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ELECTRICAL PROPERTIES AND WATER IN LUNAR SOIL. G.R. Olhoeft, D.W. Strangway and A.P. Annan Departments of Geology and Physics, University of Toronto, Toronto.

Samples from Apollo 15, 16, and 17 had quite low loss tangents while samples from prior missions had significantly larger loss tangents (1) which we attribute to water contamination.

The effects of water on electrical properties have been discussed by several authors (2,3, and others). We have (4,5) previously shown the large effect of water on soil sample 14163,131. Cadenhead et al (6) and Holmes et al (7) have shown that the specific area of lunar samples has a large irreversible increase by a factor of 2 to 5 when the soil samples are exposed to water vapor. Olhoeft (8) has shown that the electrical properties of a fully outgassed basalt have the character shown in fig. 1. The dielectric constant and loss tangent are not modified until a monolayer of water (in this case 0.008 wt. %) has been added to the sample. More water than this can participate in dielectric response since the next layers are not so tightly bonded. The D.C. resistivity changes however at even lower water contents, since charge transfer can take place in bonded water molecules The large loss tangent for samples from the Apollo 11, 12 and 14 missions may be related to the increase in surface area, but the exact mechanism is unknown.

Lunar soil 15301,38 which has been previously studied (9) without exposure to air, has subsequently been exposed to atmosphere for 30 months and remeasured. Table 1 lists the dielectric constant and loss tangent as a function of frequency at several stages in the sample history at 25°C. Measurement A at 0.025 torr is immediately after dry nitrogen transfer and the beginning of vacuum system pumpdown. Measurement B is after 24 hours at $1 \times 10^{-7}$ torr and after some solar wind gases were lost. Measurement C is after several days at $1 \times 10^{-7}$ Torr or lower and outgasing at 500°C. D is taken immediately upon exposure to air at 1 atm. and E is 19 hours after exposure. In both cases the difference is remarkable.

Measurements F through H are after 30 months exposure to air and on a separate unheated aliquot of 15301 from the same 10 gm. vial (note also the density difference between A-E and F-H). Measurement H is after 24 hours at $10^{-7}$ torr. This shows a 22% increase in dielectric constant and a 33% increase in loss tangent (corrected for density difference) when compared to measurement C. This increase may be due to a chemical surface alteration of the sample such as oxidation or due to the presence of islands of several layers of surface water which can not be removed from the sample except at elevated temperature in vacuum.

These results show several things, 1) the original measurement, C, was on an uncontaminated sample and hence is representative of virgin lunar soil, 2) electrical properties have large irreversible changes when the sample is exposed to moisture contamination, and 3) measurements from missions prior to Apollo 15 (when sample handling procedures were changed to prevent sample contamination) are probably unreliable.

Utilizing information of this type and of the density dependence of

ELECTRICAL PROPERTIES AND WATER IN LUNAR SOIL

Olhoeft, G.R. et al

the dielectric constant and loss tangent, it has been possible to predict the properties of the lunar regolith and the underlying rock as a function of depth (10). This information has been combined with results from the Surface Electrical Properties experiment carried on Apollo 17 to derive a model. To a first approximation the lunar surface layer to a depth of 7 meters has a dielectric constant of 3.8. This implies a surface layer density of 1.8 gm/c.c. It is also considerably higher than the value determined by radar studies. This implies that the low dielectric constant, low density surface layer is very thin perhaps a meter or less. The loss tangent is .008 much like that found in the virgin samples and implies that there is less than a monolayer of water present (.02 wt. %). Beneath this a layer composed largely of rock of dielectric constant 7.5 and loss tangent .035 is present.

