Letters to the Editor

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Diffusion of Lithium into Germanium and Silicon

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THE diffusion of lithium into p type single crystals of germanium and silicon[1] has been measured at temperatures between 450 and 1000°C by the pn junction method previously described:[2] The experiments were carried out by heating metallic lithium[3] on the surfaces of specimens of germanium and silicon (0.125 cm thick) in a helium atmosphere. Hemispherical n type regions of low resistivity were observed to form, showing that lithium not only diffuses rapidly at the temperatures employed but also acts as a strong donor in germanium[4] and silicon.

The diffusivity D and the surface concentration C_0 of Li in Ge and Si were calculated by means of Eqs. (1) and (2) given in reference 1. Corrections were introduced for the change in mobility with impurity concentration.[5] The assumption was also made that each Li atom contributes one conduction electron.

The equations $D=13\times10^{-4}\exp(-10\,700/RT)$ and $D=94\times10^{-4}\exp(-18\,100/RT)$ were found to describe the dependence of diffusivity of Li in Ge and Si, respectively, for the temperature range studied, where D is given in cm²/sec and $R=1.98$ calories. The maximum errors in the activation energies are estimated as ±1000 calories for Ge and ±3000 calories for Si. These results are shown in Fig. 1, where D is plotted against reciprocal of mean effective absolute temperature.[6]

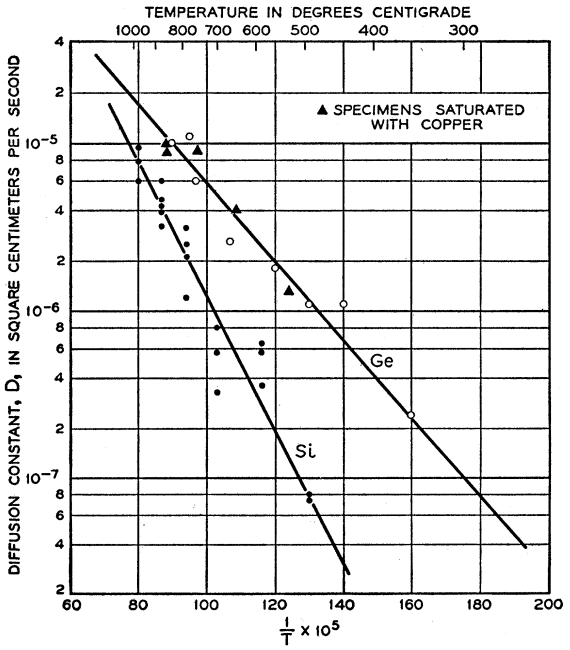

FIG. 1. Diffusion constant *versus* reciprocal of absolute temperature for Li in Ge and Si.

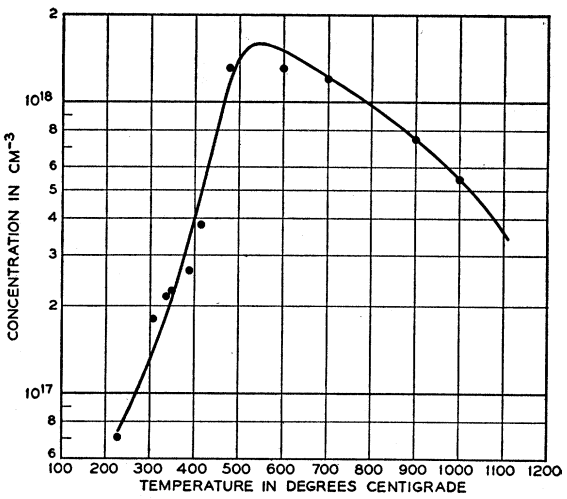

FIG. 2. Solubility of Li in Si as a function of temperature.

Inasmuch as copper is also known to diffuse rapidly into germanium and silicon[7] several specimens of germanium (see Fig. 1) were diffused in the presence of copper. No appreciable effect on the results was evident.

Calculated values of C_0 range from 6.1×10^{16} to 1.4×10^{18} cm^{-3} for Li in Ge and from 2.0×10^{17} to 8.0×10^{18} for Li in Si, but they are subject to large error. Determinations of the solubility of Li in Si have been made by measuring the change in resistivity upon saturation at a series of temperatures. These results are shown in Fig. 2. Similar measurements for Ge have not as yet been possible because of a rapid precipitation of Li at room temperature.

Resistivity and Hall measurements[8] on Li doped Ge single crystals indicate a distribution coefficient between liquid and solid Ge for Li of greater than 0.01 and a donor level 0.01 ev below the conduction band. Precise determinations of distribution coefficient are difficult because of the precipitation previously mentioned.

[1] The authors are indebted to E. Buehler and G. K. Teal for supplying these crystals.
[2] C. S. Fuller, Phys. Rev. **86**, 136 (1952).
[3] Spectrographic analysis made at Bell Laboratories showed only Ca, K, and Na present to greater than 0.005 percent.
[4] It has been called to the authors' attention that W. C. Dunlap, Jr., and R. N. Hall at the General Electric Research Laboratory have independently reported lithium to act as a donor element in germanium.
[5] Haynes, Pearson, Debye, and Prince, unpublished data [Bull. Am. Phys. Soc. **28**, No. 2, 10 (1953)]; Esther M. Conwell, Proc. Inst. Radio Engrs. **40**, 1327 (1952).
[6] J. L. Ham, Trans. Am. Soc. Metals **31**, 849 (1943).
[7] C. S. Fuller and J. D. Struthers, Phys. Rev. **87**, 526 (1952).
[8] J. A. Burton and F. J. Morin, unpublished results.

The Mobility of Slow Electrons in Polar Crystals

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WE have calculated the mobility of slow electrons in polar crystals using the same basic approximation as in our calculation (with T. D. Lee) of the effective mass.[1] The mobility has previously been calculated by Fröhlich and Mott[2] using perturbation theory. The dimensionless constant α which measures the strength of the electron lattice interaction is, however, between 1 and 6 for typical polar crystals, whereas the validity of perturbation theory requires $\alpha<1$. The calculation of LLP for the effective mass was found to have considerable validity (~20