Photothresholds in Mg2Ge

C. A. Mead

Citation: Journal of Applied Physics 35, 2460 (1964); doi: 10.1063/1.1702881
View online: http://dx.doi.org/10.1063/1.1702881
View Table of Contents: http://scitation.aip.org/content/aip/journal/jap/35/8?ver=pdfcov
Published by the AIP Publishing

Articles you may be interested in

Interface magnetism of Co2FeGe Heusler alloy layers and magnetoresistance of Co2FeGe/MgO/Fe magnetic tunnel junctions

Magnetic properties of Mn-doped chalcopyrites: (Be Sn, Be Ge, Mg Ge) N 2

Large magnetic effect on photothresholds in doped EuO
AIP Conf. Proc. 24, 401 (1975); 10.1063/1.30156

ThirdOrder Elastic Constants of Ge, MgO, and Fused SiO2
J. Appl. Phys. 36, 2504 (1965); 10.1063/1.1714520

Preparation and some Properties of Mg2Ge Single Crystals and of Mg2Ge pn Junctions
J. Appl. Phys. 36, 2461 (1965); 10.1063/1.1714512
Shockley–Read–Hall centers.\textsuperscript{4} It can be shown that, within the depletion region, the time constant for the emission of carriers from such levels is given by\textsuperscript{5}

\[ \tau = \frac{1}{[\sigma_\text{t} V_{th} \text{ni} + \sigma_\text{p} V_{th} \text{ni}]} \]  

\textsuperscript{4} W. Shockley and W. T. Read, Phys. Rev. 87, 835 (1952).

Thermal velocity of carriers is \( v_t = 10^7 \text{ cm/sec} \) and for silicon at room temperature the intrinsic carrier concentration \( n_i \) is \( \approx 10^{10} \text{ cm}^{-3} \). These values, together with typical carrier capture cross sections \( \sigma_\text{p} = \sigma_\text{n} = 10^{-15} \text{ cm}^2 \), give \( \tau_t \approx 10^{-2} \text{ sec} \) which is in order-of-magnitude agreement with the observed transition frequency.

---

**Photothresholds in Mg\textsubscript{2}Ge**

**C. A. Mead**

*California Institute of Technology, Pasadena, California*

(Received 1 April 1964)

Optical absorption and surface barrier photoresponse measurements have been made on cleaved samples of Mg\textsubscript{2}Ge. The form of the results obtained from both techniques indicates an indirect transition at approximately 0.54 eV followed by a direct transition at approximately 1.8 eV.

The electrical properties of Mg\textsubscript{2}Ge have been studied in some detail by Redin \textit{et al.}\textsuperscript{1} and more recently, Koenig \textit{et al.}\textsuperscript{2} in an attempt to determine the energy gap of this material by means of infrared absorption measurements. Although the absorption coefficient was measured over a considerable range of temperature, the dependence upon energy could not be fit to any theoretical model and hence the value of the band gap could not be ascertained. In the present work, infrared absorption measurements have been made on cleaved samples of Mg\textsubscript{2}Ge. The energy dependence of the absorption is consistent with the theory for allowed indirect transitions.

The square root of the room-temperature absorption coefficient is plotted as a function of photon energy in Fig. 1. The form of the curve as well as its rate of increase with \( h\nu \) is very similar to that obtained with other materials where the transitions are known to be indirect. It can be seen that the result is fit well by a straight line extrapolating to 0.548 eV. This branch we interpret as arising from the phonon emission process. At low absorption coefficients, a second branch probably corresponding to the phonon absorption process can be seen. This data was obtained from transmission measurements on samples of two different thicknesses cleaved from a single large \textit{p}-type crystal (carrier concentration \( \leq 10^{17} \text{ cm}^{-3} \)). It was noted by H. Kroemer that a cleaved surface could be exposed to the atmosphere for extended periods without showing any sign of deterioration. However, if the sample was abraded in any way, a surface film formed rapidly. Since previous work was done on polished surfaces, comparison with the present results is difficult. Reflection from the sample surface as a function of wavelength is shown in the inset in Fig. 1. The maximum value of the reflectivity is of the order of 50\%. It can be seen that the value of the reflectivity did not change appreciably over the wavelength range where the reflection correction was appreciable. Hence, the absorption coefficient was

\[ \sigma \propto \frac{1}{h\nu} \]
PHOTOTHRESHOLDS IN Mg$_2$Ge

1. Low-temperature photoresponse of surface barrier unit.

2. Summary of data obtained on direct and indirect transitions in Mg$_2$Ge. The temperature coefficient of the direct edge was obtained from the 195° and 77°K data, of the indirect edge from the 300° and 77°K data.

