INFLUENCE OF ELECTRICAL FIELD ON SORPTION PROCESSES ON GERMANIUM SURFACE

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V.I. LYASHENKO, A.A. SERBA, I.I. STEPKO

Institute of Semiconductors, Academy of Sciences of the Ukrainian SSR
(Kyiv, Ukraine)

The authors found that an external electric field affects the desorption of gas molecules from the surface of germanium layers. With fields of the order of 10^5 v/cm and higher (+2 to +4 KV on germanium) the pressure in the lamp and the resistance of the sample increase (Fig. 1 and 2).

It is known that electron surface states play a great role in the sorption phenomena. This was theoretically demonstrated by F.F. Volkenstein [1] and experimentally by us in our previous publication [2]. The parameters of electron states and, hence, the characteristics of absorption are supposed to be influenced by application of an external electrical field, which would be of great practical importance for catalysis. This effect was theoretically analyzed by F.F. Volkenstein and V.B. Sandomirsky [3].

It was theoretically demonstrated that any change of the charge on one side of a thin semiconductor layer with thickness d smaller that the screening length $\frac{1}{\kappa}$, $d < \frac{1}{\kappa}$, leads to the accompanying change of the charge on the opposite side [4]. The occupation of states on the front surface of a thin semiconductor can be changed by an electrical field applied to its rear surface through a thin dielectric layer. The ionization is absent because the field does not spread out into the region, from which the molecules are absorbed onto the semiconductor front surface. Changing the applied external field (applying $\pm U$) leads to a change of the value of surface charge. If the absorption is stipulated by this charge, changing the gas pressure should be detected. The experiment was organized as follows. A thick layer of gold was deposited on one side of a mica plate of 50×50 mm in size and 60 μm in thickness and a thin Ge layer ($d \sim 10^{-5}$ mm) on its other side by evaporation in high vacuum. The electrical field applied to this condenser was concentrated in the mica plate, whose edges spread far beyond the deposited layers. The plate was mounted in a pumped out vacuum bulb.

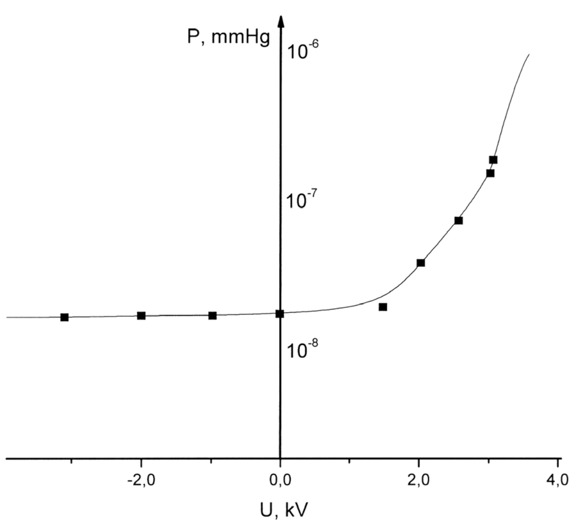

Fig. 1

The clearest field dependence of absorption processes was observed for the desorption at low pressures. The best results were obtained in the case of small surfaces for the pressure inside the bulb in the interval of 10^{-8}–10^{-9} mmHg.

The experimental results can be summarized as follows:

1. The gas pressure in the bulb depended on the sign and value of the applied voltage. Applying $-U$ to Ge led to almost no change of pressure. The pressure changed in the case of the application of $+U$ as shown in Fig. 1.

2. An increase of the gas pressure in the bulb was observed only after a first step of the application of a high U. After the evacuation of a desorbed gas, the subsequent application of the same potential, as well as its prolonged action, did not result in a change of the pressure.

3. A change of the sample resistance was observed simultaneously with changing the gas pressure under the action of the electrical field applied (Fig. 2). As can be seen from Fig. 2, the application of high voltages causing

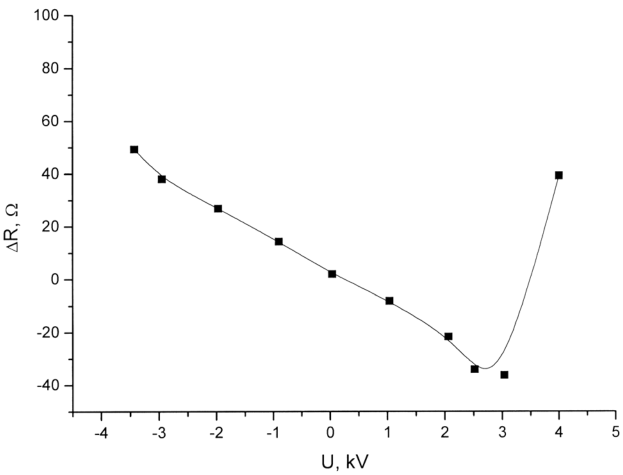

Fig. 2

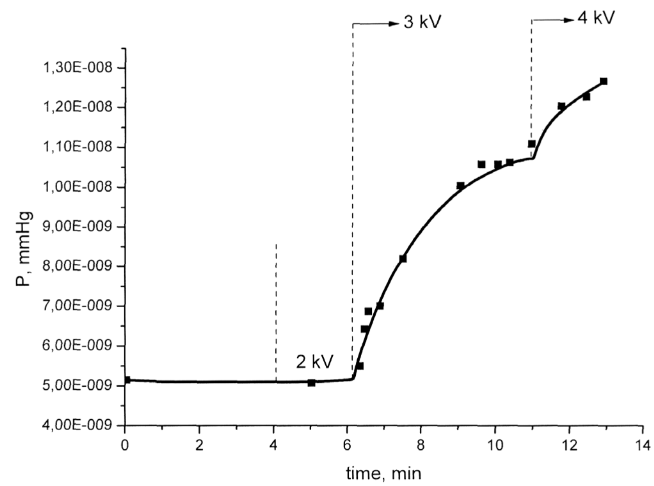

Fig. 3

a pressure increase resulted also in a sudden increase of the sample resistance, whereas it would drop, due to the field effect, for Ge with hole-type conductivity.

