The Apollo 15 Lunar Samples,
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Lunar Science Institute, 1972
Houston, Texas

FREQUENCY AND TEMPERATURE DEPENDENCE OF THE ELECTRICAL PROPERTIES OF A SOIL SAMPLE FROM APOLLO 15. G. R. Olhoeft, Lockheed Electronics Co., Houston TX 77058, A. L. Frisillo, NRC/NAS Fellow, MSC, Houston, TX 77058 and D. W. Strangway, MSC, Houston, TX 77058.

The dielectric constant, loss tangent and D.C. conductivity of soil sample 15301,38 have been measured using a three terminal technique in vacuum ($2x10^{-7}$torr) as a function of temperature to 827° C. The sample density was determined to be 1.47±0.06 gm/cc with an estimated porosity of 55%.

The D.C. conductivity data is graphically represented in Figure 1. This figure represents data accumulated as temperature was cycled from room to some maximum (T_{max}) and then back to room temperature. In the subsequent run, T_{max} was increased by approximately 100° C beyond the previous value and data taken as temperature was decreased. This process continued until the largest value of T_{max}=827°C was reached. As may be observed from Figure 1, no hysteresis in the D.C. conductivity was observed as has been reported by other authors using solid samples (Refs. 1 and 2). The activation energy, as calculated from Figure 1, is 0.50±0.08 ev.

Representative dielectric properties are given in Tables 1 and 2 and are illustrated in Figure 2. The dielectric constant at room temperature is nearly frequency-independent with a value of about 3.2. The loss tangent values at room temperature are somewhat frequency-dependent, but, as in earlier studies, they are extremely low (Ref. 3). The dielectric constant and loss tangent increase with temperature and a very distinct frequency dependence appears, suggesting a Maxwell-Wagner relaxation process due to intergranular effects. The dielectric properties show three distinct regions where the properties vary as a function of temperature. These are 25 - 200°C, 200 - 600 or 700°C and over 700°C. At least one of these break points roughly corresponds to the maximum temperature reached during a lunation.

Although no hysteresis was seen in the D.C. conductivity, a definite dielectric hysteresis was observed when the sample temperature exceeded about 700°C. To illustrate the observed hysteresis, the loss tangent (Tan δ) for f = 100 Hz has been plotted as a function of temperature in Figure 3. When $T_{max} \leq 700°C$, Tan δ was easily reproducible within experimental limits during each temperature cycle (middle curve). However, when T_{max} was brought to 827°C, Tan δ returned to a new value (top curve) indicating a hysteresis effect that was reproduced several times. This effect is further illustrated in Figure 4 in which curve A represents the previously observed behavior of Tan δ vs. frequency at T = 25° C ($T_{max} \leq 700°C$) and curve B indicates the new "irreversible" data at T = 25° C (T_{max}=827°C). Curves C and D show the behavior of Tan δ at the two pertinent values of T_{max}.

After completion of the temperature cycles, the sample was then exposed to air and measured at several different times. This data is presented in Figure 5 in which curve A represents Tan δ for $T_{max} \leq 700°C$ and B is for T_{max} = 827°C which was obtained prior to exposure to air. Curve C in this figure is for data recorded immediately after the sample was exposed to air with no time allowed for temperature equilibrium with ambient conditions to be established. Data recorded after 3.5 hours (curve D) shows a tendency toward higher values of Tan δ at all frequencies. After 19.5 hours (curve E), enough moisture has been absorbed by the sample to raise Tan δ by approximately an order of magnitude. These results are consistent with those reported earlier by our laboratory on an Apollo 14 sample (Ref. 3).

Several days after exposing the sample to air, the sample was again placed into the apparatus and allowed to remain in a vacuum of 2×10^{-7} torr for three days. The density of the sample in this run was determined to be 1.63 ± 0.06 gm/cc. The final measurement of Tan δ vs. frequency at 25°C (curve F in Figure 5) does not show the earlier observed hysteresis. In fact, this data seems to indicate that if the remaining moisture was removed from the sample, nearly identical results as those for $T_{max} \leq 700°$ C would be obtained. In this sense, the hysteresis appears to be reversible. Investigations are continuing to resolve the cause of the observed hysteresis.

References:

1. Schwerer, F. C., T. Nagata and R. M. Fisher, Electrical conductivity of lunar surface rocks and chondritic meteorites, The Moon, 2, pp. 408-422, 1971.

