THE EFFECT OF OXYGEN ADSORBED ON THE SURFACE OF GERMANIUM ON THE LIFETIME OF MINORITY CURRENT CARRIERS

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Figure 1

Figure 1: Figure 1

Abstract

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THE EFFECT OF OXYGEN ADSORBED ON THE SURFACE OF GERMANIUM ON THE LIFETIME OF MINORITY CURRENT CARRIERS

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In the works of our laboratory, the chemisorption of oxygen on germanium and the effect of oxygen chemisorbed under various conditions on the electron work function were investigated ([1,2]). In these works it was shown that the fast and slow stages of chemisorption affect the electron work function differently. The data obtained led to the conclusion that fast chemisorption corresponds to the formation on the surface of germanium of a monomolecular layer of the GeO type, while slow chemisorption corresponds to a monomolecular layer of the GeO_2 type. It was of interest to determine how the various forms of chemisorbed oxygen affect the lifetime of minority current carriers in germanium.

Fig. 1. Apparatus. *1*—to the amplifier; *2*—to the pyrometer; *3*—end contacts; *4*—germanium sample.

To clarify this question, the lifetime of minority current carriers was investigated on a clean germanium surface and on germanium that had chemisorbed oxygen.

The effect of oxygen on the lifetime, which was measured from the decay of photoconductivity, had previously been studied by Mädén and Farnsworth ([3]). In these experiments the germanium surface was subjected to ion bombardment and subsequent heating in vacuum. In that work the oxygen pressure did not exceed $1.2 \cdot 10^{-4}$ mm Hg. Under such treatment, oxygen adsorbed at room temperature had no effect on the lifetime. Oxygen adsorbed at 100° reduced the lifetime of minority current carriers at the germanium surface. It should be noted that in the cited work the experiments were carried out at very low oxygen pressures, which should have led to a decrease in the rate of chemisorption, especially in the slow stage. In order to compare the results on lifetime measurements with the results on the kinetics of chemisorption and the electron work function from germanium, it was necessary to carry out lifetime measurements

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

under the same conditions as in the investigations we had conducted earlier ([1,2]).

The lifetime of minority current carriers was measured by the photogalvanomagnetic method ([4,5]). An electromagnet was used as the source of the magnetic field ($B = 3200$ gauss). The light source was a 500 W cinema lamp. The light modulation frequency was 60 Hz. To amplify the signal, a narrow-band amplifier with a gain factor of $6 \cdot 10^4$ was used.

A germanium sample, in the form of a rectangular plate, was placed in a special holder located in the apparatus shown in Fig. 1. The end contacts served simultaneously for passing a direct current through the sample and for measuring the voltages of the photogalvanomagnetic effect and photoconductivity. The temperature was measured by means of a thermocouple placed in the apparatus near the germanium surface.

The experiments were carried out on samples of n-type germanium: $\rho = 20$ ohm $\cdot$ cm, $L = 1.5$ mm, and $\rho = 48$ ohm $\cdot$ cm, $L = 3.2$ mm. The germanium samples were ground and then etched in hydrogen peroxide.

Cleaning of the germanium surface was carried out by repeated reduction in hydrogen at 400°, followed by degassing in a vacuum of 10^{-7} mm Hg at the same temperature. The lifetime on a germanium sample treated in this way practically did not differ from the lifetime on a freshly etched surface.

All lifetime measurements were carried out at room temperature. The effect of oxygen, chemisorbed at various pressures in the temperature interval 20–400°, on the lifetime was investigated. The results obtained at 20° are presented in Fig. 2, where P_{O_2} is the oxygen pressure and τ is the effective lifetime. The lifetime was measured over the course of 10 min after admission of the gas.

Fig. 2. Dependence of τ on $\lg P_{O_2}$.
1 —n-type germanium, $\rho = 48$ ohm $\cdot$ cm; 2 —n-type germanium, $\rho = 20$ ohm $\cdot$ cm

From data on the study of the kinetics of oxygen chemisorption it follows that, for completion of the fast stage of chemisorption at a pressure of 10^{-3} mm Hg, less than 1 min is required. The slow chemisorption, however, whose completion at low pressure requires several days, increases with increasing pressure, the chemisorption rate being proportional to the square root of the pressure.

Fig. 3. Dependence of τ on annealing temperature T.

1 –in vacuum; 2 –in oxygen

From the results obtained by us it follows that the fast and slow stages of chemisorption affect differently the lifetime of minority current carriers at the surface of germanium. From the data shown in Fig. 2, measured 5 min after the start of the experiment at the given pressure, it is seen that at oxygen pressures not exceeding 0.1 mm Hg, oxygen chemisorption does not affect the lifetime. Under these conditions mainly the fast stage of chemisorption takes place. At higher pressures, where slow adsorption takes place, the lifetime decreases, and this decrease depends on the residence time of germanium in oxygen. From Fig. 2 it is seen that during prolonged residence of germanium in oxygen (17 hr), over which slow adsorption increases, the decrease in τ corresponds to the section indicated by the dashed line.

The effect of annealing in vacuum of germanium with chemisorbed oxygen was also studied in the temperature interval 20–400°. These experiments were carried out with n-type germanium samples having $\rho = 48$ ohm $\cdot$ cm, $L = 3.2$ mm. The results of the experiments are given in Fig. 3 (curve 1). Annealing of germanium at each temperature was carried out for 1 hr. From these data it is seen that, as the annealing temperature is raised, the lifetime increases. This increase is considerable at a temperature of 400°, and the value

the lifetime after heating depends on the heating time. Heating in vacuum for 3 hours increases the lifetime to the value corresponding to a clean surface. The effect of oxygen adsorbed at high temperatures on the lifetime of minority current carriers was also investigated. It was shown that when germanium is heated in the presence of oxygen in the gas phase (5 mm Hg), the lifetime decreases from 100 μsec at room temperature to 40 μsec after heating at 400° (Fig. 3, 2).

Comparison of the results obtained in measuring the effect of adsorbed oxygen on the electron work function with the results obtained in studying the effect of oxygen adsorbed on germanium on the lifetime leads to the conclusion that rapid adsorption of oxygen, which has no effect on the lifetime, leads to a small change in the electron work function, whereas slow chemisorption, in the course of which a layer of the GeO_2 type is formed on the surface, leading to a considerable increase in the electron work function, simultaneously leads to a large decrease in the lifetime.

When germanium with chemisorbed oxygen is heated in vacuum, i.e., under conditions in which the reaction $GeO_2 + Ge = 2GeO$ takes place, the work function decreases, and under these conditions an increase in the lifetime is observed.

Heating germanium in oxygen, leading to large increases in the work function, leads to a considerable decrease in the lifetime. It is not yet possible to draw an unambiguous conclusion as to the extent to which the results obtained satisfy the theory of Garrett and Brattain[6], which establishes a relation between the surface recombination velocity and the surface charge. These data suggest that

the change in lifetime upon oxygen adsorption is connected to a considerable extent with the formation on the germanium surface of an oxide of the GeO_2 type. Areas of germanium covered with this oxide are apparently centers of surface recombination.

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Note: Figure translations are in progress. See original paper for figures.