DIFFUSION OF CHARGED CARRIERS THROUGH THE FRONT OF A SHOCK WAVE IN BISMUTH

A. G. Ivanov, V. N. Mineev, E. Z. Novitskii, Yu. V. Lisitsyn, and Yu. N. Tyunyaev

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It is known that the passage of a shock-wave front (SWF) through a dielectric polarizes the latter and causes current flow in a closed circuit of which this dielectric is one of the elements [1,2]. Similar effects accompany also shock compression semiconductors [3]. It is of interest to investigate also electric processes in SWF in metals.

There are two reasons why an emf should arise on a SWF in a metal.

1. The difference in the concentrations of the high-mobility areas ahead and behind the SWF, due to the compression of the matter, leads to diffusion of these carriers and emf as a result of violation of electroneutrality of the substance in front and behind the SWF.[*]

2. A jumplike change in the velocity of the matter on the SWF causes violation of the electroneutrality of the substance as a result of the carriers jumping through by inertia, giving rise to an emf which opposes such a jump-through (a phenomenon similar to the Mandel'shtam-Papaleksi effect). It is obvious that if in the former case the sign of the emf ahead of the SWF coincides with the sign of the carriers, it is reversed in the latter case.

Experiments have shown that one of the metals in which this effect is sufficiently large is bismuth. Shock waves in samples made of commercial bismuth were produced with the aid of explosive setups described in [4]. The experimental setup is shown in Fig. 1. The sample thickness was ℓ = 0.17 - 0.97 cm, and the diameter 2 cm. The parameters of the material behind the SWF (pressure 260 kbar, temperature 1800°K, compression 1.4) were calculated from the known state of the screen [4] and the equation of state of the bismuth, which is given in [5].

A typical oscillogram of the signal registered in the experimental setup of Fig. 1a is shown in Fig. 2a. At the instant t_1 when the SWF enters the sample, a voltage jump is produced across the resistance R. When the SWF emerges from the sample (t_2), the voltage drops abruptly.[**] The duration of the voltage U(t) as a function of the time coincides with

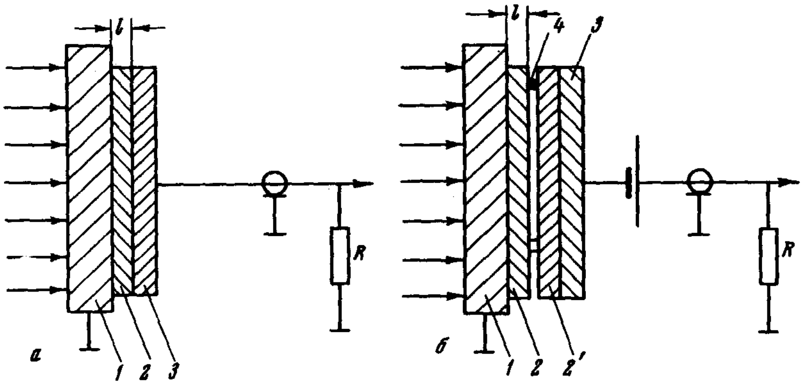

Fig. 1. Experimental setup: 1 - aluminum scrren 1 cm thick, 2, 2' - bismuth samples, 3 - copper electrode, 4 - insulator (teflon) 0.05 cm thick, R (100 ohm) - input resistance of OK-33 oscilloscope. The arrows indicate the propagation direction of the SWF.

the calculated time of motion of the SWF through the sample:

$$t_2 - t_1 = \ell/D$$

(D = 0.5 mm/μsec is the SWF velocity).

A characteristic feature of all the obtained U(t) traces is a noticeable rise of the voltage 0.3 - 0.5 μsec prior to the emergence of the SFW from the sample, regardless of the sample thickness. In Fig. 1a, the emf produced on the SWF is practically entirely across R. Therefore the growth of U(t) when the SWF approaches the electrode 3 can be attributed to the occurrence of a "precursor" at 0.1 - 0.15 cm in the undisturbed substance ahead of the shock wave. No such phenomenon was observed in solid dielectrics or semiconductors, but according to [6] it took place in rarefied argon, where the depth of penetration of the "precursor" was on the order of several meters.

