"III Congreso Latinoamericano de Astrobiología (2021)"
Revista Mexicana de Astronomía y Astrofísica Serie de Conferencias (RMxAC), **55**, 74–76 (2023)

https://doi.org/10.22201/ia.14052059p.2023.55.20

APPLICATION OF RAMAN SPECTROSCOPY IN THE IDENTIFICATION OF CARBONACEOUS MATERIALS IN THE CARBONACEOUS CHONDRITE ALLENDE

T. P. Donato[1], B. L. Nascimento-Dias[2], and M. E. Zucolotto[1]

RESUMEN

Las condritas carbonáceas son meteoritos que atraen un gran interés científico, porque son objetos que tienen una gran cantidad de material orgánico, como hidrocarburos en sus estructuras. El objetivo principal de este trabajo es identificar la presencia de materiales de carbono en el meteorito Allende (condrita carbonácea). Para eso, se utilizará la técnica de espectroscopia Raman como metodología de investigación. Entre las formas de detectar compuestos orgánicos, las bandas D y G presentes en los espectros Raman son medios para obtener este tipo de información. Estas bandas pueden aportar datos sobre la disposición cristalina, así como caracterizar el grado de evolución estructural y determinar el grado de grafiteación de un material carbonoso. Por último, la espectroscopía Raman es una técnica con gran potencial, ya que es práctica, rápida y puede ayudar en el estudio en la identificación de materiales de carbono.

ABSTRACT

Carbonaceous chondrites are meteorites that attract great scientific interest, as they are objects that have a large amount of organic material, such as hydrocarbons in their structures. The main objective of this work is to identify the presence of carbonaceous materials in the Allende meteorite (carbonaceous chondrite). For this, the Raman spectroscopy technique will be used as a research methodology. Among the ways to detect organic compounds, the D and G bands present in Raman spectra are ways to obtain this type of information. These bands can contribute with data on the crystal arrangement, as well as characterize the degree of structural evolution and determine the degree of graphitization of a carbonaceous material. Finally, Raman spectroscopy is a practical and fast technique with a lot of potential that can help in the study of the identification of carbonaceous materials.

Key Words: carbonaceous chondrites

1. INTRODUCTION

Carbonaceous chondrite meteorites are important scientific objects to be studied, as they carry in their compositions the history behind the formation of the planetary system and possibly the chemistry of the origin of life. They have in their constitution the presence of minerals such as olivine and pyroxene, metallic iron-nickel, volatile and carbonaceous elements (2 % to 5 %) (Elsila et al. 2016).

These carbonaceous elements are important for understanding the synthesis of organic matter. And through their crystal morphologies, the degree of thermal metamorphism to which these meteorites were subjected during their formation can be understood (Bonal et al. 2006). In order to identify these elements, laboratory and analytical techniques are used, such as Raman Spectroscopy (Nascimento-Dias et al., 2021).

Therefore, this work searches for carbonaceous elements in the Carbonaceous Chondrite Allende meteorite, through spectral analysis made using Raman spectroscopy.

2. METHODOLOGY

2.1. *Allende*

In 1969, more than 2 tons of the Allende meteorite fell near the city of Pueblito, in the state of Chihuahua, Mexico, and since then it has been one of the largest specimens in its class and one of the most studied (Clarke et al. 1971). According to The Meteoritical Society, this celestial object is a chondrite of the CV3 group, characterized by large chondrules, many of which are surrounded by igneous edges, large refractory inclusions and an abundant matrix (40 vol%). The V represents the standard meteorite called Vigarano, while petrological type 3 refers to the high number of chondrules, low degree

[1]National Museum - Federal University of Rio de Janeiro, Quinta da Boa Vista - São Cristóvão, Rio de Janeiro - RJ, 20940-040, Brasil (tatiane18.tpd@gmail.com).
[2]Federal University of Juiz de Fora (bruno.astrobio@gmail.com).

III Latin American Congress of Astrobiology (3CLA)(Virtual-Modality, August 3-6, 2021)
Editors: Leticia Carigi, Sandra I. Ramírez Jiménez, Miguel Chávez Dagostino, and Millarca Valenzuela - DOI: https://doi.org/10.22201/ia.14052059p.2023.55.20

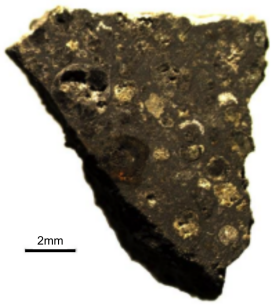

Fig. 1. Allende Meteorite Fragment.
Source: Nascimento-Dias, 2018.

of aqueous alteration and unbalanced mineral associations.

