

states of Co⁶⁹ and Cu⁶³. No experimental evidence was secured for the existence of such states in the disintegration of Ni⁶⁹ and Ni⁶⁸.

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Non-Linear I-V Characteristic of Ge at Very Low Temperatures

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BOTH Estermann¹ and Gerritsen² have found in pure Ge samples, in the temperature region of liquid He, that the current-voltage relation is non-linear and usually shows a small asymmetry. At sufficiently high temperatures, however, the non-linearity and asymmetry disappear and at room temperature, a linear $I-V$ characteristic is found.

These facts may be qualitatively understood if we assume, as was done by Estermann, that in the "pure" samples, the concentrations of donors and acceptors are (almost) equal. In that case, we must expect local fluctuations in the concentrations causing the existence of n type domains and p type domains with $n-p$ barriers between them. As has been pointed out by James,³ who considered an analogous situation for PbS, we may expect that the domains will combine to form a small number of continuous n type paths or p type paths. In each path there will be islands and peninsulas of the other type. The current will mainly flow in the n paths and p paths, avoiding the islands and peninsulas and therefore it uses only a fraction of the total cross section. This is so because the $n-p$ barriers are quite high at low temperatures namely about 0.7 eV for Ge.

A qualitative explanation of the observed non-linear $I-V$ characteristic follows now directly from the above picture. For let us consider a p type island in an n type path with the electron current flowing in the direction of the arrow (see Fig. 1). The flow

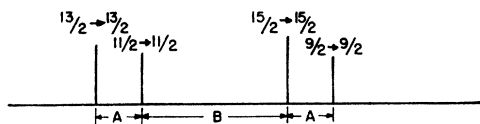


FIG. 1.

through the island will be prevented by barrier a as the flow is in the backward direction for this barrier. As soon, however, as the voltage over the specimen has been increased to such a value that the voltage difference between a and b becomes 0.7 V, the barrier at a will be wiped out and the current will flow through the island too. An analogous reasoning holds for the peninsulas. Also if a favorable voltage difference develops between a certain point of an n path and the adjacent point of a p path, the barrier between them may break down, thus causing a more favorable flow pattern. The described effects will cause a non-linear $I-V$ characteristic of the observed type in which the current increases "too much" with increasing voltage. At higher temperatures the effect will be much less marked because the conductivity increases so quickly that it will be hard to build up sufficient voltage between a and b without causing disturbing heat effects at the same time.

The slope of the characteristic at $V=0$ gives the resistance of the continuous n paths and p paths and its temperature dependence should be characteristic of the material without barriers.

In order to account for the asymmetry we must realize that the electron current can pass from the p path to the adjacent n path but not in the other direction. Therefore, the flow pattern will usually not be the same for both directions of applied voltage. As, however, there are a large number of obstructions for the current in both directions we must expect only a small resultant asymmetry. As this asymmetry is caused by the rectifying property of $n-p$ barriers, it will not show up for voltage drops across the barrier corresponding with kT . Therefore we will find less asymmetry at higher temperatures where the applied voltage will be low in order to limit the current density. Furthermore, the barrier height is less at higher temperatures.

The shape of the $I-V$ characteristic is determined by the distribution of the $n-p$ barriers and the conductivities of the n and p paths. The fact that the shape of the $I-V$ characteristic is almost invariant with temperature in the liquid He range is in accordance with the experimental result that the conductivity of the n and p paths is independent of temperature in that range. However, an explanation for this behavior of the conductivity appears to be missing.

If the above considerations are correct we expect the high frequency resistance of pure Ge in the liquid He range to be considerably lower than the d.c. resistance and the $I-V$ characteristic should be linear at very high frequencies.

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A Preliminary Report on the Fine Structure of the Microwave Absorption Spectrum of Oxygen*

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USING a Zeeman modulation spectrograph, we have observed the microwave absorption spectrum of oxygen at low pressures ($\sim 10^{-1}$ millimeters of Hg), where the fine structure is completely resolved. Though several previous studies of the microwave absorption of oxygen have been made at pressures of the order of an atmosphere, no one has before detected this absorption at sufficiently low pressures to resolve completely the fine structure,** which has been theoretically predicted by Van Vleck.¹ Some experimental evidence for the fine structure was obtained by Beringer² in his wartime measurement of the resonance absorption of oxygen in the region of 5 millimeters wave-length. Recently, this work has been repeated by Strandberg, Meng, and Ingersoll³ at pressures of 80 cm of Hg with the result that somewhat better evidence was obtained for the fine structure. The overlapping absorption of many lines at such high pressure prevented the accurate measurement of several properties of oxygen such as the line breadth parameter and the spacing of the fine structure levels.

In our work an absorption line is detected by a narrow-band, phase sensitive detector and is displayed on an Esterline Angus Automatic Recorder. The receiver operates at 4000 c.p.s. The absorption lines are modulated at the same frequency with an alternating magnetic field, which is applied by means of a solenoid which is placed around the wave guide cell. The field strength used in modulation is usually the order of a gauss. To reduce eddy currents, the wave guide cell is slotted down the center.

So far, sixteen of the fine structure lines have been detected and measured with a cavity wave meter. These tentative frequencies are listed in Table I. They are now being measured more precisely