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29 April 1969

Moon: Electrical Properties of the Uppermost Layers

Abstract. *Presently available data on the electrical conductivity of the uppermost lunar surface layers are in accord with the presence of dry, powdered rocks in which the dielectric loss tangent is frequency-independent over several decades of frequency. These powders have typical direct-current conductivity values of about 10^{-13} to 10^{-16} mhos per meter and dielectric constants of about 3.0, depending on the packing. Thus the surface layers of the moon are likely to have an extremely low electrical conductivity. At high frequencies normal dielectric losses lead to much higher apparent conductivities that are frequency-dependent.*

A great amount of data on the electrical and thermal nature of the lunar surface has been collected over the past few decades; microwave and infrared thermal emission data and direct measurements of radar reflectivity have been used to determine the temperature variation during lunations and eclipses. Some of these results have been interpreted by Piddington and Minnett (*1*) and others (*2, 3*). The apparent temperature variation during lunations and eclipses is small at microwave frequencies but quite large at infrared frequencies. This is an indication that thermal energy in the microwave range is derived from a finite thickness of the moon's surface whereas the thermal energy in the infrared range is derived from the surface layer itself.

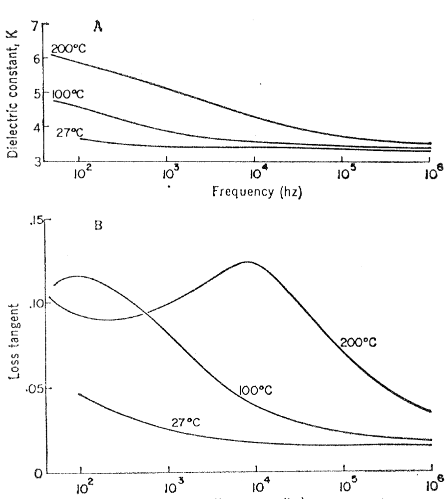

Fig. 1. Data on the dielectric constant (A) and loss tangent (B) of basalt as a function of frequency and temperature.

The dielectric constant ε is known from radar reflections, and the thermal parameter $(k\rho c)^{-\frac{1}{2}}$ (where k is the thermal conductivity, ρ is the density, and c is the specific heat) is known from observations of the surface temperature fluctuation. The magnitude of the thermal parameter has been supplemented by direct observations of the lunar surface made by the Surveyor spacecraft (*4*). The value of $(k\rho c)^{-\frac{1}{2}}$ is still somewhat uncertain, but it appears to be about 500 in the lunar mare and perhaps about 240 to 400 in the vicinity of the crater Tycho where Surveyor 7 landed. This is somewhat less than the values near 1100 ususally predicted from earth-based observations. The decrease in amplitude and the phase lag in the temperature in the microwave region provide information about the variation of thermal and electrical energy with depth.

These observations indicate that the temperature variations at the lunar surface do not extend to a significant depth. If we assume that the surface layer is uniform and that the properties are temperature-independent, it is possible to estimate a value for the penetration depth of the thermal energy in the microwave range. This penetration depth can be simply interpreted in terms of a loss tangent or an apparent electrical conductivity (*3*). Radar reflections indicate that the dielectric constant is about 2.8 (*5*).

Values of the electrical conductivity (*6*), the dielectric constant ε, and the dielectric loss tangent have been determined for a series of powdered samples (*6*). Figure 1 shows a typical example of the dielectric properties of a vacuum-dried, powdered basalt as a function of frequency up to 1 Mhz for a range of temperatures. At low frequencies, both the dielectric constant and the loss tangent increase quite consistently. As the temperature increases, values of the dielectric constant and the loss tangent also increase, an indication that a thermal activation process is involved. This is probably related to a relaxation process centered at frequencies of about 10^{-3} hz. In the basalt sample a second relaxation occurs of the classic Debye type (see *7*).

There is a peak in the loss tangent curve which is thermally activated. This shows up as a step in the corresponding curve of dielectric constants. This relaxation is due to the presence of biotite in the basalt (*6*). At room temperatures and at frequencies of 10^{3} hz or greater, the dielectric constant and the loss tangent both approach a constant value. Additional relaxation peaks may exist at higher frequencies, but, if none do, the dielectric constant approaches a value of 3.5. The exact

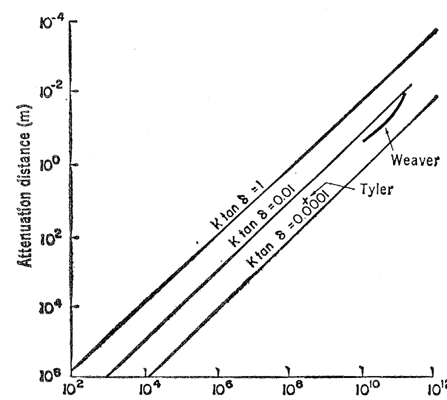

Fig. 2. Theoretical curves for attenuation depth as a function of frequency for constant values of K tan δ. Superimposed values for the lunar surface show that K tan δ is approximately equal to 0.003.

value of the loss tangent varies somewhat from sample to sample but the range we have observed is restricted to values between 0.001 and 0.02. It is somewhat difficult to understand the nature of this frequency-independent loss tangent but it is a well-recognized property of many technical dielectrics and is common in dry materials (*8*). It appears that exceedingly dry, powdered rock samples at frequencies of 10^3 hz or higher are likely to have a loss tangent that is nearly frequency-independent.

