Oral presentation

Combined 3D ED and nanotexture analysis for the study of meteorites and meteoritic impacts.

Gemmi, M.[1], Parlanti, P.[1], Mugnaioli, E.[2], Campanale, F.[2,3] , Folco L. [2], Giuli G.[4], Pratesi G.[5], and Veron M.[6]

[1]*Electron Crystallography, Istituto Italiano di Tecnologia, Pontedera, Italy,* [2]*Dipartimento di Scienze della Terra, Università di Pisa, Pisa, Italy,* [3]*Dipartimento di Scienze dell'Ambiente e Della Terra, Università degli Studi di Milano-Bicocca, Milan, Italy,* [4]*Università di Camerino, sez. Geologia, Camerino*, *Italy,* [5]*Università di Firenze, MEMA, Firenze*, *Italy,* [6] *Université Grenoble Alpes, CNRS, Grenoble INP, SIMaP, Grenoble, France.*

mauro.gemmi@iit

A lot of meteorites and rocks transformed by meteorite impacts exhibit a crystalline texture that goes well beyond the usual limit for standard analysis in an SEM. For the study of these textures and the determination of the crystalline phases present in the sample, a technique with a spatial resolution in the nanometer range is required. At the same time the sample should be studied avoiding its destruction and retaining the spatial relation between the crystalline phases. We present here some analyses on meteorites and impactites which are carried out by combining 3D electron diffraction (3D ED) for crystalline phase determination [1] and texture and phase analysis using a scanning diffraction method known as PACOM (Precession Assisted Crystal Orientation Mapping) [2], both on FIB thin sections.

We applied this methodology to three sets of samples: impactite ejecta belonging to the Australasian tektite/microtektite strewn field, a piece of the Alfianello L6 ordinary chondrite and Fe-Ni oxide spherules generated by the impactor which created the Kamil crater (Egypt)

In the case of the Australasian ejecta 3D ED allowed the structure determination of the TIO2-II high pressure polymorph, which is a Zr-free srilankite endmember. The texture analysis indicates that TiO2-II nucleates inside well-ordered rutile grains which retain a topotactic relation with the embedded TiO2-II, suggesting a partial transformation of rutile due to P-T wave during the impact [3].

In the case of the Alfianello L6 ordinary chondrite we identified on a FIB lamella a nanocrystalline domains formed by coexisting nanograins of ringwoodite and wadsleyite [4]. The two high pressure phases of olivine were unambiguously identified by 3D ED and their structures solved ab-initio. The two phases show a systematic difference in the Fe/Mg ratio which is higher as expected in the rigwoodite grains. Full texture analysis at the nanoscale has been performed.

In the case of the spherulites from Kamil crater we discovered a quite complex scenario in which a matrix of Fe-Ni oxides grains exhibiting fine exsolutions of two different phases is permeated by a Si rich fluid which remains as an amorphous interstitial component. PACOM and HREM imaging revealed that the two exsolved Fe-Ni oxide phases have a trevorite (the Fe-rich component) and a bunsenite (the Ni-rich component) structure and that they form micrometric grains inside which they are coherent. The amorphous interstitial part is formed by two components: SiO_x amorphous droplets and a silicic component rich in Fe and P. This second component has been found both in an amorphous and in a crystalline form. Now and then, in fact, 3D ED detects the presence of olivine with a P content as high as 3%-4%at in these interstitial veins. The full crystallochemical characterization at the nanoscale seems to suggest a formation model in which the Ni-Fe-P melt from the meteorite oxidizes and mixes with the melted quartzite from the target. The oxidized Fe and Ni crystallize in Fe-Ni oxides micrometric grains which, upon cooling, exsolve the two abovementioned phases. The remaining Fe together with P enriches the silicic melt, which forms a glass that fills the interstitial void.

The combination of 3D ED with PACOM allows at the same time the discovery of new crystal phases present in micrometric planetary materials and to obtain a global crystallochemical view, which is essential for understanding the thermal history of the sample. Based on this information it is possible to build a formation model of the retrieved sample and to speculate on its origin. We envisage a crucial application of this methodology to any kind of planetary material coming from sample return missions.

[1] Gemmi M et al. (2019) ACS Cent. Sci. 5:1315-1329.

[2] Viladot D. et al. (2013) Journal of Microscopy 252:23-34.

[3] Campanale F et al. (2024) Meteoritics & Planetary Science 59: 529-543

[4] Carone L., De Santis V., Pittarello L., Pratesi G., Gemmi M., Parlanti P., Steiger-Thirsfeld A., Di Michele A., Giuli G. (2024) Congresso Nazionale SISP 2024 Bormio Italy