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**Abstract**

**Full Text**

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## **EXPLANATION OF THE SATURATION OF THE DRIFT VELOCITY OF CURRENT CARRIERS IN PIEZOELECTRIC SEMICONDUCTORS**

*(Presented by Academician B. P. Konstantinov, 21 XI 1963)*

Recently R. W. Smith (<sup>1</sup>) discovered, in semiconductors possessing piezoelectric properties (CdS, CdSe, GaAs), saturation of the drift velocity of current carriers at  $v_{dr} > s$ , where  $s$  is the speed of sound. The fact that the break in the current-voltage characteristic occurs at  $v_{dr} \approx s$  convincingly indicated a connection of this phenomenon with the generation of ultrasonic vibrations. Somewhat later Mac Fee (<sup>2</sup>) repeated R. W. Smith's experiments and recorded a large flux of ultrasonic energy accompanying the deviation of the current-voltage characteristic from Ohm's law. This deviation can be understood by using the concept of an acoustoelectric current constituting part of the total current. At  $v_{dr} > s$  the acoustoelectric current is directed opposite to the direction of amplification of the sound, and consequently also opposite to the current. Therefore the increase of current with voltage is slowed. A similar explanation is contained in Hutson's work (<sup>2</sup>); however, to explain the steady-state regime he invokes a nonlinear mechanism of acoustic losses due to phonon-phonon interaction.

In the present work it is shown that the limitation of ultrasonic amplification is caused by the limitation of the drift velocity of current carriers, so that the mechanism proves to be self-consistent. The excess power released in the sample at such voltages, when  $v_{dr} > s$ , is spent not on generating ultrasonic vibrations, but is released directly in the form of Joule heat. If one considers the amplification of thermal noises with allowance for the frequency dependence of the amplification coefficient, and also the fact that the potential difference on the sample is determined not only by the ohmic part of the electric field but also by the acoustoelectric emf, then the current-voltage characteristic of the sample will have the form

$$V = \frac{|j| sd}{j_s \mu_n} + \frac{2 \varepsilon \omega_m}{3 \varepsilon \pi s} \frac{\exp \left[ -\frac{\eta^2 \omega_D d}{4 \varepsilon c s} \left( 1 - \frac{|j|}{j_s} \right) \right]}{\sqrt{\frac{\eta^2 \omega_D d}{4 \varepsilon c} \left| 1 - \frac{|j|}{j_s} \right| - 1}}, \quad (1)$$

where  $j$  is the density of the current flowing through the sample;  $d$  is the length of the sample;  $s$  is the speed of sound;  $\omega_m = \sqrt{\omega_\sigma \omega_D}$ ;  $\omega_D = s^2/D$ ;  $j_s = ens$ ;  $n$

is the concentration of free electrons in the material;  $\varepsilon$  is the dielectric constant;  $\omega_\sigma = 4\pi\sigma/\varepsilon$ ;  $\sigma = en\mu_n$ ;  $\mu_n$  is the electron mobility;  $e$  is the electron charge;  $c$  is the elastic constant;  $\eta$  is the piezoelectric constant.

Formula (1) explains the experimental results of work ( $\hat{1}$ ). In application to CdS with  $\sigma = 0.01 \Omega^{-1}\text{cm}^{-1}$  at  $T = 300^\circ\text{K}$ ,  $d = 0.5 \text{ cm}$ ,  $\eta^2/2\varepsilon c = 0.015$ , formula (1) has the form

$$V = \left\{ 8 \cdot 10^2 \frac{|j|}{j_s} + 10^{-4} \frac{\exp \left[ -225 \left( 1 - \frac{|j|}{j_s} \right) \right]}{\sqrt{225 \left| 1 - \frac{|j|}{j_s} \right| - 1}} \right\} \text{ volts,}$$

i.e., it leads to a sharp saturation of the current at  $|j| > j_s$ , or to saturation of the drift velocity.

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## CITED LITERATURE

1. R. W. Smith, *Phys. Rev. Letters*, **9**, 87 (1962).
2. A. R. Hutson, *Phys. Rev. Letters*, **9**, 296 (1962).

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

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