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Developments of single particle analysis by TOF-ICP-MS for study of nanosize matrix phases in primitive meteorites

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Matrix minerals in primitive chondrites have been shown to be a very complex assemblage of solids having different origins (presolar and interstellar, solar condensates, fragments of chondrules and Ca-, Al-rich inclusions) and histories (nebular and parent body alteration, metamorphism). Because of the small size of matrix minerals (nm to µm size), studies of the matrix have combined in situ techniques (e.g. TEM, NanoSIMS, ...) with semi-bulk (considering the nm size of many matrix components) techniques (MEB, X-ray mapping, Raman spectroscopy, ...).

Here we report on developments made using the time-of-flight ICP-MS Vitesse (Nu instruments) at IPGP to get a statistical analysis, for a given meteorite, of the chemical composition (and mineralogy) of tens of thousands of individual matrix minerals in the size range ≈ 50-500 nm (named in the following NP for nanoparticles), in order to advance our understanding of the origin of the various matrix phases.

We used the procedure previously reported [1] to get the elemental composition (Na, Mg, Al, Si, K, Ca, Ti, Cr, Mn, Fe) of individual NPs. However, one difficulty is the absence of certified standard of nanosize mineral grains. Thus, we developed a set of minerals (olivine, feldspath, corundum, kaolinite) grounded to nanometer size grains that were analyzed together with a set of nanosize grains made from international reference glasses. These analyses allow us to improve the limitations of the technique (thresholds, detection levels, and statistics for the various elements). As a first test, thousands of NPs extracted (without grinding) from the matrix of the Allende chondrite were characterized. The results first show that various components can be identified in the matrix (fayalitic olivine, metal, sulfides, various oxides, ...) in agreement with previous studies of Allende. In addition, their compositional range, size distribution and statistical abundances were determined.

[1] Tharaud M., Schlatt L., Shaw P., Benedetti M. F. (2022) Nanoparticle identification using single particle ICP-ToF-MS acquisition coupled to cluster analysis. From engineered to natural nanoparticles. *J. Anal.At. Spectrom.* 37, 2042-2052.