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SOLAR WIND IMPLANTATION EFFECTS IN THE LUNAR REGOLITH

J. P. Bibring, M. Maurette, R. Meunier, Centre de Spectrométrie de Masse du CNRS - 91 Orsay.
L. Durieu, C. Jouret, Institut d'Optique Electronique du CNRS - 31 Toulouse.
O. Eugster, Physikalishes Institut, Universitat Bern - Bern.

Ultra-thin coatings have been observed by high voltage electron microscopy, on micron-sized grains extracted from various dust samples returned to the Earth by the Apollo 11, 12, 14, 15 and Luna 16 missions. The coated grains are markedly rounded and they are generally loaded with very high densities of tracks, or they contain high concentrations of very small crystallites. Selected area electron diffraction combined to thermal annealing and chemical etching experiments, indicate that the coatings are radiation damaged layers. Artificial implantations with low energy ($0.2 \lesssim E \lesssim 5$ keV/amu) helium, neon, argon, krypton and xenon ions, strongly support the hypothesis that these layers result from an " ancient " solar wind implantation in the grains, as they reproduce the rounded habits and the superficial coatings observed in the natural dust grains.

Although the artificial coatings represent a complex dynamic balance between the lost and the formation of amorphous material, their thicknesses roughly vary as $E^{0.5}$ and do not depend on the atomic number of the ions, when E is expressed in keV/amu. Therefore it is possible to study the thermal properties of the ancient solar wind by analysing the distribution of the coating thicknesses in dust samples collected at various " young " and " old " locations in the lunar regolith, particularly in well stratified core tubes. A preliminary survey of such a distribution, based on 130 different " counts ", suggests that the average energy of solar wind ions stays approximatively constant over periods of about 100 to 1000 years. This distribution also reveals a surprising high frequency of periods dominated by the " apparent " emission of low energy ($0.2 \lesssim E \lesssim 1$ keV/amu) ions, and a steep decrease in the frequency of the high energy periods ($E > 1$ keV/amu), when the solar wind energy increases (figure 1).

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The albedo of soil samples from all missions was studied as a function of several characteristics of their finest grains (400 Mesh residues), which most likely cover the coarser ones, and therefore should dominate the optical properties of the regolith. The albedo of the samples was found to be strongly correlated to their proportions in coated grains, but not to their glass contents or to their concentrations in strongly absorbing ions. Furthermore the computed reflecting power of a simple multielectric structure, constitued of a semi-infinite slab of crystalline matter with an index of refraction n_1, coated with a metamictized layer of index $n_2 < n_1$, and thickness $\Delta \sim 350$ A°, qualitatively reproduces the spectral variation of lunar albedo, characterized by an increase in albedo at short and long wavelengths (figure 2). Furthermore, a very slight chemical etching of the dust grains, that only removes their ultra-thin coatings, considerably increases the albedo of sample 10084 and modify its spectral variations. Therefore the albedo of lunar soil samples certainly depends on their irradiation history in the solar wind, and is perhaps slightly " modulated " either by metamorphic events occuring subsequently in the regolith and modifying the optical properties of the coated grains, or by the mineralogical composition of the Lunar dust, as shown by the beautiful Apollo 15 X-Ray fluorescence experiment (1).

The ultra-thin coatings, considered as " markers " for the thermal properties of the ancient solar wind, have various other implications concerning for example : elemental and isotopic abundances in the solar corona, the origin of indigenous lunar carbone and methane (2), the nature and time constant of various lunar dynamic processes and ancient lunar atmospheres (3).

References

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FIGURE 1

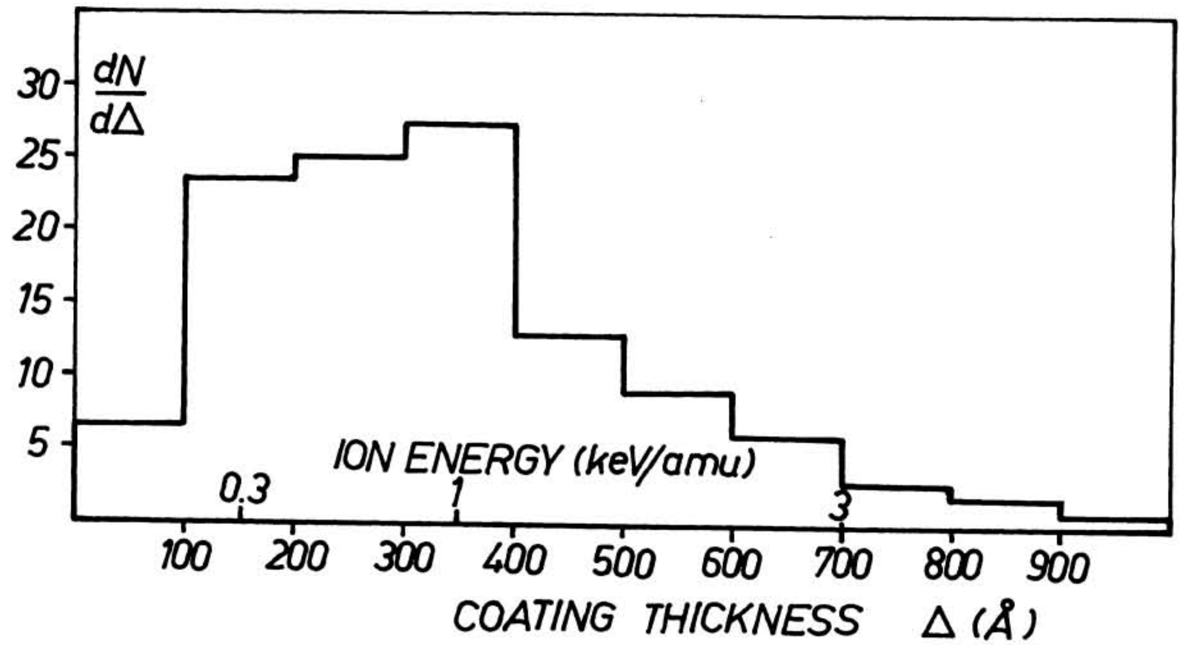

FIGURE 2