The circuit (Fig. 1b), with an external emf source, is a capacitive pickup for the measurement of the velocity of the free surface [7]. In the absence of a "precursor," a current surge of definite magnitude is produced in the circuit of such a pickup at the instant of the emergence of the SWF on the free surface, proportional to the mass velocity behind the SWF. In the presence of the "precursor" in front of the SWF, electric currents will enter into the gap between the samples 2 and 2', causing a gradual increase of the current in this circuit prior to the emergence of the SWF to the free surface of the sample 2.

Direct experiments performed in accordance with the scheme 1b at E = 700 V (field intensity in the gap 14 kV/cm) have shown that the character of the current in the circuit confirms the existence of a "precursor." A typical oscillogram for a field directed in the gap

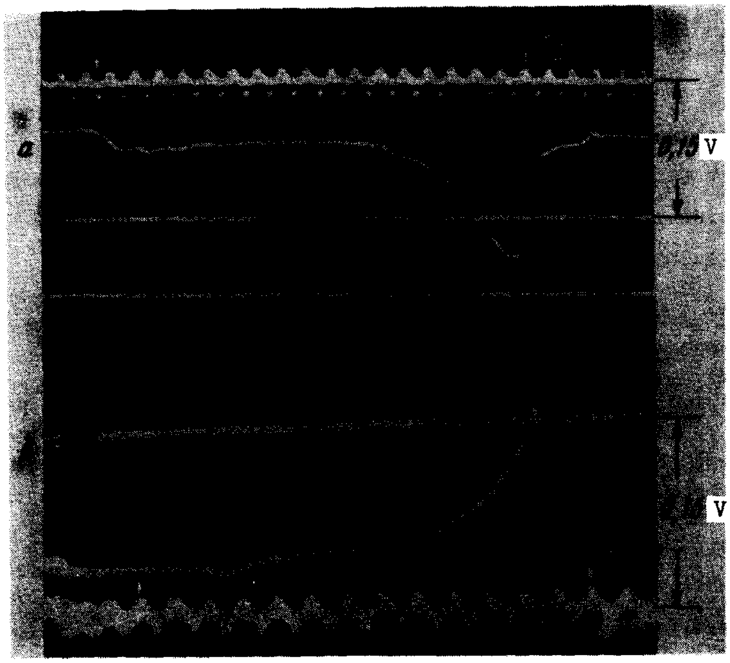

Fig. 2

from 2 to 2' is shown in Fig. 2b. When the sign of the field is reversed, only the polarity of the registered signal changes.

Since the intensity of the field in the gap was approximately half the breakdown value for air under normal conditions, a saturation current, determined by the number of carriers from the "precursor," was flowing through the circuit at each instant. This made it possible to estimate the value of the charge σ diffusing from the free surface into the gap upon approach of the SWF: $\sigma \sim 10^{-10}$ C/cm^2 (or 10^9 carriers/cm^2).

The fact that the registered signal had a negative polarity in the experiments made with the setup of Fig. 1a indicates that the carriers moving in front of the SWF in bismuth are negative, apparently electrons.

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* The transport of the ions of the metal is neglected, in view of the low mobility of the ions compared with that of the carriers.

** The instants t_1 and t_2 were determined by means of a reference signal.

ABSORPTION OF ENERGY OF HOT ELECTRONS BY SEMICONDUCTOR SURFACE

A. I. Klimovskaya and O. V. Snitko
Semiconductor Institute, Ukrainian Academy of Sciences
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It was shown in a number of theoretical and experimental papers [1] that the mobility of carriers decreases with decreasing thickness of the crystal. It was predicted theoretically in [2] that the situation may be reversed in strong electric fields, the carrier mobility increasing with increasing thickness. There is no experimental confirmation of such an effect. Investigations are known in which broadening of the region of validity of Ohm's law in thin layers was observed [3], but this might have been due either to the diffuse nature of the scattering [1] or to the cooling of the carriers on the surface [2].

The present study was undertaken to verify the conclusions of [2] experimentally. In this communication we present the results of an investigation of the thickness dependence of the current-voltage characteristics in thin surface layers of n-Si, from which we conclude that the energy of the hot electrons is absorbed by the surface of the semiconductor.

The investigations were made on n-Si single crystals (ρ = 200 ohm-cm) at two fixed temperatures (300 and 77°K). The resistance behavior of the contacts, which were prepared by the technology of [4], was monitored against the form of short current pulses flowing through the sample. To obtain thin surface layers we used the surface field effect [5] in