Negative-affinity emitter based on a semiconducting ferroelectric

A. G. Zhdan, V. B. Sandomirskiĭ, and E. V. Chenskiĭ

(Submitted November 28, 1974; resubmitted January 3, 1975)
ZhETF Pis. Red. **21**, No. 3, 199–200 (February 5, 1975)

We wish to call attention to the feasibility, in principle, of producing a semiconducting-ferroelectric emitter with negative affinity.

As is well known,[1] in a free plate of a ferroelectric semiconductor below the Curie point the spontaneous polarization near the surface is screened by the free and localized carriers, and surface bending of the bands takes place as a result. The semiconducting ferroelectric surface richer in electrons acquires a lower work function and a situation may arise analogous to that existing in emitters with negative electron affinity.[2]

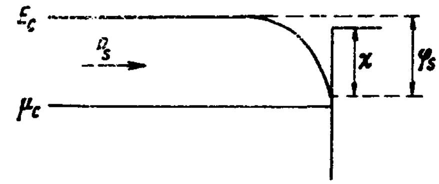
In the absence of surface states, this bending of the bands can be determined from the formula[1]

$$\mu_c - \phi_s \approx T \ln \frac{|\alpha| P_s^2}{4TN_c},$$

where μ_c is the Fermi level in the volume of the semiconducting ferroelectric and is reckoned from the bottom of the conduction band, T is the temperature in energy units, N_c is the effective density of the quantum states in the conduction band, P_s is the spontaneous polarization, and α is the coefficient of P^2 in the expansion of the free energy of the ferroelectric. Relation (1) is valid when the impurity concentration N is much less than N_c. For typical values of the parameters $N_c \approx 10^{19}$ cm^{-3}, $\alpha = -10^{-3}$, $P_s = 5\times10^4$ cgs esu, and $T \approx 300$ °K we have $|\alpha| P_s^2/4TN_c \approx 1$. Consequently, the bending of the bands is $\phi_s \approx |\mu_c|$. Thus, in a broad-band semiconducting ferroelectric this quantity can amount to several electron volts.[1)]

The emissivity of such a system can be controlled by temperature variation of the spontaneous polarization, and its sign can be controlled by the electric field.

In a multidomain semiconducting ferroelectric, the emission depends on the number of domains with corresponding sign of the spontaneous polarization, which



Band scheme of semiconductor-ferroelectric emitter with negative electron affinity. E_c–bottom of conduction band, μ_c–Fermi levels, P_s–spontaneous polarization, χ–electron affinity, ϕ_s–bending of bands.

emerged to the emitting face. This circumstance makes it possible to control the emission current by varying the extent to which the sample is divided into domains, and also permits a study of the domain structure by examining the topography of the emission patterns. We note that the surface states greatly weaken the influence of the spontaneous polarization on the bending of the bands, if their density is $N_s \geq P_s/q$. Usually, however, $P_s/q \approx 10^{14}$ cm^{-2} and $N_s < 10^{-14}$ cm^{-2}. A number of concrete constructions of semiconducting ferroelectric emitters is proposed in[3].

1) To produce negative electron affinity, an additional treatment of the surface by active coatings may be necessary.[2]

[1] E. V. Chenskiĭ, Fiz. Tverd. Tela **12**, 586 (1970) [Sov. Phys.-Solid State **12**, 446 (1970)].
[2] N. N. Petrov, Zh. Tekh. Fiz. **41**, 2473 (1971) [Sov. Phys.-Tech. Phys. **16**, 1965 (1972)].
[3] A. G. Zhdan and V. B. Sandomirskii, Inventor's Certificate No. 404142 with priority 17 April 1972, Invention Bulletin No. 43, p. 162, 1973.