SOLAR WIND IMPLANTATION SYNTHESIS. J-P. Bibring and F. Rocard,
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It is well known that mature lunar fines release a rich variety of organic compounds upon etching, pyrolysis or ionic bombardment, the origin of which is the Solar Wind (SW) irradiation of the lunar surface (1). However, the nature of the compounds directly synthesized by the SW implantation has not been determined yet, because of the chemical influence of the release processes themselves. In order to characterize the SW implantation chemistry, with implications both in planetology and in astrophysics, we have performed in situ IR spectroscopy measurements of i) lunar sample 10084 and ii) SiO_2 grains and thin films implanted with H and C ions.

EXPERIMENTALS: Controlled thin (< 3000 Å) SiO_2 films were prepared by vacuum deposition of SiO_2 vapor, produced with an electron gun device, onto nitrocellulose substrates. These substrates were then removed by pyrolysis (200°C, 1 hr). Both these films and micron-sized SiO_2 grains were implanted with various ions : H^+, D^+ at fluences up to 5.10^{17} cm^{-2} ; $^{12}C^+$, $^{13}C^+$, up to 5.10^{16} cm^{-2}; energies 1 to 3 keV/amu. The samples were then observed with a Perkin Elmer 283 IR spectrometer. In order to improve the sensitivity, the signals were digitalized and processed by a LeCroy M 3500 MCA, which enables to detect absorptions down to 10^{-4}, by accumulation of repetitive spectra. Grains samples (terrestrial and lunar) were prepared using the standard KBr micropellet technique.

RESULTS FOR IMPLANTED SiO_2: A) The implantation of ^{12}C (or ^{13}C) ions in SiO_2 induces the synthesis of $^{12}CO_2$ and ^{12}CO (or $^{13}CO_2$ and ^{13}CO), as shown in fig.1. Both the CO_2 and CO bands differ from the corresponding gaseous features, in two ways: i) instead of the usual P-R double structure, they appear as single bands, showing no rotational structure (fig.2); ii) they are slightly shifted towards smaller wavenumbers, by $\sim$ 10 cm^{-1} (CO_2) and $\sim$ 20 cm^{-1} (CO). B) Whenever the ^{12}C (or ^{13}C) implantation is followed by that of H ions, the spectra show a very significant decrease of the CO band intensity, whereas the CO_2 remains unchanged. This behaviour does not happen when i) He is implanted instead of H, or ii) H is implanted first, and the ^{12}C (^{13}C) next (fig.3). It demonstrates that the implanted H reacts chemically with the synthesized CO. Likely products are CH_4, HCO and H_2CO.

SW SYNTHESIS OF CO_2 IN LUNAR FINES: We have searched for CO_2 in lunar sample 10084, known to constitute a mature soil sample (heavily irradiated by the SW), by IR spectroscopy in the 2400 - 2300 cm^{-1} region, where the main CO_2 vibration band is located (fig. 4b). For comparison, fig. 4a represents the spectrum of SiO_2 grains, implanted with ^{12}C ions. It exhibits the implanted CO_2 band, superimposed on the double P-R structure corresponding to some residual gaseous CO_2 in the spectrometer. Thus, the band in fig. 4b under the arrow is interpreted as CO_2 synthesized by the Solar Wind. With the same sensitivity, no CO band appear in the 2200-2000 cm^{-1} region; this can be understood by the results of the C + H implantation into SiO_2 grains.

IMPLICATIONS IN PLANETOLOGY AND ASTROPHYSICS: the IR spectroscopy of lunar samples and artificially irradiated grains characterizes the implantation chemical effects expected to play a major role in many astrophysical problems (2). For example, they may account for the composition of the tenuous lunar atmosphere, the zodiacal cloud, the synthesis of molecules in circumstellar shells and interstellar clouds. UV, visual and IR unidentified features might

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be explained by the excitation of molecules blocked within implanted grains. Implantation of icy grains might also result in the synthesis of complex molecules; implications for organic chemistry within icy planetary bodies (cometary nuclei, outer planets satellites...) should be further explored.