4. It is established that a change of the pressure (and the resistance) is not an instantaneous process but a function of time, as shown in Fig. 3. The gas pressure almost did not change at the values of applied voltage up to + 2 kV. It increased at the voltage reaching + 3 kV. Raising the applied voltage more (up to 4 kV) resulted in the further increase of the pressure. These experimental facts can be understood by taking into account that the external electrical field changes the occupation of electron surface states which are the centers of absorption [1]. Only chemically absorbed molecules remain on the surface of Ge under vacuum of 10^{-8}–10^{-9} mmHg. The application of $+U$ leads to a decrease of the number of electrons on the Ge surface. In this case, a part of molecules bound by surface electrons desorb, and the pressure increases. Applying $-U$ would lead to an increase of the number of electrons, which would cause both an increase of the absorption of molecules and a drop of the gas pressure. However, we did not find any pressure drop in our experiments. This fact can be explained by that a small drop of the gas pressure due to the absorption on the sample can be compensated by a desorption from the walls of the bulb. Another reason can be that bigger negative voltages are required to detect the field-stimulated absorption.

One can also explain the other above-mentioned experimental fact. Namely, applying the same $+U$ repeatedly does not lead to the additional desorption and a change of the pressure. The latter may be attained only after the application of a greater $+U$.

The sudden (as compared with the field effect) increase of the sample resistance (Fig. 2, after 4 kV) can be explained by a considerable decrease of the band bending on the surface due to the field-induced desorption of molecules, which leads to a decrease of the conductivity of the layer of p-Ge. One cannot exclude also that a decrease of the band bending on the surface due to the desorption is accompanied by a change of the occupation of surface states, whose distances from the chemical potential level increase, which decreases the charge screening the conductivity.

The experimental results described above show the importance of sorption processes for the conductivity of semiconductors, which should be taken into account in investigations of semiconductor surfaces with the use of the field effect. This circumstance was not previously given a necessary attention.

To prove that the change of the gas pressure is caused just by the sorption processes on the semiconductor surface, we carried out analogous experiments but with a gold layer deposited onto a mica plate instead of the Ge layer. No pressure change was detected in the voltage range of ± 5 kV. The effect was not also observed for the thick ($d \gg \frac{1}{\kappa}$) layers of Ge in accordance with the analysis presented above.

Although a special method was used to prevent the ionization, the influence of a field of only one sign calls a question whether the increase of the gas pressure is related to the possible ionization on Ge at $+U$. However, if it would be the case, the same ionization effect will have place in the case of two gold layers, which was not observed experimentally.

The pressure increase after a first step of applying $+U$ and its absence after the repeated and prolonged voltage applications also testify that the ionization does not occur in the cases studied. The further desorption is observed only after the application of greater $+U$. If the ionization does occur, it would induce increasing the gas pressure every time, as well as for the thick films. Thus, the increase of the gas pressure is caused by the desorption of a gas from the surface of germanium due to a decrease of the value of negative charge under the action of an external electrical field.

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LYASHENKO VASYL IVANOVYCH (30.01.1902–18.03.1975)

Vasyl Ivanovych Lyashenko was the outstanding Ukrainian physicist-experimenter. He was born on January 30, 1902 and died at the age of 73. V.I. Lyashenko passed the complex and heavy course of life – beginning from the Konotop railway school, the Phys.-Math. Faculty of Kyiv University (1928), a junior scientific researcher of the Kyiv Institute of Physics of Academy of Science of Ukraine – up to Professor of Kyiv University and Head of one of the biggest departments of the Institute of Semiconductors in Kyiv, laureate of the State's prize of Ukraine in Science and Technology (1969). He is the founder of the first well-known scientific school on the physics of semiconductor surfaces in Ukraine. His most distinguished studies were devoted to surface and catalytic phenomena in semiconductor-based structures. In 1938 in Zh. Eksp. Teor. Fiz. (**8**, N 7, pp. 818–821) was appeared his outstanding work on the observation of new phenomenon: the electropolarization of and the rectification on the contact metal-semiconductor region. Later on (1940), it was rediscovered and called the Schottky barrier. The next pioneer result was related to the electro-adsorption effect – charging the semiconducting oxide surface (Cu_2O) [Zh. Eksp. Teor. Fiz. **20**, 854 (1950)]; similar experiments was done on Ge by Nobel's prize winner J. Bardeen at the same time. It is also worth noting the experimental discovery and study of the electron mechanism of catalysis, predicted theoretically by F.F. Volkenshtein, by V.I. Lyashenko with co-workers [Dokl. Akad. Nauk Ukr. SSR **3**, 350 (1962)]. The systematization of the parameters of surface states was presented in the monograph written by V.I. Lyashenko together with his co-workers [V.I. Lyashenko, V.G. Litovchenko, I.I. Stepko, V.I. Strikha, and L.V. Lyashenko, *Electron Phenomena on Semiconductor Surfaces* (Naukova Dumka, Kyiv, 1968) (in Russian).