satisfied[4].

The connection between the CRP and the Harari model was recently considered also by Desai [1, 2], who showed that if we assume the formula (2a) for Im $T_{\Delta\lambda}$, then the total amplitude $T_{\Delta\lambda}$ can be represented in the form of contributions of a pair of complex-conjugate poles.

In conclusion we note that, within the framework of two-component duality, the procedure proposed above for using the sum rules can be applied also to contributions connected with the Pomeranchon in the case when the effective contribution of P and of its "accompanying" cut can be represented in CRP form.

[1] B. Schrempp-Otto and F. Schrempp, Preprint DE3V 71/46, 1971.
[2] R.J.N. Phillips, Paper at the Amsterdam International Conference on Elementary Particles, 1971.
[3] G.F. Chew and D.R. Snider, Phys. Lett. 31B, 75 (1970); J.S. Ball, G. Marchesini, and F. Zachariasen, Phys. Rev. Lett. 25, 1389 (1970).
[4] V.A. Tsarev, Paper at International Seminar on Binary Hadron Reactions, Dubna, 1971.
[5] B.R. Desai et al., Phys. Rev. Lett. 25, 1389 (1970).
[6] N.P. Zotov and V.A. Tsarev, Yad. Fiz. 14, 806 (1971) [Sov. J. Nuc. Phys. 14, No. 4 (1972)].
[7] H. Harari, Phys. Rev. Lett. 26, 1400 (1971); SLAC-PUB-914, 1971.
[8] A. Logunov, L. Soloviev, and A. Tavkhelidze, Phys. Lett. 24B, 181 (1967).
[9] F. Schrempp, Phys. Lett. 29B, 598 (1969).
[10] N.P. Zotov, S.V. Tarasevich, and V.A. Tsarev, ZhETF Pis. Red. 14, 120 (1971) [JETP Lett. 14, 79 (1971)]. N.P. Zotov, O. Suguhashi, and V.A. Tsarev, Kratkie soobshcheniya po fizike (Brief Physics Communications), FIAN No. 9, 1971.
[11] P. Sonderegger, Paper at International Seminar on Binary Hadron Reactions, Dubna, 1971.
[12] B.R. Desai, Preprint RLO 1388-614, 1971.

NEGATIVE DIFFERENTIAL CONDUCTIVITY OF A TWO-VALLEY SEMICONDUCTOR HAVING NO NEGATIVE SECTION OF THE V(E) CHARACTERISTIC

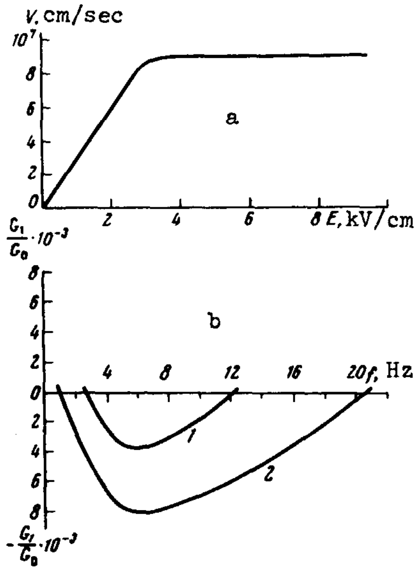
E.D. Prokhorov and N.I. Beletskii
Khar'kov State University
Submitted 25 November 1971
ZhETF Pis. Red. 15, No. 2, 102 - 104 (20 January 1972)

It is known that the negative differential conductivity of a two-valley semiconductor in which the Gunn effect is observed depends on the carrier mobility μ_1 in a weak electric field. At low carrier mobility (e.g., ∿2000 - 3000 cm^2/V-sec for GaAs), the negative section in the static V(E) characteristic vanishes [1]. The ensuing current instability should also vanish.

We show below that in such a semiconductor, i.e., when the V(E) characteristic has no negative section, there appears under certain conditions and in a definite frequency band a negative differential conductivity due to the inertia of the carrier redistribution among the conduction subbands.

---

[4] We note that the amplitudes obtained by us with the aid of the sum rules for [6] for the reaction $\pi^- p \to \pi^0 n$ satisfy the conditions (2) and have correctly predicted the polarization [11].



a - V(E) plot, b - plot of G_1/G_0 vs. f at $E_0 = 5$ kV/cm and $E_1 = 2.1$ kV/cm (1) and $E_0 = 10$ kV/cm and $E_1 = 7.1$ kV/cm (2).

