NEGATIVE DIFFERENTIAL CONDUCTIVITY (NDC) CONNECTED WITH ACOUSTOELECTRIC CURRENT

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The formation and propagation of sound-flux bunches was observed in certain semiconductors under conditions of acoustic instability [1-3]. This phenomenon is outwardly similar to electric domain formation [4]. However, the nature of the NDC responsible for the formation of acoustic domains is still unclear. We shall show in this note that the N-shaped current-voltage characteristics can be inherent in this stationary and homogeneous state that should set in during amplification of sound. This state can further be unstable against domain formation and then, in fact, it does not arise.

Consider a sound flux W(x, t) with $q\ell >> 1$ (q = wave number of sound, ℓ = electron mean free path). Let the flux propagate in the direction of the electronic supersonic drift (x axis). This may be either an external flux or a flux developed as a result of intrinsic fluctuations. In the latter case the order of magnitude of q corresponds to the maximum gain. The continuity equation for W(x, t) is

$$\frac{\partial W}{\partial t} + s\frac{\partial W}{\partial x} = -s(\alpha + \alpha_L)W, \tag{1}$$

where s is the speed of sound and α and α_L are the electronic and spin absorption coefficients. Using a method similar to that developed in [5], it is easy to express the antisymmetrical part of the electron distribution function in terms of the flux W (the symmetrical part is assumed to be in equilibrium). With the aid of the obtained distribution function, we calculate α and the electron-current density j. We shall confine ourselves henceforth to the case when electron scattering by an ionized impurity prevails. Then

$$\alpha(w,\beta,\xi_0) = \alpha_0(\xi_0)\{\Gamma(4) - \beta e^{\xi_0}\Gamma(\tfrac{5}{2})\Gamma(\tfrac{5}{2},\xi_0)]/\Gamma(4)(w+1)\}, \tag{2}$$

$$\frac{j}{ens} = \beta + \frac{w}{(w+1)}[\Gamma(\tfrac{5}{2},\xi_0)/\Gamma(\tfrac{5}{2}) - \Gamma(4,\xi_0)\beta/\Gamma(4)]. \tag{3}$$

Here $w = W/W_0$, where W_0 is the characteristic flux ($W_0 \gtrsim 1$ W/cm^2), $\beta = \mu E/s - (D/sn)(\partial n/\partial x)$, where E is the electric field intensity, μ and D are the mobility and diffusion coefficient in a weak field ($\mu/D = e/kT$), n is the electron density, $\xi_0 = \hbar^2q^2/8mkT$, and $\Gamma(\nu)$ and $\Gamma(\nu, \xi_0)$ are the complete and incomplete Γ functions. The first term in (3) corresponds to the ohmic current, and the second to the acoustoelectric current.

The complete system of equations includes, besides (1) - (3), also the Poisson equation and the continuity equation for the electrons. Being interested in the homogeneous and stationary state, we set the equations with respect to x and t equal to zero. Then Eq. (1) has the trivial solution $w_1 = 0$. It is clear from (3) that in this state ($w = w_1 = 0$) the current-voltage characteristic is ohmic. Substituting (2) in (1) we verify that above the threshold field, i.e., when

$$\beta > \beta_0(\xi_0) = e^{-\xi_0}\Gamma(4)\Gamma^{-1}(\frac{5}{2})\Gamma^{-1}(\frac{5}{2}, \xi_0)[1 + \frac{a_L(\xi_0)}{a_0(\xi_0)}], \tag{4}$$

there exists one more stationary state

$$w_2 = a_0(\xi_0)[\beta e^{\xi_0}\Gamma(\frac{5}{2})\Gamma(\frac{5}{2}, \xi_0) - \Gamma(4)]/a_L(\xi_0)\Gamma(4) - 1. \tag{5}$$

From (3) we find that in this state ($w = w_2$)

$$\frac{j}{ens} = \Gamma(\frac{5}{2}, \xi_0)/\Gamma(\frac{5}{2}) + [\Gamma(4) - \Gamma(4, \xi_0)]\beta/\Gamma(4) - a_L[\Gamma(4)\Gamma(\frac{5}{2}, \xi_0) - \beta\Gamma(\frac{5}{2})\Gamma(4, \xi_0)]/a_0\Gamma(\frac{5}{2})[\beta e^{\xi_0}\Gamma(\frac{5}{2})\Gamma(\frac{5}{2}, \xi_0) - \Gamma(4)]. \tag{6}$$

