

LIBS POTENTIAL FOR CARBON DETECTION IN DIFFERENT METEORITE GROUPS (CHONDRITES AND ACHONDRITES). G. S. Senesi¹, P. Manzari², B. Marangoni³, G. Nicolodelli³, O. De Pascale¹, ¹CNR - Istituto di Nanotecnologia (NANOTEC) - PLasMI Lab, Via Amendola 122/D, 70126 Bari, Italy, giorgio.senesi@cnr.it, ²Space Italian Agency-Rome, Italy, paola.manzari@asi.it, ³Instituto de Física, Universidade Federal de Mato Grosso do Sul (UFMS), Campo Grande – MS, Brasil.

Introduction: The type of carbon bearing minerals in meteorites depends on their group, and includes carbonates in martian meteorites and chondrites to carbides and graphite/diamond in presolar grains in chondrites and organic matter in carbonaceous chondrites. These minerals imply important constraints on the history of their parent bodies, thus the detection and spatial localization of carbon in meteorites are very important. The detection and quantification of not combined carbon are usually performed by either destructive techniques including Total Organic Carbon and Inductively Coupled Plasma Mass Spectrometry or by techniques implying sample preparation, such as Scanning Electron Microscopy using Au to coat the sample surface, whereas vibrational spectroscopies such as Infrared and Raman are generally used to analyse carbon compounds.

In this study, preliminary results are reported on the use of Laser-Induced Breakdown Spectroscopy (LIBS) for the qualitative and quantitative analysis of meteorite samples of very diverse nature and origin. In particular, carbon minerals have been identified and discriminated with minimal sample loss and in air and the content of inorganic and organic carbon has been measured by atomic spectral lines C(I) and molecular bands C2 (Swan) and CN [1-6]. Differently from other techniques, LIBS is able to detect both elemental and combined carbon even at ppm levels on the whole fragment or petrographic thin section of a meteorite.

Samples and methods: A carbon bearing pig-iron sample, which is an intermediate product of the iron industry and the basic ingredient before further processing to produce the desired grades of steel, originated from an industrial source was used as a standard and compared with two ordinary chondrites (H3 and L3 types) and one eucrite Northwest Africa 4051 found in Algeria for their carbon content.

The LIBS system used consisted of a Nd:YAG laser (Quanta-Ray, Spectra Physics) operating at a wavelength of 1064 nm. The IR pulse was generated at a maximum energy of 100 mJ and a width of 10 ns. A Stellarnet spectrometer system in the non-gated mode was used to detect and select only the wavelengths in the spectral range from 190 to 300 nm with a resolution of 0.2 nm. The temporal parameters used in this experiment were optimized for the best LIBS signal, i.e., the delay time was 500 ns and the gate time 1 ms.

A total of 10 measurements were performed on the samples by exploring the sample surface at different positions and accumulating 2 shots at each of them and obtaining one spectrum for each shot.

Results and Discussion: Although LIBS analysis of atomic C has generally considered the two emission lines of C at 193.03 and at 247.86 nm, the meteorite samples studied are rich in Fe, which prevents a correct identification and subsequent C quantification by the C line at 247.86 nm without a proper correction to eliminate or reduce the Fe interference (mainly the Fe line at 247.94 nm). Differently, the C line at 193.03 nm is not interfered by other elemental emission lines and can be spectrally resolved by LIBS.

Figure 1 shows the LIBS emission spectra of the C line at 193.03 nm in the pig iron sample (black line), the eucrite Northwest Africa 4051 (red line), the Chondrite L3 (blue line), the Chondrite H3 bulk sample (purple line) and its thin petrographic section (green line).

As expected, the highest intensity of the carbon peak is shown by the pig iron sample due to its carbon content of about 4.9wt%, which is followed by eucrite Northwest Africa 4051 and then by the chondrites. Although the presence of carbon in type 3 Ordinary Chondrites could be ascribed to terrestrial contamination, these meteorites can host carbon in different phases, i.e. as graphitized carbon, amorphous carbon, carbon combined in terrestrial carbonates and/or as indigenous hydrocarbons, kerogen-like materials and other complex organic molecules [7]. However, the chondrite samples examined show less carbon in the spots analyzed with respect to eucrite that should have a lower (tens of ppm) carbon content present in amorphous or graphitic phases or as CO/CO₂ dissolved in silicate minerals [8].

Conclusions: Results of this preliminary investigation have shown the potential of LIBS in revealing significant differences in spectral emission line of C in chondrite and achondrite meteorites in comparison to a pig iron sample. These differences would result from the specificity of meteorites analysed and the post-ablation evolution of the concerned plasma plume. The interconnection between ablation and emission events generated from each sample appears able to characterize and differentiate them from other materials with a highly similar chemical composition.

As the LIBS technique appears able to detect down to ppm of carbon and does not require any sample manipulation or preparation, it is worth conducting further analyses on additional samples, validated with other standard techniques, to identify the carbon bearing phase and draw calibration curves for each meteorite group. Further, an important added value of LIBS is the potential use of miniaturized field-portable instrumentations to be used directly in situ for a reliable, rapid, repetitive and sequential measurement of carbon in a large number of samples on large areas.

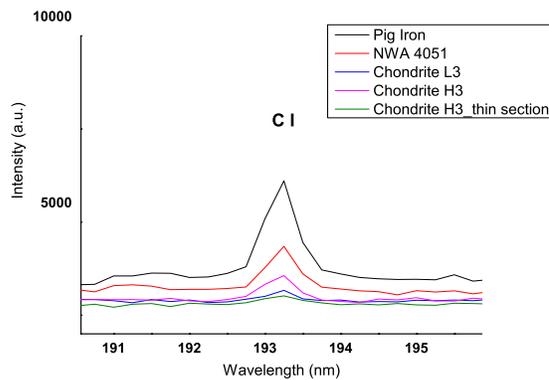


Figure 1 - The C line at 193.03 nm in LIBS spectra of pig iron (black line), eucrite Northwest Africa (NWA) 4051 (red line), Chondrite L3 (blue line), Chondrite H3 bulk sample (purple line), and its thin petrographic section (green line).

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