2. Schwerer, F. C., G. P. Huffman, R. M. Fisher and T. Nagata, D.C. electrical conductivity of lunar surface rocks with complementary Mossbauer studies, Lunar Science III, Rev. Abst. of papers presented at Third Lunar Science Conference, Houston, 10-13 January, 1972, pp. 686-687, ed. by C. Watkins.

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Table 1

Dielectric Constant

Freq/Temp (°C)	25	330	610	827
10^2	3.24	3.86	21.4	-
10^3	3.20	3.49	7.54	-
10^4	3.18	3.35	4.75	30.2
10^5	3.17	3.29	3.80	10.6
10^6	3.17	-	3.55	4.35

Table 2

Loss Tangent

Freq/Temp (°C)	25	330	610	827
10^2	0.010	0.11	0.69	-
10^3	0.0058	0.046	0.56	-
10^4	0.0033	0.017	0.28	1.1
10^5	0.0032	0.0052	0.12	0.53
10^6	0.001	0. -	0.032	0.24

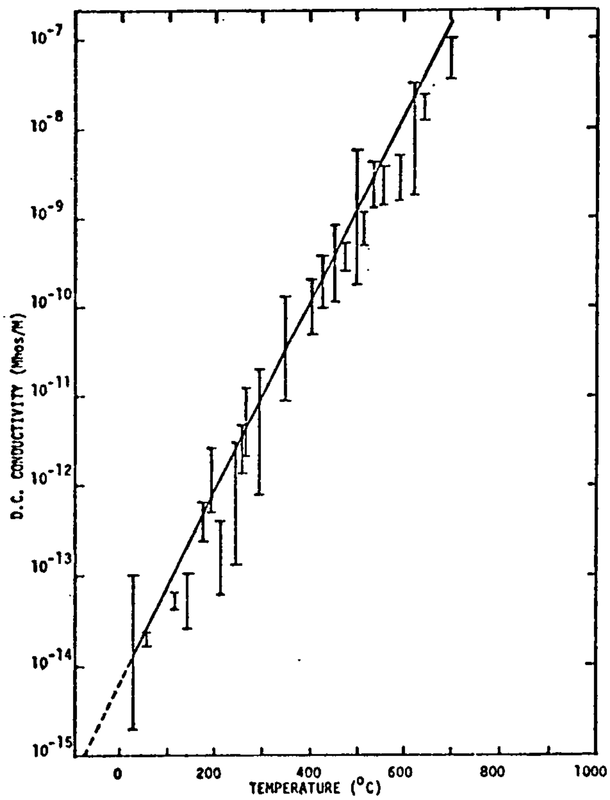


Figure 1: D.C. conductivity as a function of temperature.

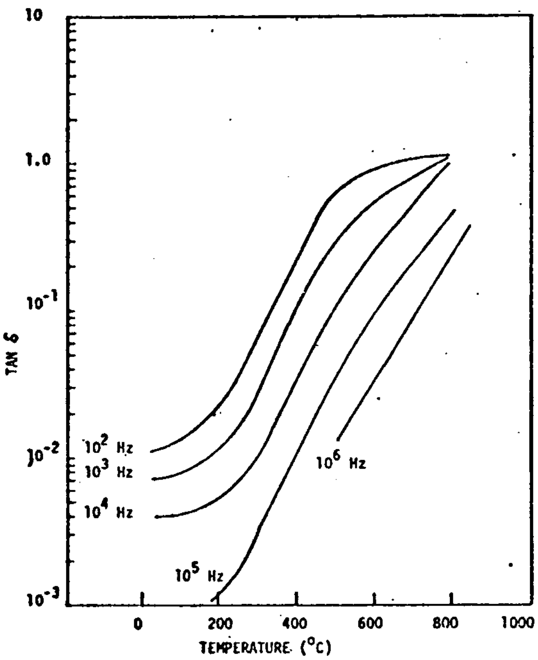
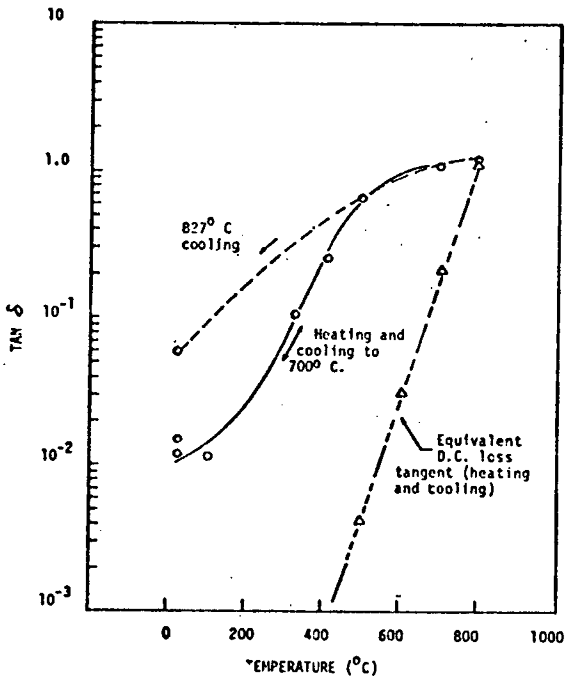