We consider a two-valley semiconductor with a V(E) characteristic of the type shown in Fig. a (we assume, for concreteness, that this is GaAs with $\mu_1 \sim 3000$ cm^2/V-sec). In a homogeneous crystal in the absence of concentration effects, the change of the electron concentration in each of the conduction subbands, following a change in the electric field intensity, is described by the equations

$$\frac{\partial n_1}{\partial t} = -\frac{n_1}{\tau_1} + \frac{n_2}{\tau_2}, \tag{1}$$

$$n_1 + n_2 = n_0$$

n_1 is the electron concentration in the central valley, n_2 the electron concentration in the side valleys, n_0 the electron concentration in the conduction band, τ_1 the time of electron relaxation from the central valley to the side ones (and depends strongly on the field), and τ_2 the time of electron relaxation from the side valleys to the central ones (depends little on the field and equals $\sim 2 \times 10^{-12}$ sec [2]). The relaxation time τ_1 depends on E in a complicated manner. In our calculations we assumed an approximation in the form

$$\tau_1(E) = \tau_2 \frac{E_n}{E - E_n}, \quad E > E_n \tag{2}$$

which agrees sufficiently well with the actual $\tau_1(E)$ dependence for the low-mobility case under consideration. In (2), E_n is the threshold electric field intensity, $E = E_0 + E_1 \cos \omega t$, E_0 is the dc component of the electric field on the sample, and E_1 the amplitude of the ac component. From (1) and (2) we obtain

$$\frac{\partial n_1}{\partial t} = -\frac{E_0 + E_1 \cos \omega t}{E_n \tau_2} n_1(t) + \frac{n_0}{\tau_2}. \tag{3}$$

The initial condition is determined from (3) with $\partial n_1/\partial t = 0$.

From (3) we determine $n_1(t)$, the time dependence of the electrons in the central valley following application of a microwave field to the sample. Knowing $n_1(t)$ we can determine

$$V[E(t)] = \left[\frac{n_1(t)}{n_0} (\mu_1 - \mu_2) + \mu_2 \right] E(t). \tag{4}$$

The dynamic V(E) characteristics given in (4) make it possible to determine the shape of the current flowing through the diode, the amplitude of its first harmonic, and, if the acting voltage is known, also the active conductivity of the sample in the frequency band.

Equations (3) and (4) were solved by numerical methods with a computer. We used in the calculations $E_n = 3$ kV/cm, $n_0 = 10^{15}$ cm^{-3}, $\mu_2 \sim 100$ cm^2/V-sec, $\mu_1 \sim 3000$ cm^2/V-sec, $E_0 = 10$ kV/cm, and $E_1 = 7.1$ kV/cm for one case and $E_0 = 5$ kV/cm and $E_1 = 2.1$ kV/cm for another case. The results were used to plot G_1/G_0 against f (Fig. b), where G_1 is the conductivity of the sample for an appropriate bias and amplitude of the acting voltage, and G_0 is the active sample conductivity in a weak field.

The calculation results show that a two-valley semiconductor having no negative section in the V(E) characteristic has a negative differential conductivity in a frequency band (Fig. b). With increasing dc electric field intensity, the frequency band in which the negative differential conductivity is observed broadens. The negative differential conductivity of such a semiconductor can be used for generation and amplification. According to the calculations, the efficiency of a generator based on the negative differential conductivity of such a semiconductor is 0.6 - 0.7%.

[1] J.B. Bott and C. Hilsum, IEEE Trans. ED-14, 9, 492 (1967).
[2] E.M. Conwell and M.O. Vassell, IEEE Trans. ED-13, 1, 22 (1966).

THERMOKINETIC EFFECTS IN LIQUID METALS

V.B. Fiks
Semiconductor Institute, USSR Academy of Sciences
Submitted 29 November 1971
ZhETF Pis. Red. 15, No. 2, 104 - 107 (20 January 1972)

Perturbation of the electron subsystem of a metal by a temperature gradient leads to the appearance of forces acting on the ionic "core": 1) the electron "wind" force $F_{ni}^{(0)}$ due to momentum transfer from the electrons to the ions, 2) the direct force $F_q^{(0)}$ exerted on the lattice ions by the thermoelectric field, and 3) the force F_p due to the electron-gas pressure gradient. In a homogeneous unbounded metal, the total density of these forces is equal to zero [1].

Near the metal surface, however, the local mechanical equilibrium may be disturbed. If the electrons are diffusely scattered when they collide with the surface, then a fraction of the momentum flux is transferred to the metal surface and the electron "wind" force at a point z near the metal surface will differ from the volume value, $F_{ni}(z) \neq F_{ni}^{(0)}$. The additional scattering mechanism may change the thermoelectric field E and the force $F_q = qNE$ it exerts on the ionic "core" (q is the ion charge and N the number of ions per cm^3). Thus, the electron kinetic force produced at the surface of the metal in a layer of thickness on the order of the electron mean free path ℓ is

$$F = (F_{ni} - F_{ni}^{(0)}) - (E - E^{(0)})qN. \qquad (1)$$

These forces produce in liquid metals thermokinetic phenomena governed by a purely electronic mechanism, namely thermoosmosis (flow of metal) and thermophoresis (motion of particles in the metal). We consider electronic thermoosmosis in a liquid metal. Let the metal be located in a flat capillary (see the figure) of width $a \gg \ell$. The temperature gradient is directed along the x axis ($\nabla T = (\partial T/\partial x)$). The metal circuit is open and the current is equal to zero. In the free-electron approximation the force of the electron "wind" is equal to [1]