THE HALL MOBILITY IN AMORPHOUS SEMICONDUCTORS BY MODIFIED RELAXATION TIME APPROXIMATION

ХОЛЛОВСКАЯ ПОДВИЖНОСТЬ НОСИТЕЛЕЙ ТОКА В АМОРФНЫХ ПОЛУПРОВОДНИКАХ В ПРИБЛИЖЕНИИ МОДИФИЦИРОВАННОГО ВРЕМЕНИ РЕЛАКСАЦИИ

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The paper [1] presents a phenomenological theory of modified relaxation time, which allows the calculation of transport characteristics in non-crystalline semiconductors. This theory seems to describe qualitatively and partially also quantitatively a great variety of transport phenomena in non-crystalline semiconductors [1, 2].

This note is the addition of two aspects complementary to the above theory:

a) when observing more precisely the physical reality one must consider the presence of both scattering mechanisms (thermal scattering and scattering on charge defects). While thermal scattering takes place at higher temperatures, scattering on charge defects predominates at lower ones;

b) the obtained results must be numerically re-evaluated without using any approximations.

In the expression for modified relaxation time

$$\tau(E) = \tau_k(E) f(E) \tag{1}$$

we use $\tau_k(E)$ in the form of a function

$$\tau_k(E) = \frac{\tau_{of}\tau_{oc}E^{3/2}}{\tau_{of} + \tau_{oc}kTE^2} \tag{2}$$

which is the resulting relaxation time in the mutual influence of both scattering mechanisms (for thermal scattering $\tau_f = \tau_{of}E^{-1/2}/kT$ and for scattering on the charge defects $\tau_c = \tau_{oc}E^{3/2}$ [3]).

In agreement with the modified relaxation time theory [1] we obtained the expression for $\tau(E)$:

$$\tau(E) = \tau_1(E)\left\{1 + \frac{I_k - d}{d}\exp\left[-\alpha(W-E)\right]\right\}, \tag{3}$$

where $\tau_1(E)$ will be expressed in the form:

$$\tau_1(E) = \tau_k(E)\frac{d}{l_k}\exp\left[-\lambda(W-E)^{1/2}\right], \tag{4}$$

where l_k is the mean free path corresponding to the crystalline state, d is the mean distance between barriers, W is the height of the barrier, E is the energy of the electron and the parameter $\lambda = 4\pi\frac{(2m^+)^{1/2}}{h}d_b$, where m^+ is the effective mass of the electron, d_b is the width of the barrier and h is the Planck constant. The constant α is defined by the approximative relation $\alpha = l_k\lambda^2/2d$.

Expression (3) for $\tau(E)$ allows the Hall mobility to be calculated in the form:

$$\mu_H = \frac{e}{m^+}\frac{\langle\tau^2\rangle}{\langle\tau\rangle}. \tag{5}$$

When $E > W$, then $\tau(E) = \tau_k(E)$, and for $E < W$ one obtains the following expression:

$$\langle\tau^n\rangle = \frac{\int_0^W E^{3/2}\exp(-E/kT)\{\tau^n(E) - \tau_k^n(E)\}\,dE + \int_0^\infty E^{3/2}\tau_k^n(E)\exp(-E/kT)\,dE}{\int_0^\infty E^{3/2}\exp(-E/kT)\,dE} \tag{6}$$

$$n = 1,2.$$

These integrals cannot be treated analytically and that is why we applied the numerical analysis. The integrals in the numerators of expression (6) were solved by means of Gauss's numerical method of the 20th order, and by Chebyshew's method of the 15th order.

Typical results of the calculated thermal dependences μ_H vs T are expressed in Fig. 1.

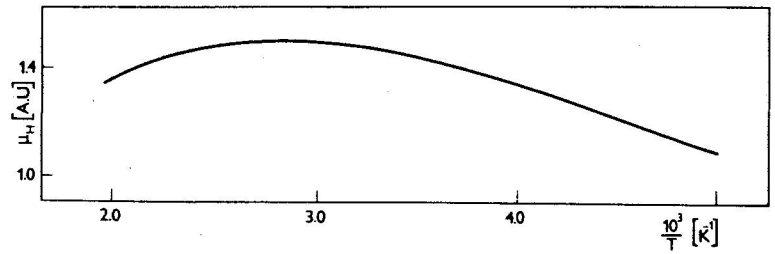

Fig. 1a. Calculated dependence of $\ln\mu_H$ vs $1/T$ for the barrier height $W = 0.2$ eV. The values of the other parameters are mentioned in the text.

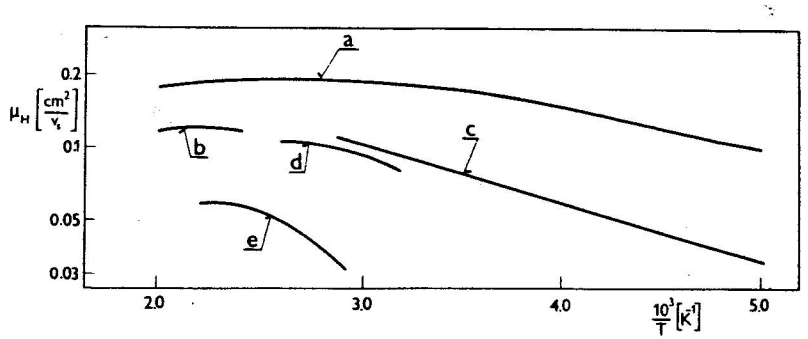

Fig. 1b. Temperature dependence of the Hall mobility. Theoretical (a) and experimental (b, c, d, e) curves [10].

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The following numerical values of the parameters were used for the calculation: $d = 50$ Å, $l = 1000$ Å, $d_b = 20$ Å, $\alpha = 10\,\mathrm{eV}^{-1}$, $m^+ = 0.3\,m_0$. These values seem to reflect the physical reality reasonably and were previously suggested also by other authors [1, 2, 4, 6]. Relaxation times were chosen in such a way that the thermal scattering should predominate at temperatures about 300—400 °K, which could also reflect the reality. At a lower temperature range the dependence of $\ln \mu$ on $1/T$ suggests that the mobility shows only a week temperature activation (about 0.01 eV). This fact has been experimentally commonly observed. At higher temperatures extreme values of this dependence may be obtained.

For a further comparison of the above mentioned calculation with the experiment we refer to the review article [10]. Experimental results published in this article show the above basic characteristic, i.e. a weakly activated low temperature range and a high temperature maximum. The results of the Emin and Holstein theory, [11, 12] which is based on the idea of the existence of small polarons and on the hopping conduction mechanisms, are also included in this paper [10].

A qualitative agreement of these theories with the modified relaxation time theory is not surprising, because as shown in [13], the modified relaxation time theory may reflect the transport of electrons as the combination of both the free motion in the crystalline medium and a localized motion in the polaron states.

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