Surface Electrical Conductivity of Germanium

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In a previous work[1] it was shown that in cuprous oxide, the mobility as determined by the Hall effect is greater with molecular adsorption than in vacuum. This may be explained either by a surface zone conductivity, or by scattering of electrons by surface charges. A conclusive answer was not obtained in Ref. 1.

With molecular adsorption, as is well known, the surface charge changes not only as a consequence of changes in the filling of existing surface levels, but also as a consequence of the formation of new ones. Cleaner conditions for experimentation with change of surface charge may be obtained if the latter is changed by means of an external electric field. In this case, only a change in the filling of existing surface levels occurs, no new surface levels being created. Therefore, the present work was carried out using an external electric field as a means for the reversible change of surface change.

The investigation was made on germanium. A monocrystalline plate of germanium with soldered contacts for the measurement of the Hall effect and conductivity was cemented with polystyrene lacquer to a thin sheet of mica (50-30μ). A metallic plate was cemented to the rear side of the mica sheet (opposite the surface of the sample) with a guard ring around it. The Hall effect and conductivity were measured both with and without an external electric field ($+V$ and $-V$ on the metal plate). Based on the results obtained, the effected value of mobility u_e was calculated by the usual formula. In view of the fact that the samples had bipolar conductivity, the real value of mobility could have been obtained by Peierls' formula, but because of the lack of appropriate data, we could not use it. Therefore, for such samples, the calculated values of u_e are somewhat low. The calculated results for some of the samples are given in Table I which contains values of the resistance R , its changes ΔR, evoked by the external electric field, the Hall emf V_x and its change ΔV_x, and also calculated values of u_e and Δu_e. The specific resistances of the samples ρ are also indicated. The measurements were repeated many times and were fully reproducible.

Sample No	V, kV	R, Ω	ΔR, Ω	V_x, mV	ΔV_x, mV	u_e, cm^2/V-sec	Δu_e, cm^2/V-sec	ρ, Ω·cм
24	0 −2	997 1015	+18	1.65 1.86	+0.21	2340 2580	+240	12.0 12.2
	0 +2	1008 943	−65	1.67 1.44	−0.23	2340 2148	−192	12.0 11.3
27	0 −2	4537 4882	+245	1.02 1.43	+0.41	653 850	+197	47.6 51.3
	0 +2	4556 3556	−1000.	1.04 0.36	−0.68	661 294	−367	47.9 37.3

Under the action of an external electric field, the resistances of the samples with electronic and proper conductivity increased with $+V$ and decreased with $-V$ on the metal plate. This corresponds with the results observed by us[2] as well as by other authors[3,4]. The Hall emf V_x and the mobility u_e also changed; with $-V$ on the metal plate they increased, and with $+V$ they decreased.

The change of mobility under the influence of an external electric field may be treated as was done by us in a previous work[1], where the surface charge was changed by molecular adsorption, namely: either by the existence of surface zone conductivity, or by scattering of electron waves by surface charges. If surface zone electronic conductivity exists, then the mobility of electrons on the surface is less than in the volume.

Sample No	ρ, $\Omega\cdot$cm	u_ρ, cm^2/V-sec	$\Delta\rho_\perp$, $\Omega\cdot$cm	$\Delta\rho_\perp/\rho$, %	$\Delta\rho_\parallel$, $\Omega\cdot$cm	$\Delta\rho_\parallel/\rho$, %	d, μ
40 (1)	41	1350	0.9	2,2	0.7	1.7	1390
40 (2)	41	1520	1.0	2,4	0,75	1.8	1570
40 (4)	37.1	1350	1,0	3,0	0,6	1.7	160
40 (5)	34.6	1240	0.9	2.6	0.7	2.0	210
41 (1)	6.26	1470	0.21	3.3	0.15	2.4	210
41 (2)	7.46	1030	0,29	3.9	0.20	2,7	200

We also performed measurements of the Hall effect and the specific resistance ρ on 6 samples without the action of an external electric field for various thicknesses of the samples d. It was observed that with a decrease of d, the quantities u_e and ρ decreased. Thus, for example, with sample 38, with a decrease of d from 1880 to 210μ, ρ decreased from 8.9 to 8.2 Ω cm, and u_e decreased from 1480 to 845 cm$^2/V$ sec., and with sample 37, with a decrease of d from 1800 to 200μ, ρ decreased from 8.5 to 4.9Ω cm, and u_e decreased from 1760 to 921 cm^2/Vsec. If the decrease of mobility were due to the scattering of electrons by surface traps, it could be expected that with a decrease of d, ρ would increase. However, it is observed to decrease; u_e decreased in all cases. These results strongly testify to the existence of surface zone conductivity, although scattering by surface charges also exists.

In order to clarify this question finally, we performed experiments on the change of resistance of samples in a magnetic field in two positions; in the first, when the sample was set perpendicular to the magnetic field, $\Delta\rho_\perp$, and in the second, when it was set along the field, $\Delta\rho_{||}$. In the first position of the sample, the magnetic field acts on both the volume and the surface conductivity, but in the second position, it acts only on the volume. Measurements were performed on ten samples. It was observed that $\Delta\rho_\perp > \Delta\rho_{||}$. In order to remove doubt as to whether the observed $\Delta\rho_\perp > \Delta\rho_{||}$ might be due to anisotropy of the magnetic properties of germanium or to inhomogeniety of the sample, we cut two samples out of a monocrystal, the samples having been at right angles to one another in the monocrystal. Furthermore, the homogeneity of the samples was verified by the absence of a volume photo-emf. Two such pairs of samples were cut from one bar, and one pair from another bar. The results of measurement showed that $\Delta\rho_\perp > \Delta\rho_{||}$; part of the results are presented in Table II.

It appears to us that the material presented here gives a basis for the assertion that surface zone conductivity exists in the samples of germanium investigated by us. We see no other explanation at present.

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