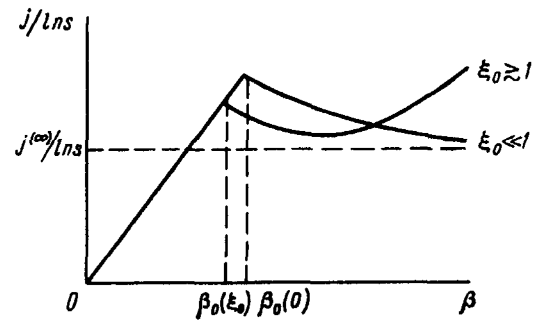
Below the threshold ($\beta < \beta_0(\xi_0)$) the j( ) dependence is ohmic. In the field interval

$$\beta_0(\xi_0) < \beta < e^{-\xi_0}\Gamma(4)\Gamma^{-1}(\frac{5}{2})\Gamma^{-1}(\frac{5}{2}, \xi_0)\{1 + \sqrt{a_L(\xi_0)[\Gamma(4, \xi_0) - e^{\xi_0}\Gamma^2(\frac{5}{2}, \xi_0)]/a_0(\xi_0)[\Gamma(4) - \Gamma(4, \xi_0)]}\} \tag{7}$$

the differential conductivity is negative ($d_j/d_\beta < 0$ and the current-voltage characteristic is of the form shown in the figure. When $\xi_0 \to 0$, saturation of the current takes place with increase in β: as $\beta \to \infty$ we have

$$j(\beta) \to j(\infty) = ens\ [1 + \frac{a_L}{a_0}\Gamma(4)\ \Gamma^{-2}(\frac{5}{2})]\ (\text{see}(6)).$$

On the other hand, the threshold current exceeds the saturation current: $j(\beta_0) > j(\infty)$. This explains the appearance of a drooping section on the current-voltage characteristic when $\beta > \beta_0$. When ξ_0 is finite and β large, the current increases. The reason is that, by virtue of the conservation laws, the electrons with $\varepsilon < T\xi_0$ do not interact with the phonons and are acted upon only by the electric field.



We note that a current-voltage characteristic of the type shown in the figure was observex experimentally in low-resistance CdS crystals [6]. The authors of that reference and of the succeeding ones [7,8] have reached the conclusion that their experimental data agree with the theory developed for $q\ell \gg 1$, and does not agree with the theory for $q\ell \ll 1$. This gives grounds for assuming that the NDC mechanism considered by us (which holds when $q\ell \gg 1$) will prove to be useful for the interpretation of the indicated experiments. In particular, the observation current oscillations and domain formation [7, 0, 10] can be attributed to the instability of the stationary state (5). Calculation shows that such an instability should indeed arise if the NDC is sufficiently large.

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ERRATA

Article by F. V. Lisovskii and Ya. A. Monosov, "Echo Pulses in Yttrium Iron Garnet," (Vol. 5, No. 1, p. 3).

An additional experimental investigation of the phenomena described in the article has revealed that the observed "anomalies" in the behavior of the magnetostatic echo pulses (the independence of the echo-pulse duration of the exciting-pulse duration, the displacement of the echo pulse behind the trailing front of the exciting pulse, dependence of the delay time on the peak power of the exciting pulse) are produced not by the properties of the ferrite, but by the lack of suitable protection of the receiver against overload by the exciting pulse. Therefore the echo pulses described in the paper should be regarded as ordinary magnetostatic pulses, the initial sections of which could not be observed as a result of receiver overlad.

Article by V. M. Lobashov et al., "Circular Polarization of Gamma Quanta from Ta^{181}," (Vol. 5, No. 2, p. 60).

The corrected Table I follows:

Source	Filter thickn.	δ	P
^{46}Sc ^{82}Br	2 mm	$+(0.5\pm0.3)\cdot10^{-7}$	
^{181}Ta I	2 mm	$-(3.3\pm0.7)\cdot10^{-7}$	Polarization of Ta^{181} γ quanta with allowance for control experiment errors
^{181}Ta II	1 mm	$-(2.9\pm0.65)\cdot10^{-7}$	
^{181}Ta III	2 mm	$-(2.4\pm0.65)\cdot10^{-7}$	$-(6\pm1.1)\cdot10^{-6}$
Averaged with weight		$-(2.9\pm0.4)\cdot10^{-7}$	$-(6\pm0.8)\cdot10^{-6}$
^{46}Sc ^{82}Br	2 mm	$-(0.7\pm0.6)\cdot10^{-7}$	

Article by E. S. Itskevich and L. M. Fisher, "Measurement of Shubnikov - de Haas Effect in Graphite at Pressures up to 8 kbar," (Vol. 5, No. 5, p. 115)

The name of the organization supplying the synthetic graphite (NIIGrafit - Graphite Reserach Institute) was left out of the article.