Dependence of τ_r on Pressure

No. of specimen / dyne/cm²	τ_r, μsec 0	$1\cdot10^9$	$2.4\cdot10^9$	$4\cdot10^9$	$4.5\cdot10^9$	$6\cdot10^9$	0
1	1.35	—	0.75	1.23	—	—	1.35
2	2.38	—	1.90	2.30	—	2.68	2.32
3	6.85	—	4.65	6.65	—	—	6.85
4	8.30	6.10	5.30	6.73	8.10	—	8.30
5	4.35	3.20	3.08	4.80	—	—	4.35
6	2.00	1.75	1.18	3.30	—	—	2.00

of the p-n junctions in our diodes were small, and therefore recombination of the minority carriers at the surface of the germanium round the injection contact played a significant part, a certain effective lifetime was measured. Taking into account the effect of the space-charge on the relaxation of a transient [7]

$$\tau_r = \tau_e + R_j C_j, \qquad (1)$$

where C_j is the charging capacitance of the p-n junction, and R_j is the resistance of a p-n junction with a small bias of $(2-3)\cdot10^{-3}$ V. Results of measuring τ_r are given in the table.

It can be seen from the table that τ_r falls by a factor of 1.5 to 2 for a pressure of about $(2-3)\cdot10^9$ dyne//cm², and with a further rise in pressure it increases. The quantity τ_r only approximately reflects the change in τ_e with increased pressure since the value of C_j also depends on the pressure. The capacitance of the p-n junction was measured at different pressures by the resonance method, and the dependence of C_j on pressure obtained in this way is given in Fig. 3. This dependence of C_j on pressure can be explained qualitatively as follows. With zero bias

$$C_j = A\left(\frac{\varepsilon\varepsilon_0 qN_d}{2\varphi_k}\right)^{1/2}, \qquad (2)$$

where ε and ε_0 are the dielectric constants of the semiconductor and of free space respectively and N_d is the concentration of donor impurity atoms,

$$\varphi_k = \frac{kT}{q}\ln\frac{p_p\cdot n_n}{n_i^2}. \qquad (3)$$

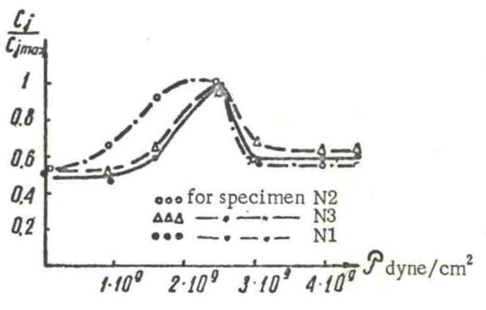

Fig. 3

Because of the compression of the semiconductor in the region of the p-n junction N_d may increase and therefore C_j also. On the other hand with an increase in pressure the deformation of the energy band of n-germanium becomes all the more marked directly in the region of the space-charge of the p-n junction.

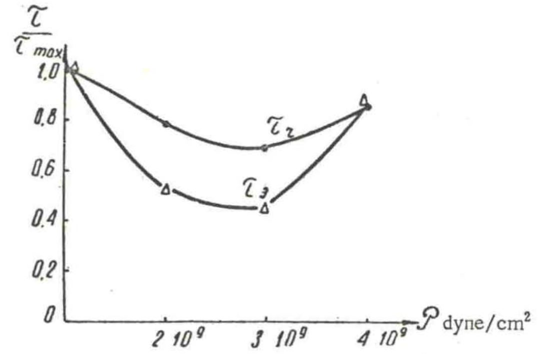

Fig. 4

This should lead to an increase in φ_k and a reduction in C_j, since in the presence of the contact there are two semiconductors (p- and n- regions of the p-n junction) with different widths of forbidden zone, and the width of the forbidden zone of the n-semiconductor falls with increase in the pressure (the mechanical stress in the p-region is practically zero). Apparently the interaction of these factors also leads to a complicated dependence of C_j on the pressure, which has been found experimentally. The resistance of the p-n junction R_j changes very little with increase in pressure. Knowing R_jC_j for different pressures we can calculate τ_e from (1).

The dependence of τ_r and τ_e on pressure is given in Fig. 4 for one of the specimens. It can be seen from the graph that τ_e changes more sharply than τ_r with increased pressure. The reduction in τ_e with a rise in pressure is due, apparently, to an increase in the number of defects, which act as recombination centers [5]. The subsequent increase in τ_e may be caused by a rise in the level of injection at which τ_e is measured. The measurement of τ_e at all pressures was carried out with the same dc bias, and as a result the excess concentration of holes at the boundary of the space-charge region and the base

$$\Delta p = p_n\left(e^{\frac{qV}{kT}} - 1\right) \qquad (4)$$