<table>
<thead>
<tr>
<th>Temperature (°K)</th>
<th>Indirect threshold (eV)</th>
<th>Direct threshold (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorption</td>
<td>300</td>
<td>0.548±0.004</td>
</tr>
<tr>
<td>Surface barrier response</td>
<td>195</td>
<td>0.54 ±0.01</td>
</tr>
<tr>
<td></td>
<td>77</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>≈10</td>
<td>0.57</td>
</tr>
<tr>
<td>Temperature coefficient (10$^{-4}$/°K)</td>
<td>≈2±1</td>
<td>3.5</td>
</tr>
</tbody>
</table>

The abrupt increase in photoresponse at 1.8 eV is very similar to that observed for a number of other materials$^4$, and is attributed to direct transitions from the valence to conduction band. Similar data were taken at 77° and 195°K. A rather accurate value for the direct edge can be obtained by subtracting the extrapolated response due to indirect transitions.

Fig. 2. Low-temperature photoresponse of surface barrier unit.

Fig. 3. Photoresponse (R) due to direct transition as obtained by subtraction of the extrapolated indirect response.

planations for this increase in response could be advanced, but at present the author has no definitive experiment to evaluate the various alternatives.

It should be noted that the values quoted are photothresholds which are closely related to, but not identical with, the band gap energies. A T. O. phonon energy of 0.0256 eV can be deduced from infrared reflectivity data of McWilliams and Lynch. Assuming that the ratio of the L. O. and T. O. phonon energies is approximately the same as in MgSi, the L. O. phonon energy is approximately 0.031 eV. Presumably the indirect band gap can be obtained by subtracting the L. O. phonon energy from the threshold, giving $E_g = 0.516 \pm 0.005$ eV at $300^\circ$K and $0.54 \pm 0.01$ at $10^\circ$K. The phototresholds for the direct process can differ from the direct band gap by as much as 0.15 eV due to direct exciton formation, multiphonon processes, and possibly other broadening phenomena as well.

The author would like to thank H. Kroemer for supplying the samples of MgGe, W. G. Spitzer for helpful discussions, and H. M. Simpson for the fabrication of the samples. The work was supported in part by the Office of Naval Research and the International Telephone and Telegraph Company.

---

JOURNAL OF APPLIED PHYSICS

VOLUME 35, NUMBER 8

AUGUST 1964

Electrical Measurements and X-Ray Lattice Parameter Measurements of GaAs Doped with Se, Te, Zn, and Cd and the Stress Effects of These Elements as Diffusants in GaAs

J. BLACK AND P. LUBLIN

General Telephone & Electronics Laboratories, Incorporated, Bayside, New York
(Received 30 January 1964)

The room-temperature lattice parameter of GaAs doped with Zn, Cd, Te, and Se has been measured with a precision of ±3 parts in $10^6$ using an x-ray powder diffraction technique. Electrical measurements and microscopic examination of samples were used to qualify the measured lattice parameters and allow limits of the solute lattice dilation coefficient ($\beta$) to be calculated. For Zn in GaAs, $\beta < 1.2 \times 10^{-24}$ cm$^2$/atom; for Cd in GaAs, $\beta > 1.1 \times 10^{-24}$ cm$^2$/atom; for Se, $\beta > 1.3 \times 10^{-24}$ cm$^2$/atom; and for Te, $\beta > 1.7 \times 10^{-24}$ cm$^2$/atom. Limits of the stresses that could be generated at the onset of the diffusion of Zn, Cd, Te, or Se into GaAs are derived from these $\beta$ values. It appears likely that these stresses will be sufficient to cause plastic flow and the generation of large numbers of dislocations for diffusion of any of these elements into GaAs under conditions of high diffusant surface concentration and high temperature. Preliminary experiments show that the diffusion of zinc into GaAs at 1100°C can generate a high dislocation density in the diffused layer.

INTRODUCTION

WHEN a semiconductor is heavily doped to produce a high concentration of free carriers, significant changes may occur in the lattice parameter as a result of the doping. If dopants which affect the lattice spacing are introduced by diffusion, high stresses can build up in the diffused semiconductor as a result of the lattice mismatch which is developed across the diffusion front. These stresses can lead to plastic deformation or cause embrittlement of a diffused sample. Recent work, for example, has shown that highly disturbed surface layers can be produced in silicon by the indiffusion of boron; this is consistent with the marked decrease of the lattice constant of silicon at high boron concentrations. Generally, the region of the diffused semiconductor most affected by these lattice parameter changes will be near the $p$-$n$ junction. This is significant since high stresses or plastic flow near the $p$-$n$ junction are known to have extreme effects on the properties of a $p$-$n$ junction device. In view of the intensive development of GaAs devices in the last few years, it is important to know if significant changes occur in the lattice parameter of GaAs upon heavy doping with elements which are useful for $n$- and $p$-type doping, i.e., group II, IV, and VI elements.

The first measurements of the lattice parameter of doped GaAs were made by Kolm, Kulin, and Averbach in 1957. They studied the effect of additions up to 2 at. % of Si, Ge, Sn, and Pb on the lattice spacing of GaAs. From their measurements it appears that all of these group IV elements cause a marked decrease in the lattice parameter of GaAs, each of the elements causing

---