HYDROGEN, CARBON AND TEFLON ON THE SURFACES OF LUNAR SAMPLES

Many of the unusual characteristics exhibited by the surfaces of lunar samples arise because of their long exposure to low energy from the particles solar wind and to the products of micrometeorite impact. In our research program we have tried to single out particular aspects of solar wind and impact generated processes that can be studied by both measurements of elemental abundances, particularly H and C, in the outer micron of lunar samples and also by controlled simulation experiments (1,2). In this abstract we shall touch briefly on several examples of these measurements.

F: Because fluorine is a negligible constituent of the solar wind, surface enhancements of F would demonstrate the existence of deposition processes involving volcanic vapors and impact generated volatiles interacting with the surfaces of lunar materials. Our previous studies of F concentrations, using a resonant nuclear reaction technique, have been complicated by the presence of Teflon or Freon contaminants that arose in the collecting, transportation and handling of the samples (2). Large surface peaks (200-2500 ppm in the outer 0.2µm) were observed in all of the chips and fines measured previously (2). Between 0.2 and 1 micron the F concentration is usually constant, although at levels that are consistently higher than other bulk analyses of rocks and soils. (See for example, 3). The first terrestrial substance to touch the vast majority of lunar samples was a Teflon bag. Therefore, we have sought special samples with very different handling with respect to Teflon exposure. (Unfortunately, one must also take into account the liberal use of Freon in all phases of lunar sample handling).

Three chips from rock 76215 were probed: 76215,19 was a projecting knob which was most subject to abrasive contact with the Teflon bag in which the sample was returned; 76215,33 was a crystal-lined vug which has been shielded from the bag. As shown in Fig.1, the knob displays over a factor of 10 higher F concentration at all depths than the vug interior, though the shapes of the profiles are similar. Another chip, 76215,32, part of the inner wall of a vug showed a small surface peak (150 ppm) with ~20 ppm at 1µm depth. The large excess on the surface of 76215 is probably the result of the contact with the Teflon bag. Fluorine deposited from the lunar atmosphere should have been present in the vugs as well. (However, if the atmospheric F atoms were travelling on ballistic trajectories, less F would be deposited in the vug.) All 76215 samples were ultrasonically cleaned in methanol; thus, the high F on the knobs is not due to superficially adhering particles. It may be present as a thin film due to outgassing of the Teflon bag onto the sample under lunar vacuum conditions, due to the compression of the bag around the sample during pressurization of the LM, or both. We cannot rule out that the 200 ppm F surface layers on the vug samples are lunar in origin. However, it is also possible that outgassing of the sample bag on the lunar surface created an internal atmosphere which was getterted by the pristine lunar surfaces to 200 ppm F levels.

Samples 15012,63 and 15012,67 are 5 mm, partially glass coated, soil breccia fragments obtained from the stainless steel Sealed Environment Sample Container (SESC) and thus have never been exposed to Teflon. The glassy sides show only a small (~50 ppm) very sharp surface peak (Fig.1). However, the soil
breccia surfaces have sizable (~300 ppm) surface enhancements above the 200 ppm concentration at a 1μm depth. Ultrasonic rinsing in methanol did not remove these peaks in the soil breccia F distributions for 15012,67. Unfortunately, the 15012 results leave the situation still confused. Nevertheless, we think it unreasonable to expect to find two fragments with friable soil breccia surfaces having a lunar F vapor deposit and whose glass-coated surfaces do not have this vapor deposit. It is most likely that there are sources of F contamination other than the obvious Teflon bags. We have handled a large number of terrestrial and meteoritic samples in our laboratory and have never seen the type of F surface peaks found on the lunar samples. The vacuum seal on the 15012 SESC did not hold, thus we may be examining gettered F from the LM cabin atmosphere or from the SESC container while on the lunar surface. It may be significant that about the same F levels (200-300 ppm) were observed on the 15012 fragments, the 76215 vugs, and many other lunar surfaces.

Surface Carbon Measurements: We are using two different nuclear reactions: (1) $^{12}$C($^3$He,$n$)$^{14}$O $\rightarrow ^{14}$O $+ ^{14}$N* $\rightarrow ^{14}$N $+ \gamma$ detecting the 2.31 MeV delayed gamma rays. This method has very low background but is comparatively insensitive. We can, however, set an upper limit of 1000 ppm for the average C concentration in the outer 0.6 micron of sample 76215,33. This is less than would be expected from typical bulk soil C contents (~100 ppm) if all the C is on surfaces of grains, but is roughly a factor of 3 higher than estimated by Hayes, et al. (4) allowing for recycling of carbon into a volume correlated component (e.g. agglutinates). We plan to improve our detection efficiency to measure samples with better sensitivity. (2) $^{13}$C($^3$He,$\alpha$)$^{12}$C, detecting the alpha particles emitted at back angles. In this way, we can probe $^{13}$C depth distributions by measuring the $\alpha$ energy spectrum at a fixed $^3$He beam energy. Even though the $^{13}$C abundance is much lower, the higher cross section for this reaction gives it comparable sensitivity to the $^{12}$C($^3$He,$n$).

H: Our previous measurements of hydrogen distributions in lunar sample surfaces indicated that the trapping of H in radiation damage sites must play a primary role in determining both the H concentration and distribution (2). We are now concentrating on simulation experiments to study the radiation damage and trapping mechanisms in a more quantitative and unambiguous way. A silica glass disc was damaged with $2 \times 10^{16}$ ions/cm² of 84KeV $^{15}$N ions. We are able to quantitatively measure the implantation profile of the $^{15}$N using the sharp resonance of the $^{15}$N(p,$\alpha \gamma$)$^{12}$C reaction at 0.897 MeV. In order to see if the diffusion of H is controlled by the radiation damage gradient, we exposed the implanted disc to boiling H₂O for 5 minutes and found that the resulting H profile is strikingly similar to that for $^{15}$N (Fig.2). This experiment was done as a prelude to measurements with implanted protons. In a similar experiment using $^{16}$O as the damaging ion there was also preferential trapping of H from liquid H₂O at room temperature compared to undamaged samples; however, the H did not penetrate beyond 0.1 microns (2). We have used the $^{16}$O experiment as an argument that the H we observed in lunar samples at depths greater than 0.1 micron is not H₂O contamination. The situation is clearly more complex in that either (a) the reducing environment produced by N implantation permits more rapid H₂O diffusion than that produced by O implantation, or (b) the penetration is much more rapid at 100°C than at room temperature. These possibilities will soon be checked by experiment.
Elemental Sputtering Yields: As an aid to improving our understanding of the surface properties of lunar samples we have begun measurements on the sputtering of terrestrial analogues by low energy charged particles. Since the moon's surface has been highly sputtered by solar wind ions, it may be that many of the unusual surface phenomena arise from this source. In our measurements the sputtered atoms are collected on a carbon foil; the concentrations and distribution of the collected atoms are determined by the back-scattering of a high-energy $^{16}$O beam from the collector foil. Since the $^{16}$O beam is heavier than the $^{12}$C target there is no contribution from the collector material. We were able to clearly resolve the individual elemental constituents when artificial Apollo 11 glass (Corning, 191EKN glass) was sputtered using 100 KeV Ar ions. Preferential sputtering of light elements was observed, and preliminary analysis indicates that the elemental yields are consistent with a sputtering rate that is inversely proportional to the mass of the sputtered atom.

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REFERENCES


FIGURE 1.
F depth profiles. The 15012 profile is for the glassy surface.
FIGURE 2.
Depth profile for 84 KeV $^{15}$N ions implanted in quartz glass (solid curve) H introduced by dipping glass into boiling H$_2$O.
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