In this work, a fragment of the Allende meteorite (Figure 1) was used, acquired from the National Museum of Rio de Janeiro, through Dr. Maria Elizabeth Zucolotto, and it was preferentially chosen because it is a carbonaceous chondrite.

2.2. *Raman Spectroscopy*

In addition to being fast and non-invasive, Raman spectroscopy has a high spatial resolution, making it possible to obtain information about the molecular vibration mode of any organic or inorganic material, as long as the molecule is polarizable (Nasdala, 2004). This technique provides sample data by determining the energy levels of atomic and molecular systems by wavelength (Raman and Krishnan, 1928).

The Raman spectra were obtained using Confocal SENTERRA BRUKER from the Federal University of Juiz de Fora (UFJF). The instrument is equipped with a thermoelectrically cooled CCD (ANDOR DU420-OE) with a spectral resolution of 4 cm^{-1} in the range 100-4000 cm^{-1} (50 $\times$ 1000 micrometer gap) and continuous automatic calibration (theoretical accuracy 0.1 cm^{-1}). The analyzes were performed with a 100X objective in the Raman microscope and a standardized 632.8 nm laser, with Si chip at 5 mW, was used for excitation. Raman spectra were processed with Origin 9.5 software. Peaks were fitted using Lorentzian functions.

3. RESULTS AND DISCUSSION

Raman spectroscopy is very sensitive to the degree of structural order of polyaromatic organic matter. The typical Raman spectrum of such material exhibits several characteristic bands of these compounds, among which the D and G bands stand out, which provide information on the internal crystallographic structure of the meteorite, and it can also

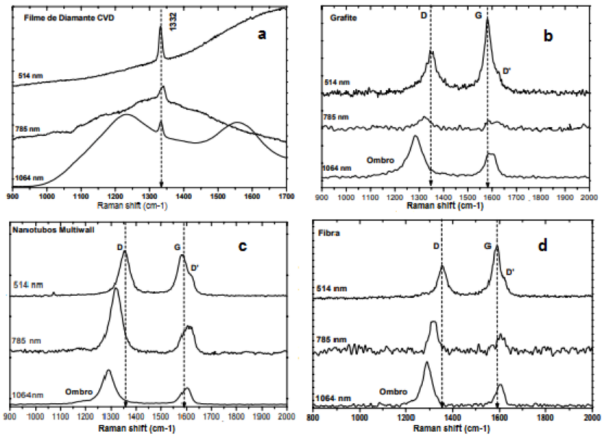

Fig. 2. Graphics of D and G band materials composed of carbonaceous elements: a) Diamond film; b) Graphite; c) Carbon nanotubes; d) Carbon fiber.
Source: Image modified from Lobo et al, (2005):

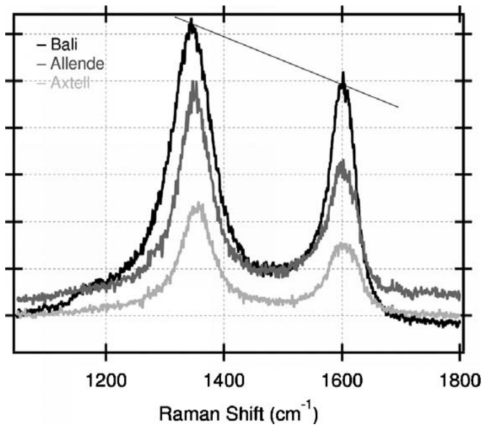

Fig. 3. Graphics with D and G bands in meteorites.
Source: Image modified from Bonal et al.(2006).

characterize the degree of structural evolution and determine the graphitization of the carbonaceous material (Silva-Pereira, 2015).

According to Lobo et al (2005), D and G band patterns appear in materials composed of carbonaceous elements that were analyzed in their work, using the Raman technique, such as Diamond, graphite, nanotube and carbon fibers tapes (Figure 2) . In addition to terrestrial samples, Bonal et al (2006) analyzed meteorites using the same approach, which also showed similar patterns of D and G bands, indicating the presence of carbon in their samples (Figure 3).

