

V. L. Bonch-Bruevich

Moscow State University

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A study was made of several singularities of the static dielectric susceptibility of a disordered semiconductor; these singularities are connected with the characteristic features of its energy spectrum.

It seems that by now there have been established two main features of the energy spectrum of a disordered semiconductor with a random force field, namely, the existence everywhere of a dense spectrum of discrete levels in the forbidden band (regarded as a gap for the mobility) [1 - 4], and the presence of a relatively smooth random bending of the bands [4, 5]. In the present article we study some singularities of the static dielectric susceptibility α of materials of this type. We consider only the contribution made to α by electrons localized on discrete levels (the "atomic" contribution, in connections with Items 3 and 2, is evidently of no particular interest). The temperature T will be assumed to be sufficiently small, $T \ll E_C - F$, $F - E_V$, where E_C and E_V are the upper and lower limits of the gap for the mobility, and F is the Fermi level, which is located within this gap.

1) The specific temperature dependence of α is determined by the redistribution of the carriers over the levels. When the ionization energy W is altered, a change takes place both in the state density $\rho(W)$ and in the polarizability of each individual center¹⁾. The considered contribution to the polarizability is

$$\alpha = \alpha_e + \alpha_h, \quad (1)$$

where α_e and α_h are connected, respectively, with the electrons on the donors and with the holes on the acceptors. Obviously,

$$\alpha_e = \int \bar{\rho}_e(W) \chi_e(W) n_F(W) dW, \quad (2)$$

where $\bar{\rho}_e$ is the smoothed-out density of states²⁾, $\chi_e(W)$ is the effective polarizability of an individual center with ionization energy W , and n_F is the Fermi function. The integral is taken here, strictly speaking, over the entire forbidden band. The formula for α_h is similar to (2). The term "effective" is used to emphasize that the contribution to χ_e is made not only by the deformation of the electron shell of the given spectrum but, generally speaking, also by transitions to other centers. Owing to these transitions, the function χ_e itself can contain an integral of $\bar{\rho}$ with respect to energy; however, the ensuing temperature dependence is weak. Indeed, a change from transitions to states with energies relatively close to F (in the energy region ΔW near F) is small relative to the parameter $\exp(-2\gamma R)$, where $R^3 = 3/\pi\rho(F)\Delta W$, γ is the reciprocal radius of the electron localization at the level F (it is obvious that $\Delta W \ll |F|$). On the other hand, the degree of occupation of the states with $W \ll |F|$ is practically independent of T (being close to zero). The temperature dependence of α can be obtained explicitly in two limiting cases. Namely, we denote by W_0 the characteristic energy over which the function $\bar{\rho}_e(W)$ changes noticeably. When $W_0 \gg T$, the expression in the right-hand side of (2) is the usual Fermi integral. Calculating it by the standard method and taking into consideration the condition $n - p = \text{const}$ (n and p are the total densities of the localized electrons and holes), we obtain

$$\alpha = \alpha_0 + \delta\alpha,$$

$$\alpha_0 = \int_{|F_0|}^{\Delta_0} \bar{\rho}_e(W) \chi_e(W) dW + \int_{\Delta_0 - |F_0|}^{\Delta_0} \bar{\rho}_h(W) \chi_h(W) dW, \quad (3)$$

$$\delta\alpha = \frac{\bar{\rho}_e \bar{\rho}_h}{\bar{\rho}_e + \bar{\rho}_h} (\chi_e + \chi_h) \delta\Delta - \frac{\pi^2}{6} T^2 \left\{ \bar{\rho}_e \chi_e' + \bar{\rho}_h \chi_h' + (\chi_e + \chi_h) \frac{\bar{\rho}_e \bar{\rho}_h' + \bar{\rho}_e' \bar{\rho}_h}{\bar{\rho}_e + \bar{\rho}_h} \right\}. \quad (4)$$

Here Δ_0 is the width of the forbidden band at $T = 0$, $\delta\Delta$ is its temperature shift, and F_0 is the Fermi level at $T = 0$. The first term in (3) is the value of α at $T = 0$; the second is the temperature correction. The "minus" sign in the second term of (4) is connected with the fact that we have $F < 0$ in the assumed normalization of the energy ($E = 0$). The values of \bar{p}_e , χ_e and \bar{p}_h , χ_h in (4) are taken, respectively, at $W = |F_0|$ and $W = \Delta_0 = |F_0|$.

Usually $\delta\Delta$ depends linearly on T . However, the parameters contained in the first and second terms in the right-hand side of (3) can be significantly different, and the second of them can, generally speaking, not be discarded. When $T \gg W_0$ we obtain

$$\delta\alpha \sim C \exp\left(-\frac{|F|}{T}\right), C > 0. \quad (5)$$

The Fermi level is reckoned in this case from the nearest boundary of the gap. We note how the form of the $\delta\alpha(T)$ dependence (and possibly also the sign of $\delta\alpha$) changes on going from the first to the second case. Its observation could, in particular, be of certain interest for a tentative estimate of the parameter W_0 . We have implicitly assumed here that W_0 are of the same order of magnitude for electrons and holes; the generalization to the opposite case is obvious.

2) In principle, temperature activation of electrons to levels with large values of the susceptibility can be replaced by optical activation (obviously, this can be of particular interest at quantum energies $\leq |F|$). The magnitude of this "photodielectric" effect (this name was coined by V. S. Vavilov) depends in obvious fashion on the effective lifetime of the electrons (holes) in the excited state.

3) The internal field produces a random polarization of the material; this polarization varies smoothly in space. In conjunction with the large polarizability of the shallow levels, this circumstance can lead to curious nonlinear effects. The latter, however, deserve a special investigation.

1) The last circumstance has obviously the same nature as the enhancement, noted in [6], of the diamagnetism of localized electrons.

2) Strictly speaking, the density of states in the given region of the spectrum is a "fence" of δ functions; the smoothed-out density of states is its envelope [7].

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