We can readily convert the data on loss tangent into an equivalent attenuation distance by noting that skin depth is given by $\sqrt{\sigma\mu\omega/2}$, where σ is the conductivity, μ is the permeability, and ω is the rotational frequency. The conductivity can be replaced by $\varepsilon''\omega$, where ε'' is the imaginary part of the dielectric constant. The loss tangent, tan δ, is given as $\varepsilon''/\varepsilon'$, where ε' is the real part of the dielectric constant. Curves of the attenuation distance as a function of frequency for values of K tan δ, where K is the relative dielectric constant, are given in Fig. 2. The measured samples have values of K tan δ ranging from 0.003 to 0.06 at frequencies up to 1 Mhz.

Direct observations of the lunar surface have been tabulated by Weaver (*9*) for the frequency range from 10 to 75 Ghz. When the attenuation depths are plotted as a function of frequency, they give a close fit to the curve for K tan $\delta = 0.003$. This value is similar to that observed for samples at lower frequencies. Tyler (*10*) used reflections from the communications channel of the Explorer 35 satellite to make an estimate of the loss tangent at 136 Mhz. This gives essentially the same value for K tan δ. The available information on absorption in the lunar surface layers over a frequency range from 136 Mhz to 75 Ghz seems to be consistent with the existence of dry, dielectric materials. There may be some resonance absorption phenomena present but the available data give no indication of this.

If this observation is correct, it implies that the uppermost lunar layer has a loss tangent of about 0.001, a value close to that of dry, powdered natural samples in the laboratory. Many samples of dry, powdered rocks exhibit data like those shown in Fig. 1. The d-c electrical conductivity of these samples at 27°C ranges from 10^{-13} to 10^{-16} mho/m. It seems probable, therefore, that the d-c conductivity of the uppermost layers is exceedingly low. Typical penetration depths that might be expected at other frequencies can be estimated from Fig. 2, although both K and tan δ tend to increase at lower frequencies.

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12 May 1969

Hormonal Stimulation of Lactose Synthetase in Mammary Carcinoma

Abstract. *A transplantable rat mammary carcinoma (R3230AC) synthesizes significant quantities of the mammary gland enzyme lactose synthetase in the immature virgin female rat. In this hormonal environment, mammary glands do not synthesize the enzyme. Prolactin further stimulates the enzyme activity in the tumors to levels found only in mammary glands of rats in late pregnancy or during lactation.*

The enzyme that catalyzes the final rate-limiting step in the biosynthesis of lactose, lactose synthetase (UDP-galactose : D-glucose-1-galactosyltransferase; E.C. 2.4.1.22), has two protein components (*1*). The A protein is a galactosyltransferase which catalyzes the synthesis of *N*-acetyllactosamine from UDP- (uridine diphosphate) galactose and *N*-acetylglucosamine (*2*). The B protein is alpha lactalbumin which behaves as a "specifier protein" and modifies the substrate specificity of the A protein from *N*-acetylglucosamine to glucose, so that lactose synthesis results (*3*). In normal mammary tissue, synthesis of both A and B protein can be stimulated by prolactin (*4*), but during pregnancy placental progesterone inhibits the synthesis of the B protein and thus prevents the synthesis of lactose until parturition (*5*).

Since this complex regulatory mechanism is integrated with the overall differentiation process in mammary tissue, it is pertinent to determine whether mammary carcinoma tissue is sufficiently differentiated to synthesize lactose synthetase and utilize this hormonal regulatory system. We now show that appreciable A and B protein activities are present in rat mammary carcinoma tissue and, furthermore, that the levels of A and B activity are stimulated by prolactin.

A spontaneous transplantable rat mammary adenocarcinoma (R3230AC) has been carried in vivo in this laboratory for 18 months in intact virgin female Fisher rats. Perphenazine (5 mg/kg), a potent stimulus for pituitary prolactin release (*6*), or ovine prolactin itself (1 mg per day) was given to groups of tumor-bearing virgin female Fisher rats. They were killed at various times after hormone treatment, and the inguinal mammary glands and tumors were removed for assay of A and B protein activities by a radioactivity method (see *2*).

Table 1 presents the A and B protein activities in immature rat mammary glands, before and after four consecutive days of perphenazine administration, and in adult lactating glands. The low enzyme activities in the unstimulated