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# ELECTRICAL PROPERTIES AND WATER IN LUNAR SOIL

Olhoeft, G.R. et al

## I

DIELECTRIC CONSTANT 25°C

| | 15301,38-1 | | | | | 15301,38-0 | | |
|---|---|---|---|---|---|---|---|---|
| | density 1.67 gm/cm³ | | | | | density 1.38 gm/cm³ | | |
| DATE: | 7/27/72 | 7/28/72 | 8/4/72 | 8/15/72 | 8/16/72 | 1/11/75 | 1/11/75 | 1/12/75 |
| TORR = | 0.025 | 1x10⁻⁷ | 8x10⁻⁸ | air | air | air | 0.020 | 1x10⁻⁷ |
| FREQ (kHz) | A | B | C | D | E | F | G | H |
| 0.010 | - | - | - | - | - | 8.76 | 3.75 | 3.77 |
| 0.020 | - | - | - | - | - | 7.30 | 3.71 | 3.72 |
| 0.050 | - | - | - | - | - | 5.93 | 3.66 | 3.67 |
| 0.10 | 3.35 | - | 3.24 | 3.78 | 6.59 | 5.17 | 3.64 | 3.65 |
| 0.20 | 3.30 | 3.26 | 3.22 | 3.70 | 5.78 | 4.63 | 3.62 | 3.62 |
| 0.50 | 3.30 | 3.30 | 3.21 | 3.60 | 4.73 | 4.15 | 3.60 | 3.60 |
| 1.0 | 3.27 | 3.21 | 3.20 | 3.51 | 4.18 | 3.92 | 3.59 | 3.59 |
| 2.0 | 3.24 | 3.20 | 3.19 | 3.39 | 3.59 | 3.77 | 3.57 | 3.58 |
| 5.0 | 3.26 | 3.19 | 3.18 | 3.28 | 3.57 | 3.69 | 3.58 | 3.57 |
| 10. | 3.26 | 3.18 | 3.18 | 3.23 | 3.40 | 3.62 | 3.55 | 3.56 |
| 20. | 3.25 | 3.18 | 3.17 | 3.21 | 3.31 | 3.57 | 3.55 | 3.56 |
| 50. | 3.24 | 3.19 | 3.17 | 3.20 | 3.25 | 3.58 | 3.55 | 3.56 |
| 100. | 3.25 | 3.18 | 3.17 | 3.20 | 3.23 | 3.63 | - | 3.57 |
| 1000. | - | 3.19 | 3.27 | - | 3.27 | - | - | - |
| | | | after 500°C | | | | | |

## II

LOSS TANGENT 25°C

| | 15301,38-1 | | | | | 15301,38-0 | | |
|---|---|---|---|---|---|---|---|---|
| | density 1.67 gm/cm³ | | | | | density 1.38 gm/cm³ | | |
| DATE: | 7/27/72 | 7/28/72 | 8/4/72 | 8/15/72 | 8/16/72 | 1/11/75 | 1/11/75 | 1/12/75 |
| TORR= | 0.025 | 1x10⁻⁷ | 8x10⁻⁸ | air | air | air | 0.020 | 1x10⁻⁷ |
| FREQ (kHz) | A | B | C | D | E | F | G | H |
| 0.010 | - | - | - | - | - | 1.16 | 0.0327 | 0.0314 |
| 0.020 | - | - | - | - | - | 0.85 | 0.0249 | 0.0260 |
| 0.050 | - | - | - | - | - | 0.58 | 0.0211 | 0.0231 |
| 0.10 | 0.015 | - | 0.010 | 0.073 | 0.592 | 0.437 | 0.0159 | 0.0168 |
| 0.20 | 0.012 | 0.0118 | 0.0078 | 0.052 | 0.477 | 0.331 | 0.0127 | 0.0131 |
| 0.50 | 0.008 | 0.0075 | 0.0071 | [illegible] | 0.344 | 0.213 | 0.0097 | 0.0097 |
| 1.0 | 0.007 | 0.0075 | 0.0059 | [illegible] | 0.232 | 0.153 | 0.0080 | 0.0080 |
| 2.0 | 0.0052 | 0.0042 | 0.0044 | 0.045 | 0.220 | 0.102 | 0.0062 | 0.0066 |
| 5.0 | 0.0045 | [illegible] | 0.0035 | 0.038 | 0.14 | 0.057 | 0.0046 | 0.0051 |
| 10. | 0.0030 | 0.0033 | 0.0033 | [illegible] | 0.062 | 0.036 | 0.0041 | 0.0045 |
| 20. | 0.0020 | 0.0030 | 0.0025 | 0.015 | 0.060 | 0.024 | 0.0034 | 0.0041 |
| 50. | 0.0020 | 0.0018 | 0.0034 | 0.0057 | 0.024 | 0.015 | 0.0009 | 0.0038 |
| 100. | 0.0010 | 0.0009 | 0.0012 | 0.0032 | 0.016 | 0.011 | - | 0.0040 |
| 1000. | - | 0.0008 | 0.0009 | - | 0.007 | - | - | - |

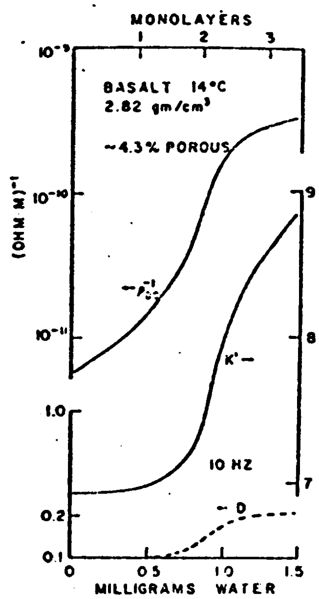


FIG. 1.