percent relative abundance). All the lines previously reported[1] as well as those in Fig. 1 were measured at rf levels comparable to those which completely saturated the one sample investigated.

As the rf level was decreased, the signal to noise ratio improved enough to show up three satellite lines in the arsenic-doped silicon. A reproduction of the actual trace is shown in Fig. 2. These lines are located midway between the four principal lines with the middle line of the three about $1\frac{1}{2}$ times as large as the side lines. A natural source for such lines is the almost forbidden transitions in which the donor nucleus flips at the same time the electron does. These transitions will produce lines precisely midway between the main lines as observed.

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[1] Fletcher, Yager, Pearson, Holden, Read, and Merritt, Phys. Rev. **94**, 1392 (1954).
[2] W. G. Proctor and F. C. Yu, Phys. Rev. **78**, 471 (1950).
[3] Portis, Kip, Kittel, and Brattain, Phys. Rev. **90**, 988 (1953).
[4] A. M. Portis, Phys. Rev. **91**, 1071 (1953).

Phosphorescence of Atoms and Molecules of Solid Nitrogen at 4.2°K

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While investigating the possibility of freezing out free radicals at liquid helium temperatures, a phosphorescent glow was observed in the solid products from an electrodeless discharge through nitrogen gas at low pressure. It is possible, therefore, that constituents of the discharge, such as atomic nitrogen, are produced in solid form. This material is observed visually as a thin layer of substance frozen on the inner surface of a single-walled vessel submerged in liquid helium. Presence of an active species on or within the solid is apparent from a visible green glow.

The apparatus is illustrated in Fig. 1. Nitrogen gas is introduced through a control stopcock from a cylinder of nitrogen and traverses the discharge region (A) at low pressure, between 0.1 and 3 mm Hg. The discharge is excited by means of a microwave (2450 Mc/sec) voltage induced by antenna (C). The single-wall lower extremity (B) immersed in liquid helium (F) acts as a trap by freezing out all gases, and thus constitutes effectively a high-speed vacuum pump for maintaining the flow of nitrogen. In order to prevent solidification of discharge products at temperatures above 4.2°K, the flow is carried to the cold walls within a passageway kept nearly at room temperature. This relatively high temperature is maintained by forcing warm helium gas between compound walls (D) surrounding the channel (E) through which the discharge products pass. A vacuum region (G) surrounds the entire assembly above chamber (B).

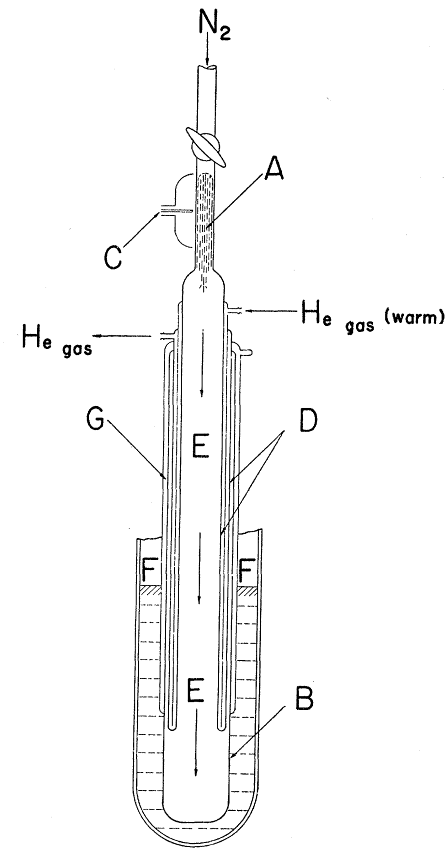

Fig. 1. Diagram of apparatus.

While the discharge (A) is maintained, the walls of the collecting chamber (B) emit a strong green glow. This glow definitely originates from the inner surface where the deposition is occurring; this is verified by observing the interior of the chamber from above. Another characteristic of the surface glow is the random occurrence of local bright spots. After the discharge has been on for several minutes, brilliant flashes of blue appearance are observed spreading as much as two or three centimeters. These flashes are restricted to the surface (not volume effects within the chamber) and appear to be explosive reactions spreading within the deposited material.

After the discharge is extinguished and the flow of nitrogen is stopped, the green glow persists for more than two minutes. During this time the glow intensity diminishes steadily, with no spontaneous flashing. Admission of warm gas (nitrogen or helium) results in increased rate of disappearance and a blue glow before extinction. Removal of the vessel from liquid helium without adding warm gas has a similar result. Once, after the disappearance of both the green and blue glows, re-immersion of the vessel (B) into liquid helium resulted in the reappearance of the green glow.

