aliphatic hydrocarbon). Moreover, Si-O stretching and structural (OH) stretching from phyllosilicates have been observed in Figure 3. Peak observed at 1621 cm^{-1} may represent aromatic/alkene. The 1438 cm^{-1} peak ($\text{C}=\text{C}$ stretching) may represent carbonate / aromatic component in the matrix [6].

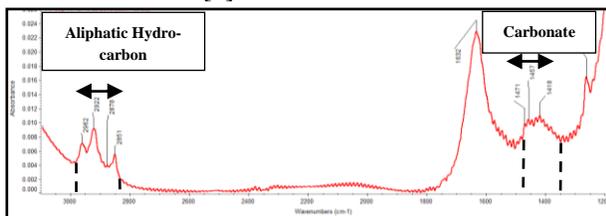


Figure 2: The FTIR spectrum between $1200\text{--}3000\text{ cm}^{-1}$ indicates the presence of carbonate and aliphatic hydrocarbon peaks in Mukundpura carbonaceous chondrite

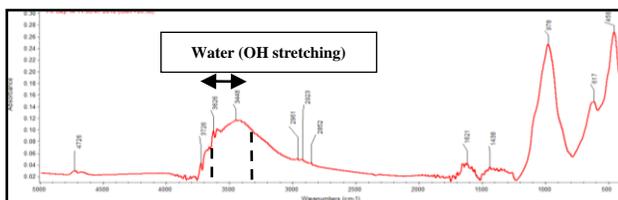


Figure 3: FTIR spectrum of Mukundpura carbonaceous chondrite showing 978 cm^{-1} peak related to Si-O stretching. Water molecule (OH) stretching and structural OH stretching (phyllosilicate) observed in between $3448\text{--}3626\text{ cm}^{-1}$.

The LRS approach shows that there is also highly disordered organic material, which is mostly abundant in the matrix component. The comparison of aliphatic hydrocarbon FTIR data observed in Mukundpura car-

bonaceous chondrite (CM2), with the Tagish Lake meteorite (C2-ung) and Murchison (CM2) carbonaceous chondrite are significantly different [7, 8], and probably suggest distinct astrochemical process (es) or different celestial sources.

Discussion: Raman spectroscopy studies indicate the occurrence of disordered carbonaceous components in matrix. Fourier Transform InfraRed (FTIR) spectroscopic studies of the Mukundpura carbonaceous chondrite (CM2) show presence of highly disordered aliphatic carbonaceous component, carbonates, suspected alkene, Si-O stretching and structural (OH) stretching from phyllosilicates (serpentine-tochilinite). Evidences of parent body aqueous alteration are well documented in this meteorite [1, 4, 5]. Thus, it is believed that the Mukundpura carbonaceous chondrite (CM2) contains the most pristine primordial carbonaceous matter recovered from space that might carry important clues about the origin of life as it also contains structural (OH) molecules.

References: [1] *GSI CHQ e-News Volume 48*, 1, January – June 2017, 3-5. [2] Ray D. and Shukla A.D. (2018) *Planetary and Space Science* 151, 149–154. [3] Tripathi R. P et al. (2018) *Current Science* 114 (1), 214-217 [4] Rudraswami N.G. et al. (2018) *Geoscience Frontiers* 30, 1-10. [5] Dutta A et al. (2020) *51st LPSC (Abstract # 1927)* [6] Salisbury J. W et al. (1992) *Infrared (2.1-25 m) spectra of minerals* (The Johns Hopkins University) [7] Matrajt et al. (2004) *Astronomy & Astrophysics (A&A)* 416(3), 983-990, [8] Fuchs et al. (1973) *Smithson. Contrib. Earth Sci.* 10, 1-39.