When analyzing three different points in the sample of the Allende meteorite, these bands appeared in the results. The G band of Graphite represents the vibrational modes of aromatic planes, which

III Latin American Congress of Astrobiology (3CLA)(Virtual-Modality, August 3-6, 2021)
Editors: Leticia Carigi, Sandra I. Ramírez Jiménez, Miguel Chávez Dagostino, and Millarca Valenzuela - DOI: https://doi.org/10.22201/ia.14052059p.2023.55.20

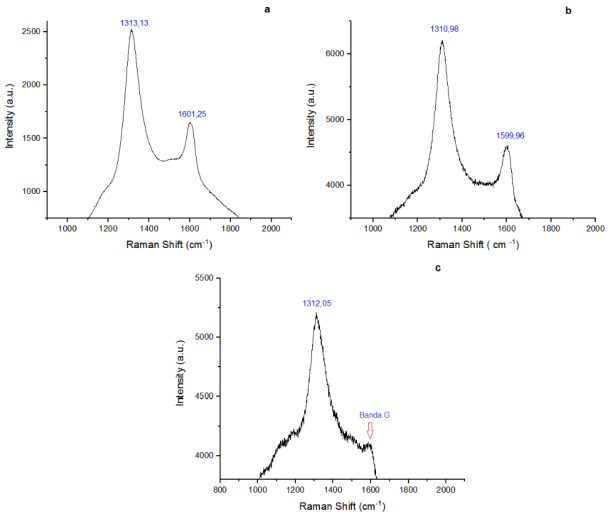

Fig. 4. D and G band in the Allende meteorite. Peak images taken from the collected spectra: All graphs share the same patterns for the D-band.

are present in organic matter, regardless of the degree of structural order of the carbonaceous element, whereas the D band of Defects represents the disorganization of the crystalline system and its deformities (Quirico et al. 2003; Bonal et al. 2006; Silva-Pereira, 2015).

These bands can have peaks ranging from 1200 to 1400 cm^{-1} in the D band (XD) and from 1500 to 1600 cm^{-1} in the G band (XG) (Lobo et al., 2005). When analyzing the sample data in Figure 4, the same behavior was found for the XD and XG peaks in graphs a and b, but in the c spectrum, it was noted that the XG peak presented a differentiated shape, which may indicate a change in the crystal structure of the carbonaceous elements in this particular spectrum, which may be amorphous in character. Therefore, the investigation about this differentiation must be continued.

4. CONCLUSION

Based on the results obtained, it was possible to observe the presence of peaks in the D and G bands, through Raman spectroscopy, showing that it is a fast, non-destructive and effective technique in the analysis of carbonaceous chondrite meteorites, since Allende is an extraterrestrial body of very heterogeneous composition.

Therefore, it is expected that this article can contribute in some way to those who are interested in working with carbonaceous chondrites and who look for information on the identification of carbonaceous elements through an alternative technique, that can help to relate them to essential elements that make up biotic chemistry, such as hydrocarbons and polycyclic aromatic rings.

Acknowledgments: T.P.D thanks M.E.Z., B.L.N.D and the Museo Nacional UFRJ for the opportunity of this study. Also to Gláucia Martini, for the help with the translation of this article into english.

REFERENCES

Bonal, E., Quirico, L., Bourot-Denise, M., & Montagnac, G. 2006, Geochim. Cosmochim. Acta, 70, 1849
Clarke, R. S. Jr., Jarosewich, E., Mason, B., et al. 1971, Smithsonian Contributions to the Earth Sciences, 5, 1
Elsila, J. E., et al. 2016, ACS Central Science, 2, 370.
Lobo, A. O., Martin, A. O., Antunes, E. F., Trava-Airoldi, V. J. & Corat, E. J. 2005, RBAV, Brasil, 24, 98
Nascimento-Dias, B. L. 2018, RBFTA, 5, 27
Nascimento-Dias, B. L., Donato, T. P., Zucolotto, M. E., & Anjos, V. 2021, JRS, 52, 1
Nasdala, L., Smith, D. C., Kaindl, R., & Ziemann, M. A. 2004, Raman spectroscopy: Analytical perspectives in mineralogical research, Spectroscopic methods in mineralogy, Anton Beran, Eugen Libowitzky
Quirico, E., Raynal, P. I., Bourot-Denise, M. 2003, MPS, 38, 795
Raman, C. V. & Krishnan, K. S. 1928, Natur, 121, 501
Silva-Pereira, J. M. 2015, Tese, PUC-Rio de Janeiro