It is known that atoms can be pumped some distance from a discharge of the type used here and that atomic concentrations of several percent are easily obtainable.[1] This, together with the facts reported above, leads us to the belief that the cause of the glows, including the phosphorescence, is connected with the presence of free nitrogren atoms in the solid lattice.

Spectra of the glows which we have observed have not yet been fully analyzed but it seems certain that the green bands are identical with those observed in 1924 by Vegard[2] and McClennan and Shrum.[3] These observers found a green glow on bombarding solid nitrogen with electrons and "canal rays" from an electrical discharge. Phosphorescence and phenomena corresponding to the blue flashes were also observed. Since the present method relies on the freezing of products from an electrical discharge rather than a bombardment with charged particles, these results might contribute to a fuller understanding of the actual mechanism involved.

The observations reported here constitute evidence for the existence of atoms coexisting with molecules in the solid phase. Using the same apparatus, products frozen from discharges through hydrogen, oxygen, and water vapor have led to a similar conclusion concerning the collection of atoms (H and O) and free radicals (OH) at liquid helium temperatures.

[1] H. P. Broida and A. G. Gaydon, Proc. Roy. Soc. (London) **A222**, 181 (1954); and R. E. Ferguson and H. P. Broida, Fifth Symposium on Combustion, 1954 (unpublished).
[2] L. Vegard, Nature **113**, 716 (1924), and **114**, 357 (1924).
[3] J. C. McClennan and G. M. Shrum, Proc. Roy. Soc. (London) **A106**, 138 (1924).

Energy Gap of Germanium-Silicon Alloys

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THE band structure of germanium-silicon alloys has been explored to the extent that the forbidden band width has been determined as a function of composition. A method of preparing homogeneous samples of these alloys was reported at a recent symposium[1] and this will be described more fully in a future publication, together with data on other properties.

In view of the theoretical and practical interest in these alloys, we are reporting here the results of measurements of the forbidden band widths as they were determined from the slopes of logarithmic plots of resistivity *versus* reciprocal temperature in the intrinsic range. The results are shown in Fig. 1 where it can be seen that the energy gap of germanium rises steeply as silicon is added until it is approximately the same as pure silicon at 50 atomic percent. The curve as drawn

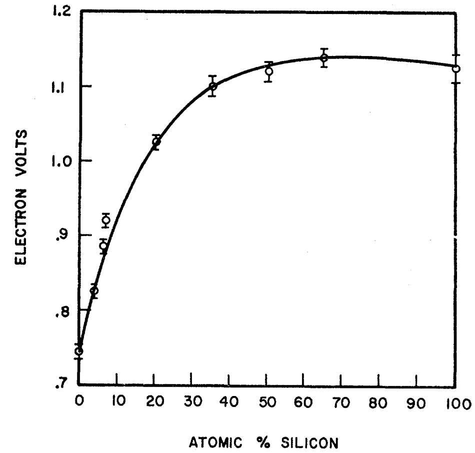

FIG. 1. Energy gap of germanium-silicon alloys against composition.

tends to have a slight maximum at about 75 percent silicon, although the existence of this maximum is uncertain since it is barely detectable within the experimental accuracy.

[1] C. C. Wang and B. H. Alexander, Am. Inst. Mining Met. Engrs. Symposium on Semiconductors, February 15–18, 1954, New York, New York (unpublished).

Paramagnetic Resonance Absorption in a Soft Carbon*

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EXTENSION of our investigation of the magnetic resonance properties of carbons and graphite at room temperature[1,2] has revealed that the width of the electronic spin resonance absorption characteristic of a soft carbon powder varies with heat treatment of the powder. The observed variation suggests the existence of a physical correlation between the width of the spin resonance absorption and the Hall coefficient.

The carbon powder was prepared from a soft coke by milling it to a mean particle size of one to two microns and then heating to the desired temperature Ht. This temperature determines to a large extent the crystallite size. Each series (having several Ht values) was obtained by heat treating a batch of the coke powder to Ht_1, removing a few milligrams of powder to be labeled by Ht_1, heat treating the remainder to Ht_2, removing more powder, etc. Five such series (with interspersed Ht values) were made from the same Texas petroleum coke powder.

Preparation of the microwave samples again[1] included aligning the graphitic planes parallel to each other throughout a given sample. The geometry in the cavity was again such that the plane containing the dc and