THE EFFECT OF AN ANISOTROPIC PRESSURE ON THE REVERSE CURRENTS AND THE LIFETIME OF MINORITY CARRIERS IN GERMANIUM DIODES

V. I. Gaman and V. F. Agafonnikov

Izvestiya VUZ. Fizika, Vol. 10, No. 6, pp. 54–57, 1967

The effect of pressure on the reverse currents, the lifetime of minority carriers and the charging capacitance of fused germanium diodes is considered. The p-n junctions are arranged in the (111) crystallographic plane. It is established that the reverse current increases rapidly with increased pressure. The lifetime of minority carriers falls by a factor of 1.5 to 2 up to a pressure of $3 \cdot 10^9$ dyne/cm^2 and the charging capacitance increases. Starting from a pressure of $3 \cdot 10^9$ dyne/cm^2 the lifetime of minority carriers increases and the charging capacitance is reduced to a particular constant value. A qualitative explanation of the dependence of τ_e, C_j and I_{rev} is given.

At the present time there are a number of papers [1–5] dealing with the effect of mechanical pressure

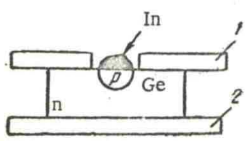

Fig. 1

on the current-voltage characteristics of semiconductor devices. In [1, 2] the effect of anisotropic pressure on the resistance of shallow surface p-n junctions was considered. It was established that the reverse currents are changed by a whole order of magnitude, while the forward currents are affected to a lesser extent. A uniaxial pressure leads to an increase in the forward and reverse currents and to a reduction in the breakdown voltage [3, 4]. Matsuo [5] obtained results which indicate that with an anisotropic pressure of the order of $1.1 \cdot 10^4$ kg/cm^2 the lifetime of the minority carrier current in Si transistors is reduced. The precise reason for these changes in reverse current and lifetime has still not been established. However, suggestions have been made that in this case we have the simultaneous action of several mechanisms associated with a) a change in the width of the forbidden zone, b) the appearance in the space-charge region of generative-recombination centers due to an increase in the concentration of defects, and c) surface effects.

In this paper we shall consider the effect of an anisotropic pressure on the current-voltage characteristic, the lifetime of minority carriers and the charging capacitance of alloyed germanium diodes. The diodes were made of n-type germanium having a specific resistance of 2–3 ohm · cm, and the p-n junction was formed in the (111) crystallographic plane at a temperature of 550° C. The thickness of the base of the diodes was 2 mm. The pressure was applied by means of a lever in a direction perpendicular to the (111) plane, i. e., along the direction of current flow. For this the diode was squeezed between two plates of plexiglass in one of which there was a circular hole. A pellet of indium projected into this hole, the diameter of which was somewhat greater than the indium pellet. Thus the edge of the plate was close to the spacecharge region of the p-n junction (Fig. 1). With this form of upper plate the minimum mechanical stress developed in the base of the diode will be distributed at the center of the p-n junction, and the stress will increase as we move from the center to the edge of the hole. The pressure is considered as the applied force divided by the area of the boundary of the diode base. It can be seen from Fig. 2 that as the pressure is increased the reverse current increases, and the greater the reverse bias the greater the increase in current due to the pressure. With a bias of 5 V and a pressure of $3 \cdot 10^9$ dyne/cm^2 the current increases by a factor of approximately three, and with a bias of 50 V by almost two orders: when the pressure is removed the reverse current returns to its initial value. The behavior of the reverse current-voltage characteristics can be explained in accordance with Rindner [1]. With an increase in the reverse voltage the space-charge of the p-n junction broadens out and falls within the region of greater

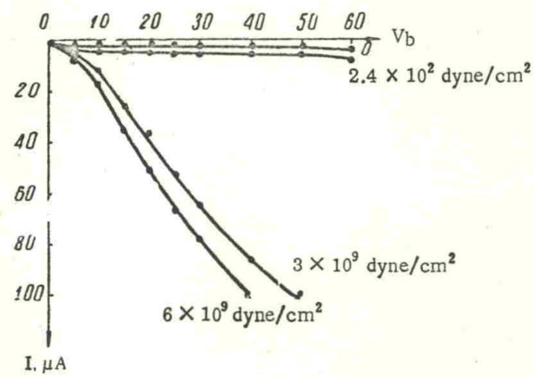

Fig. 2

mechanical stress, which in turn leads to a sharper change in current. The increase in current, starting from a pressure of the order of $(2–3) \cdot 10^9$ dyne/cm^2, causes a rise in the concentration of minority charge carriers in the diode base because of the deformation of the energy bands [3]. At lower pressures it seems that the change in reverse current can be explained by a change in the lifetime. In order to clarify this problem simultaneous measurements were made of the relaxation time τ_r of the transient on switching the diode from a neutral to a conducting state [6] at different pressures. This relaxation time τ_r for a diode with a thick base ($d \gg L_p$) should be the same as the volume lifetime of the carriers τ_p, but since the areas