D.C. ELECTRICAL CONDUCTIVITY OF LUNAR SURFACE ROCKS WITH COMPLIMENTARY MOSSBAUER STUDIES, F. C. Schwerer, G.P. Huffman, R.M.Fisher, U.S. Steel Research Center, Monroeville, Pa. 15146, and T. Nagata, University of Tokyo, Japan.

Measurements of electrical conductivity of samples from 10024, 10048 and 12053 at temperatures from 30°C to 800°C have been reported (1). These data indicate that complex changes occur during heating; in particular, the conductivity at 30°C, $\sigma(0)$, increases by several orders of magnitude after heating above 500°C in vacuum or in Ar, He, or He-2% H_2 atmospheres--effects of oxidizing atmospheres had not been studied. Recent data for terrestrial augite show that heating at 250°C in reducing environments increases $\sigma(0)$; whereas, subsequent heating in oxidizing atmospheres decreases $\sigma(0)$ to its original value. A lunar conductivity sample (12053), previously heated to 800°C in He-2% H_2, was heated to 500°C in air and $\sigma(0)$ decreased by four orders of magnitude, returning almost to its original value. Subsequent heating at 800°C in air increased $\sigma(0)$, probably indicating secondary oxidation effects. Consequently, it appears that part of the reported hysteresis in $\sigma(0)$ is due to high-conductivity surface layers formed under reducing conditions. Detailed studies of atmosphere effects and separation of bulk and surface contributions to the conductivity are in progress.

Mössbauer spectra were obtained at 300K, 78K and 4.2K for 12053 and 10048 in the virgin state and after high temperature conductivity runs. For both samples, heat treatment caused broadening of the pyroxene peaks and transfer of ~2-3% of the Fe from M2 to M1 sites. For 12053, ilmenite peaks were unaffected by heating; however, in a heated sample of 10048 ilmenite peaks were increased in intensity by ~30% relative to an unheated sample. Since spectra were taken for different specimens from 10048, these differences may be due to sampling errors; however, in view of conductivity and magnetic data (1), this increase is probably a real effect.

Mössbauer studies have been made of Apollo 14 samples including samples to be used in conductivity studies (see table). Salient features are (i) 14053 has unusually high metallic Fe and FeS content and contains a previously unreported magnetically-ordered phase, possibly a spinel, (ii) 14063 has high olivine content, (iii) 14047 and 14259 (fines) exhibit a broad paramagnetic peak near 1.35 mm/sec, possibly from a glassy phase, (iv) Apollo 14 samples in general are more heterogeneous than Apollo 11 and 12 samples.

Spectra were obtained at 2 K for samples in magnetic fields of 0 and 900 Oe (2). Large hyperfine fields exist due to long spin relaxation times in pyroxenes at this temperature. Although the spectra are complex, they are

potentially useful in determining electronic energy levels of Fe atoms in pyroxene and, consequently, valuable in understanding physical properties including conductivity. In contrast to higher temperature spectra, these low temperature spectra show considerable variation among samples. For example, in 0 magnetic field 12053 has an extermely complex spectrum but at fields of 900 Oe the spectrum sharpens into one which can be described as three or four sets of six-line magnetic peaks. By contrast 14303 and 14047 have simpler magnetic hyperfine spectra at 0 field and show relatively small changes when field are applied. Since most of the pyroxene Fe is in M2 sites in these two samples, while nearly half of it is in M1 for 12053, this leads to the tentative conclusion that only one component of the g tensor is large for M2 Fe, which in turn might imply a large splitting between d electron states of $|xy\rangle$ and $|xz\rangle$, $|yz\rangle$ symmetry at that site (3). The small temperature dependence of the M2 quadrupole splitting supports this suggestion. Further studies of this type are in progress on lunar pyroxene separates, and on terrestrial and synthetic pyroxenes.

1. F. C. Schwerer, T. Nagata and R. M. Fisher, The Moon 2, 408 (1971).
2. G. P. Huffman, G. R. Dunmyre, R. M. Fisher, P. J. Wasilewski and T. Nagata, Mossbauer Effect Methodology, Vol. 6, p. 209, I. J. Gruverman, editor, (Plenum Press, N.Y.-London, 1971).
3. G. Lang and W. T. Oosterhius, J. Chem. Phys. 51, 3608 (1969).

Relative Distribution of Fe Atoms in Apollo Lunar Samples

Phase	14053-48	14047-47	14301-65	14303-35	14063-47	14259,69 (Fines)
Silicate	.774 (P)	.849 (P,O,gl.)	.885 (P, -)	.851 P	.831 P,.25 O	.827 (P,O,gl.)
Ilmenite	.062	.031	.075	.114	.169	.027
Fe	.088	.060	.040	.020	~0	.086
FeS	.05	$\leq$.01	~ 0	.015	~0	-
Other	.026 (Magnetic)	.06 (broad,para.)	0	0	0	.06 (broad,para.)

P - Pyroxene
O - Olivine
gl - glassy phase