REFERENCES

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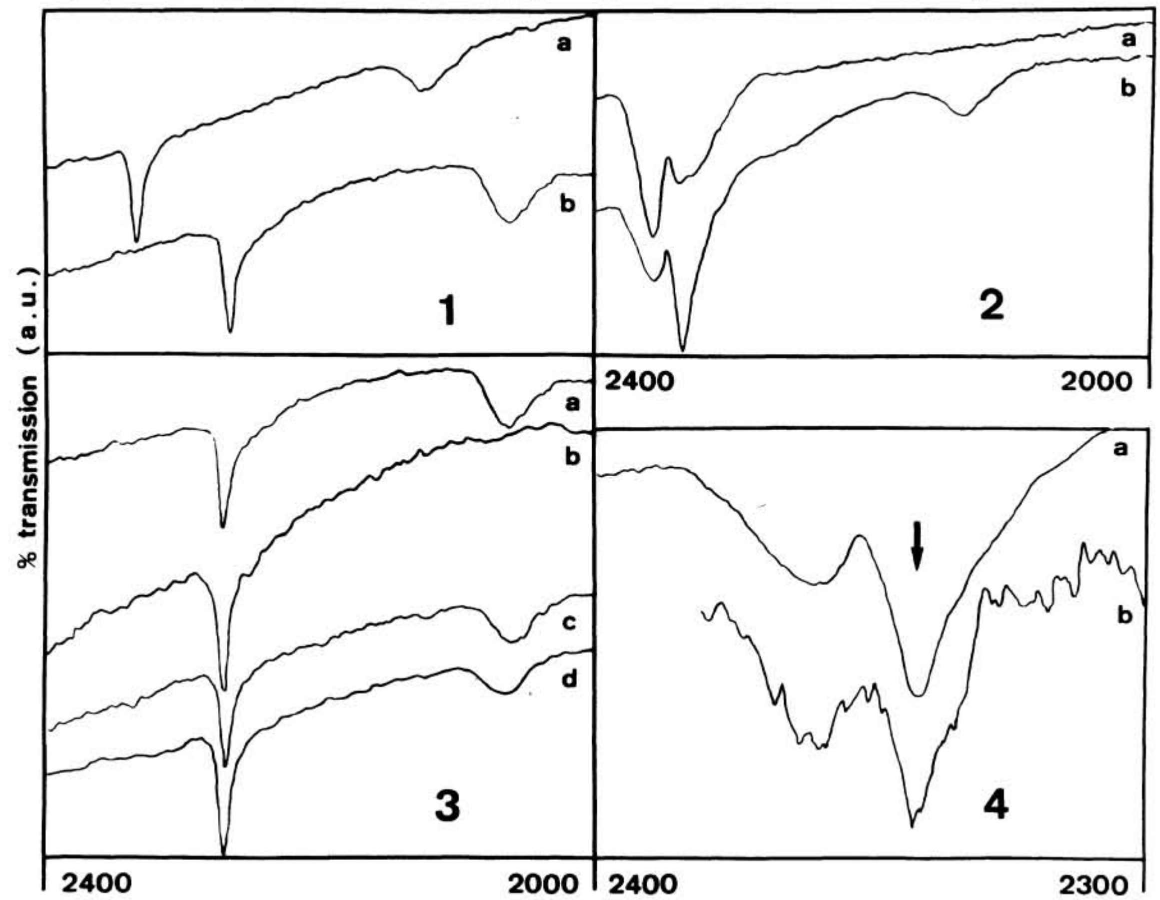

FIGURE CAPTIONS

fig. 1: 2400 - 2000 cm^{-1} spectra of SiO_2 thin films implanted with 5.10^{16} cm^{-2} ^{12}C ions (fig. 1a) and ^{13}C ions (fig. 1b), in a N_2-purged spectrometer. The implanted $^{12}CO_2$ and ^{12}CO appear as single bands, located at ∿ 2340 cm^{-1} and ∿ 2130 cm^{-1} respectively, whereas $^{13}CO_2$ and ^{13}CO are located ∿ 50 cm^{-1} towards smaller wavenumbers.

fig. 2: 2400 - 2000 cm^{-1} spectra of SiO_2 thin films (a) unirradiated and (b) implanted with 5.10^{16} cm^{-2} ^{12}C ions. Spectrum (a) exhibits the usual P-R double structure corresponding to some residual gaseous CO_2 in the spectrometer. In fig. 2b, the single band which is the signature of implanted $^{12}CO_2$ appears superimposed on this P-R structure.

fig. 3: 2400 - 2000 cm^{-1} spectra of SiO_2 thin films implanted with: (a) ^{13}C; (b) ^{13}C + H; (c) H + ^{13}C and (d) ^{13}C + He.

fig. 4: 2400 - 2300 cm^{-1} spectra of (a) SiO_2 grains implanted with ^{12}C and (b) lunar sample 10084 grains, imbedded in KBr pellets. The arrow indicates the position of implantation-induced CO_2, superimposed on some residual CO_2.

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