of the magnetic field. This appears to be consistent with gyro-interaction theory of radiowaves in the ionosphere.[3]

A detailed discussion of the phenomenon of interaction of electromagnetic waves in a gaseous discharge plasma will be published at a later date.

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Ultrasonic Attenuation Measurements in Germanium

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ULTRASONIC attenuation (scattering and absorption) in solid materials has been studied as a function of the ultrasonic frequency and as a function of the state or condition of the material for a number of materials. In particular, it has been found that differences in the state of a semiconductor can be examined by these attenuation measurements.[1] Single crystals of germanium[2] with various histories were examined over a frequency range from 15 to 100 Mc/sec. The attenuation measurements show large differences among the germanium samples; differences caused both by heat treatment and by impurities deliberately introduced.

Figure 1 shows the attenuation as a function of frequency for four samples of germanium in the frequency range from 15 to 45 Mc/sec. The top curve, marked 1, was obtained from measure-

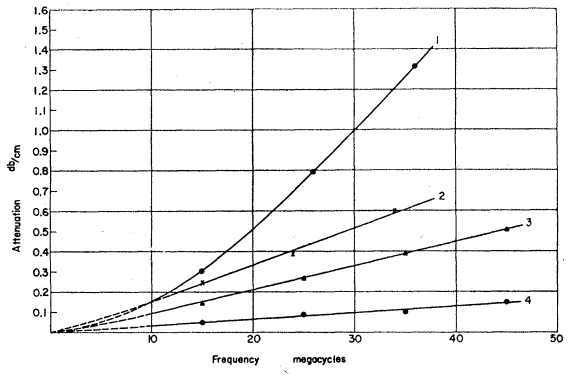

FIG. 1. Ultrasonic attenuation in germanium, as a function of frequency. Propagation normal to 100 planes.

ments on a sample of N type germanium with resistivity $\rho \cong 0.6$ ohm cm. This sample had a lot of N type impurities deliberately introduced. Curve number 2 was obtained from measurements on a sample of P type germanium, in this case with a lot of P type impurities deliberately introduced and again with $\rho \cong 0.6$ ohm cm. Curve number 3 was obtained from a sample of basic germanium with as small an amount of impurities as can readily be obtained. The resistivity was 12.7 ohm cm. The lowest curve, number 4, was obtained from a sample of germanium which was produced from pure germanium with $\rho = 13.2$ ohm cm and then raised in temperature to 915°C for one hour and quenched. The final germanium crystal was P type with $\rho = 0.2$ ohm cm. All of these single crystals were carefully oriented so that the propagation is normal to the 100 planes.

It is clear that above 20 Mc/sec there is a large difference among the samples as far as ultrasonic attenuation measurements are concerned. It seems reasonable that curves 1 and 2 should give rise to higher attenuation than curve 3, since the former samples should have many more defects than the latter sample. It is perhaps surprising that the pure germanium which has been heat treated to P type should have lower attenuation than the original crystal, especially since the heat treatment included quenching. It seems that this heat treatment has removed some of the "defects" from the germanium, but it is difficult to determine the nature of the "defects." It is of interest to note that while for each of the two samples with N and P type impurities the resistivity is 0.6 ohm cm, the attenuation differs by as much as a factor of two at 35 Mc/sec. Between the heat-treated sample and the N type impurity sample the attenuation differs by a factor of about ten to one at 35 Mc/sec.

The data pertaining to curve 4 is not quite as satisfactory as regards accuracy[3] as the other data for the remaining three curves, but the relative position of curve 4 with respect to the other curves is as shown.

It is believed that the attenuation measurements can be used to show relative amounts or numbers of defects present. It is desirable, of course, to separate or sort out the relative amounts of various types of defects. Measurements over a wide range of frequency and over a set of specially prepared samples may permit this separation or sorting of types of defects.

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[2] The germanium single crystals used in this experiment were kindly supplied to us by Dr. W. P. Mason of the Bell Telephone Laboratories.
[3] These low attenuation values are at present difficult to measure.

Temporary Traps in Silicon and Germanium

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EVIDENCE indicating the existence of trapping centers other than recombination centers for minority carriers in germanium and silicon has been obtained[1] from drift velocity measurements. Specifically, in p-type silicon at room temperature and n-type germanium at −80°C and lower temperatures some of the carriers appeared to suffer an additional time delay in their transit between emitter and collector. This straggle could be eliminated by increasing the ambient light falling on the semiconductor specimens. A qualitative explanation of these observations was made in terms of a simple trap model. For low external illumination some of the carriers are caught in "traps" where they sit for a time and then are ejected back into the conduction stream. High external illumination, however, creates sufficient electron-hole pairs to keep the traps filled, and no straggle is observed. By adjusting the external illumination so that a few of the carriers arriving at the collector are trapped once and the rest are not trapped at all, an estimate of the mean lifetime in a trap, τ_θ, can be made.

Photoconductivity and lifetime experiments recently have furnished independent evidence for the existence of traps and have led to a quantitative empirical description of traps in a uniform crystal of 28-ohm-cm p-type silicon.[2] The basic experiment with the silicon crystal is the following. The darkened crystal is first illuminated by a light source; then the source is cut off, and the decay in photoconductivity is measured as a function of time. The decay occurs in three well-defined steps: first comes a rapid decrease in conductivity with a time constant of 20 μsec; there follows a slower decrease in conductivity which asymptotically is exponential with a final time constant of 10^{-2} sec; this is followed by a very slow decrease in conductivity with a final time constant of 260 sec.

The experiment is interpreted as follows. Illumination creates electron-hole pairs at a rate sufficient to fill two sets of volume traps, deep and shallow, and also add electrons to the conduction band. When the illumination is removed, the electrons in the conduction band recombine ($\tau_r = 20$ μsec) before the occupancy