then, from the pair cross section formula, Eq. (43), of Davies, Bethe, and Maximon,[4] we thus find the bremsstrahlung spectrum at high energies:

$$(d\sigma/dk)=(d\sigma/dk)_{BH} -4a^2\frac{e^2}{\hbar c}\left(\frac{\hbar}{mc}\right)^2\frac{1}{kp_1^2}(\epsilon_1^2+\epsilon_2^2-\tfrac{2}{3}\epsilon_1\epsilon_2)f(Z). \quad (4)$$

Here $(d\sigma/dk)_{BH}$ is the Bethe-Heitler spectrum as given by Bethe,[5] including the effect of screening. Otherwise the notation is as in reference 4.

The Coulomb correction, which is given by the last term in (4), is therefore the same irrespective of the strength of the screening, and the relative correction is the same as for the pair cross section. We may furthermore use the same argument as was used by Davies, Bethe, and Maximon[4] in the case of pair production, to show that the form of the bremsstrahlung spectrum is essentially unchanged by the Coulomb correction.

In the case of no screening, the present result has in fact been obtained by Maximon[6] by integration of the differential bremsstrahlung cross section of Bethe and Maximon.[1] This, then, provides a good check on their calculation. On the other hand Bethe and Maximon[1] stated that there should be zero Coulomb correction to the Bethe-Heitler formula in the case of complete screening. This discrepancy between their result and ours arises from the fact that in bremsstrahlung the corrections due to screening and to the Coulomb effect cannot simply be superposed in the differential cross section. This is because the Coulomb correction occurs for small values of the momentum transfer q when the ingoing wave modification is used,[1] i.e., under the same conditions as the screening. But the customary expression for screening, *viz.*, the multiplication of the cross section by a form factor, is only valid in the Born approximation, i.e., only when the matrix element is *not* modified by the Coulomb correction. Therefore only the calculation of the cross section integrated over electron angles, with *outgoing* waves in the final state is reliable, and at present no result is available for the differential cross section of bremsstrahlung in the presence of both screening and Coulomb correction.

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† On leave of absence from Fysisk Institutt, Norges Tekniske Högskole, Trondheim, Norway.

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Preliminary Study of the Electrical Properties of a Semiconducting Diamond

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THE Hall effect, electrical conductivity, and point contact rectification of a semiconducting diamond have been examined as the initial studies of electrical conduction in diamonds. The specimen investigated is a blue-white, rectangular parallelepiped $0.124\times0.104\times0.356$ cm^3, and is apparently a Type IIb diamond.[1,2]

The Hall effect was determined using a standard ac Hall apparatus operating at 27 cps and a dc magnetic field. Both indium solder and silver paint electrodes have been used, but neither type seems to be entirely ohmic at all temperatures. The specimen temperature was adjusted by immersion in a cooled or heated helium stream and the temperature determined by means of a thermocouple imbedded in the sample mounting cement. The temperature excursion in the present work was limited by contact instability at low temperatures and softening of the mounting cement at high temperatures.

The Hall constant is found to be independent of magnetic field up to the highest value employed, 10 000 oersteds, both at room temperature and at -40°C, the lowest temperature reached. The sample is p-type over the entire range. The logarithm of the Hall constant as a function of reciprocal temperature is found to be

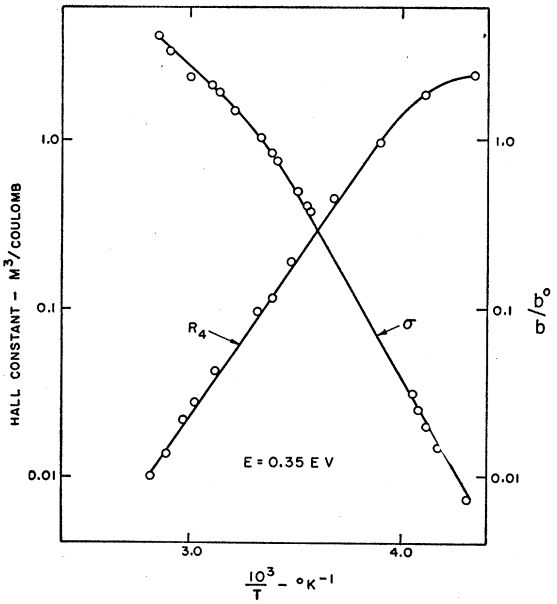

FIG. 1. Hall constant and conductivity as a function of reciprocal temperature for diamond sample.

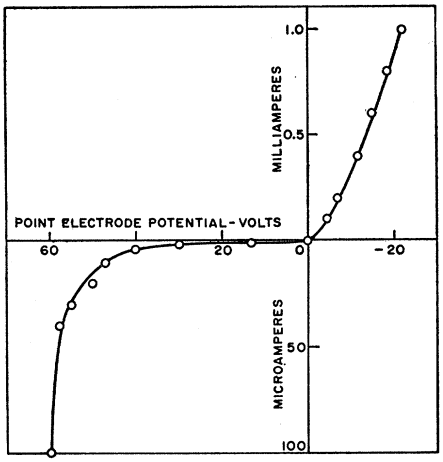

FIG. 2. Point contact rectification characteristic of diamond sample using tungsten probe.

linear except, perhaps, at the lowest temperatures, as shown in Fig. 1. The slope of the linear portion yields an activation energy of 0.35 electron volt. This agrees with the value reported by Leivo from resistance measurements.[3]

We attempted to investigate uniformity of the specimen by floating potential probe measurements using a tungsten point and a field of 3.0 volts/cm across the long dimension of the crystal. The results are inconclusive, showing variations in potential from point to point, which, however, are experimentally reproducible. It appears that there may be considerable conductivity inhomogeneity, on the surface at least. Point contact rectification examination showed that the entire surface was p-type.

Because of the suspected inhomogeneity, further measurements of the resistivity have been deferred. The conductivity of the specimen as a function of temperature was determined from resistance measurements between silver paint electrodes. These data are also shown in Fig. 1. We suspect that the curvature of this plot may be due to the electrodes, so that it seems clear that the major contribution to conductivity variation is thermal activation of carriers.

Although the nonuniformity of the specimen precludes determination of semiconductor parameters such as resistivity, carrier density, and carrier mobility, we have carried out calculations of these quantities based on the above measurements for general interest. We find the following results at room temperature:

$$p = 7 \times 10^{13} \text{ holes/cm}^3,$$

$$\rho = 760 \text{ ohm-cm},$$

$$\mu_p = 100 \text{ cm}^2/\text{volt-sec}.$$

These should be considered order-of-magnitude values only.

The point contact rectification characteristics have also been examined. A typical rectification curve for a tungsten point is shown in Fig. 2, although the exact shape depends somewhat upon the position of the probe on the surface. The sample will pass several tens of amperes in the forward direction with little difficulty, although the forward resistance is clearly appreciable. As mentioned above, p-type behavior is noted.

We hope to continue these investigations, particularly with regard to the inhomogeneities and the origin of donor sites.

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