Paris meteorite analysis by cluster SIMS imaging and micro-PIXE

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Keywords : Paris-meteorite, Cluster-SIMS-imaging, surface analysis, micro PIXE, RBS

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The study of early solar nebula processes relies on the primitive witnesses of our solar system formation, which are the primitive dust and meteorites. In this context we introduce a new approach elemental and structural analysis by ToF- (mass spectrometry coupled to imaging). The study is performed on the Paris meteorite (a CM chondrite). The interest of this meteorite is that it belongs to the family of undifferentiated chondrites which keep the memory of their primordial history.
We analyzed an area of of a fragment of this meteorite, provided by the Museum d'Histoire Naturelle (France), using a bismuth beam (25 keV and 1.3 pA) delivered by an ION-TOF V CNRSL LAEC. The mass spectrometry coupled to imaging mode allows the identification of components and their location at the same time. To avoid any problem of pollution and contamination during the sample manipulation we performed, before the experiments, a surface cleaning by bismuth beam sputtering.

The imaging results show that some elements are abundant and evenly distributed such as oxygen and sodium, others are abundant and localized like calcium, magnesium, sulfur, silicon, iron, chlorine, potassium, aluminum and cyanide. There are also minor components such as fluorine and cyanate, and traces localized or not such as phosphorus oxides, chromium, nickel, manganese, boron, copper, cobalt and organic compounds. A close analysis of ionic images allows the detection of several components. A correlation is found between the calcium and OH- ion surface distribution. The calcium ions and their oxides and hydroxides form the calcium family Ca^+, $CaOH^+$, Ca_2O^+, $(CaO)_2^+$, $(CaO)_2H^+$, $(CaO)_3H^+$, $(CaO)_4H^+$ proving the lithophile characteristic of the calcium. On the other hand, the distribution of sulfur ions and their oxides (S^-, SO^-, SO_2^-, SO_3^-, SO_4^-) overlap with the calcium region which explains the presence of calcium sulfate. A difference in positive and negative emission of silicon ions and their compounds is observed: three main areas are detected, the first for Si^+ and $SiHO^+$, the second with Si^-, and the third corresponding to the silicates ions. This difference of emission may be due to the presence of silicon in various compounds and environments. Besides these compounds, we have identified a chondrule (a structure commonly observed in this class of meteorites, formed by rapid heating at high temperatures of a solid precursor followed by cooling) embedded in a silicate and iron matrix. This chondrule is characterized by a major presence of magnesium, which probably agglomerates (Mg^+ and Mg_2^+) around the silicon (Si^-). In areas of co-existence of "Mg-Si-O" elements, we find the compound $MgSiO^+$.
In addition to the minerals, two types of organic ions with two different locations are detected. The first type is C_xH_y with several compounds $C_mH_nO_2N$ located outside the chondrule, these

ions are correlated with iron and in anti-correlation with oxygen. The second type consists of cyanides and cyanates.
In this presentation, I will discuss the first results of the Paris meteorite studied by ToF-SIMS, and its coupling with the elemental analysis by PIXE (Particle Induced X- -
PIXE and RBS (Rutherford Bakscattering Spectrometry) with the complementarity and the limitations of these methods.

The work has benefited from government aid administered by the National Agency for Research under the program for future investments (Projet ANR-10-EQPX-23). The LAEC authors thank the IAEA (LEB/11018 LEB 2007 01) for support.