Figure 2: Representative data showing temperature dependence of loss tangent at constant frequency.

Figure 3: Tanδ vs. Temperature for constant frequency, f = 100 Hz.



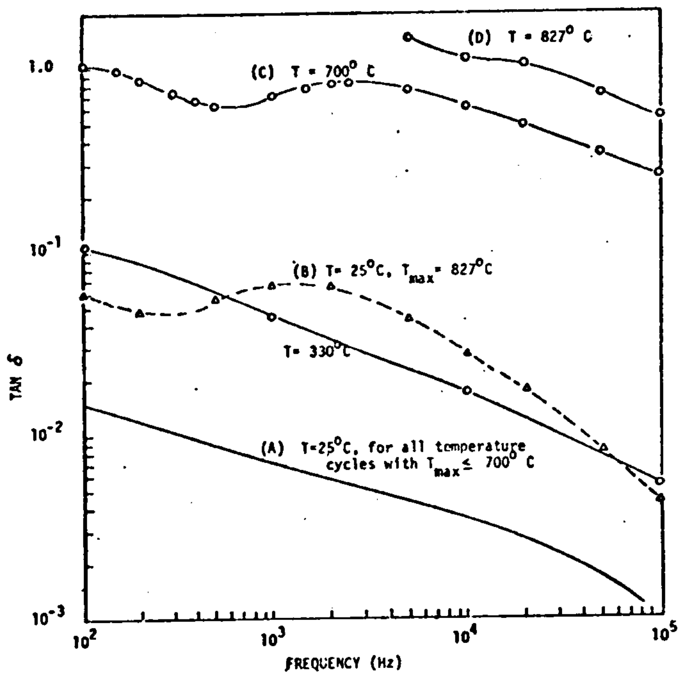


Figure 4: Tanδ vs. frequency for constant temperature showing hysteresis.

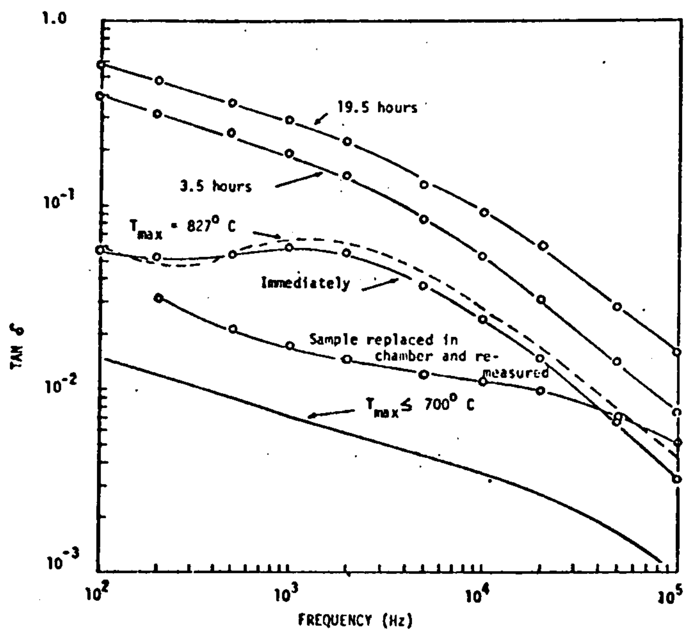


Figure 5: Tanδ vs. frequency at T = 25°C showing effect of exposing sample to air and subsequent data after sample was placed in vacuum for 3 days.