D.C. ELECTRICAL CONDUCTIVITY OF LUNAR SURFACE ROCKS

F. C. SCHWERER, G. P. HUFFMAN, and R. M. FISHER
U.S. Steel Research Center, Monroeville, Pa., U.S.A.

and

TAKESI NAGATA
Geophysics Research Laboratory, University of Tokyo, Japan

Electrical conductivities, $\sigma(T)$, of several samples of lunar surface rocks returned by Apollo 11 and 12 missions have been measured from 300 K to 1100 K. Details of these studies have been reported by Nagata *et al.*, 1971; and Schwerer *et al.*, 1971 and only salient features are reviewed here. Samples approximately $6 \times 6 \times 2$ mm (current along short dimension) were cut from a coarse-grained crystalline rock (10024,22), a fine-grained rock (12053,47) and a microbreccia or fragmental rock (10048,55). Conductivities measured during primary heating cycles are represented in Figure 1 by heavy solid lines. Data are shown explicitly only for 10024,22; however, the scatter of these data about the line is representative of that found for other samples. Analytically, the lines in Figure 1 are described by two or three exponential terms of the form $\sigma(T) = \sum_i \sigma_i^0 \exp(-E_i/kT)$ with conductivity prefactors and activation energies listed in Table I. This form for $\sigma(T)$ is expected for thermally-activated ionic or electronic conduction processes; however, the type and source of charge carriers have not been definitely identified.

Several experimental difficulties must be emphasized with respect to these data. One difficulty is illustrated in Figure 1 by the difference in conductivity measured for two samples from 12053,47. A plausible explanation is that in these studies the dimensions of the samples are such that a few large grains of a high-conductivity phase may dominate the observations. For example, specimen thickness is not much greater than the dimensions of some of the mineral phases present.

A second experimental difficulty concerns large changes in the conductivity which are observed after heating to temperatures above approximately 500 °C. This thermal hysteresis was observed in all samples studied which included samples heated in vacuum (10^{-6} T) and in Ar, He and He–2% H_2 atmospheres and for samples heated alone in quartz capsules as well as in the conductivity holder and furnace. This hysteresis is illustrated in Figure 2 by the conductivity for a sample from 12053,47 during successive heating cycles to progressively higher maximum temperatures. The reason for this hysteresis is not known although several supplementary studies have provided addition information about the changes which occur. Magnetic measurements at 23 °C and from 5 K to 90 K for a sample from 10048,55 show that during heating to 800 °C, a large fraction of the fine-particle native irons disappeared and that some redistribution of iron occurred in the pyroxene and, possibly ilmenite,

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TABLE I

Conductivity prefactors σ_i^0 and activation energies E_i for lunar surface rocks

Sample	$\sigma_i^0(\Omega\ \text{cm})^{-1}$	E_i(eV)
10024, 22	7.9×10^{-2}	0.51
	3.1×10^{4}	1.25
10048, 55	8.2×10^{-5}	0.35
	1.96×10^{-3}	0.48
	2.6×10^{14}	3.2
12053, 47 (1)	8.5×10^{-2}	0.59
	5.3×10^{3}	2.3
12053, 47 (3)	1.53×10^{-6}	0.17
	3.13×10^{-2}	0.55
	1.4×10^{5}	1.6

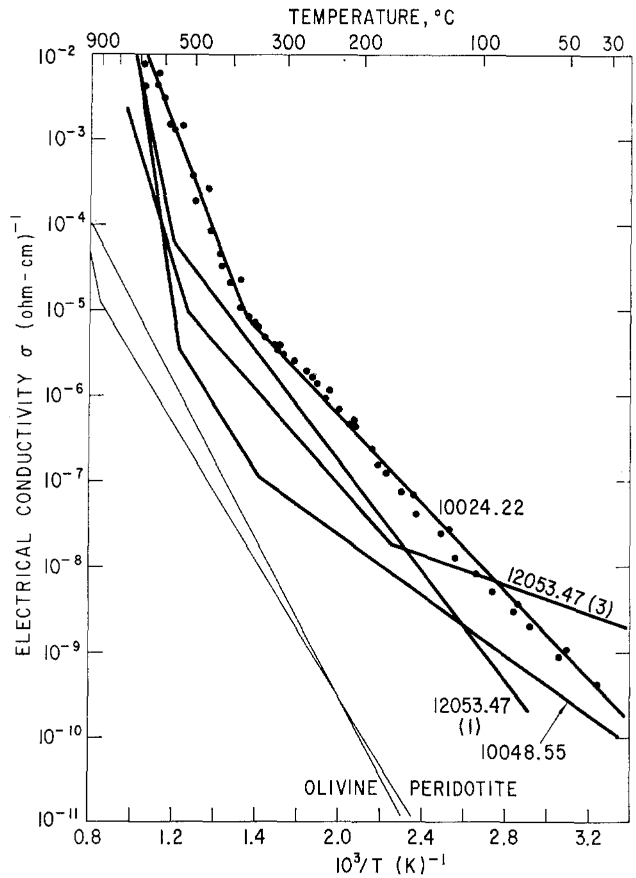

Fig. 1. Electrical conductivities of lunar surface rocks. Data for terrestrial olivine and peridotite from England *et al.* (1968).

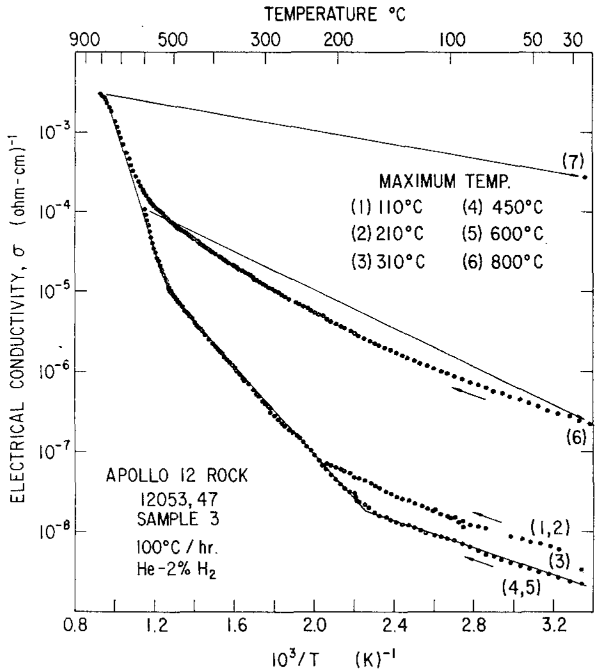

Fig. 2. Electrical conductivity of sample (3) from Apollo lunar rock 12053, 47 during successive runs (1 through 6) to progressively higher maximum temperatures. Only the initial value is shown for run 3. Point 7 shows the final conductivity value at room temperature.

phases. Preliminary Mössbauer studies at room and liquid nitrogen temperatures of samples from 12053, 47 show no large changes during heating. A slight, and expected (cf Hafner and Virgo, 1970), redistribution of Fe among cation sites occurs in the pyroxenes, and the formation of an extremely small amount of wustite (FeO) is indicated. Further Mössbauer studies of these samples at temperatures below 2 K in small applied magnetic fields are in progress. Visual examination reveals darkened zones in the samples after heating. Electron microprobe observations are in progress and it is expected that the source of this thermal hysteresis in the conductivity measurements will soon be known.

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