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INNER SOLAR SYSTEM IRRADIATION HISTORY OF MINERALS IN AN ULTRACARBONACEOUS ANTARCTIC MICROMETEORITE (UCAMM).

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Introduction: Ultracarbonaceous Antarctic Micrometeorites (UCAMMs) are interplanetary dust particles containing large amounts of N-rich polyaromatic organic matter exhibiting large D enrichments, with heterogeneous distributions of both D/H and ¹⁵N/¹⁴N isotopic ratios [1-8]. UCAMMs most probably originate from the outer regions of the protoplanetary disk, i.e. the cometary reservoir [2, 4, 5]. At least three kinds of organic matter have been identified in UCAMMs, with different nitrogen abundances and highly variable concentrations of small (typically 30-500 nanometer) minerals embedded in the organic matter [8-11]. The formation process(es) of the different kinds of organic matter found in UCAMMs and the origin of their mixing with minerals are still a matter of debate. We focus here on a mineral assemblage embedded in one UCAMM (DC06-04-43) in which we have found evidence of irradiation.

Results and discussion: A 100 nm-thick FIB section was made at IEMN Lille from a fragment of UCAMM DC06-04-43. This section was examined by STXM-XANES followed by transmission electron microscopy (TEM) [11]. The mineralogy of this UCAMM is dominated by a crystalline assemblage consisting of μ m-sized Mg-rich pyroxenes, Fe sulfides, Mg-rich olivines, and Fe-Ni metal. GEMS are embedded in the organic matter, close to the crystalline assemblage. We identified irradiation features (rims and tracks) in some crystalline pyroxenes. The rims' thicknesses range from 20 to 100 nm (average 60 ± 20 nm, 1σ) and irradiation track lengths from 15 nm to $\sim 1 \mu$ m (average 175 ± 110 nm, 1σ). The average track density is $1.72 \times 10^{10} \text{ cm}^{-2}$ (772 tracks over $4.2 \times 10^6 \text{ nm}^2$).

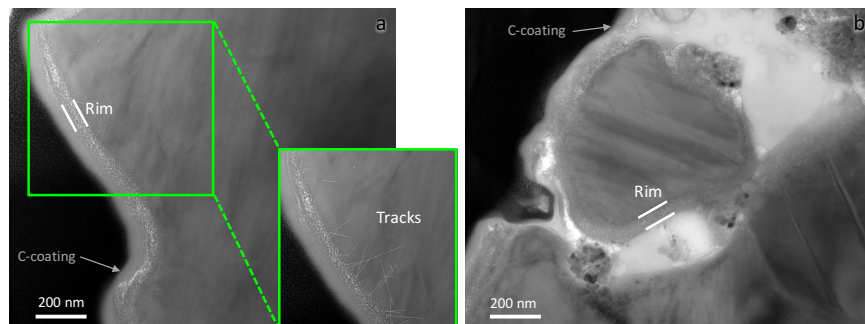


Figure: a) TEM micrograph of a pyroxene showing both irradiation rim and tracks. The tracks are highlighted in the bottom-right inset. b) irradiation rim observed around another pyroxene mineral, including on the side in contact with the organic matter. a & b: the smooth grey layer in contact with the platinum (in black) is a carbon coating applied to the sample for initial investigation by scanning electron microscopy before FIB-sectioning.

SRIM calculations [12] indicate that the observed average rim thickness corresponds to irradiation of the pyroxene by ions with energies ranging from 1 to 10 keV/nucleon, whereas the track lengths are compatible with an irradiation by Solar energetic particles (SEP). The irradiation damages of these minerals are compatible with irradiation in the inner solar system (solar wind and SEP). The average track density corresponds to a few hundred thousand years exposure in space, using the current track production rate at 1 AU determined by Berger & Keller [13]. This exposure time may have been shorter considering early irradiation by the more active young Sun. The observation of irradiation rims in minerals embedded in the organic matter implies an irradiation of these minerals before transport to the outer regions of the protoplanetary disk and later incorporation in the UCAMM parent body. In the scenario where the N-rich organic matter is formed by irradiation of ices by Galactic cosmic rays [4, 14], these minerals would be shielded from irradiation (e.g. buried in ice) in the parent body. The fact that crystalline minerals are usually found in association with low-N organic matter suggests that the low-N and N-rich organic matters in UCAMMs formed in different locations, and/or over different timescales.

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