ELECTRON CAPTURE IN SEMICONDUCTORS WITH DISLOCATIONS IN QUANTIZED MAGNETIC FIELD

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Electron capture by the dislocation centre in the quantized magnetic fields for semiconductors with dislocation are investigated. The effective cross-section of electrons is calculated on the basis of Pillaver capture theory. It is shown that the effective cross-section on the capture increases proportionally to H^2 with logarithmic accuracy with increase of the external intensity of the magnetic field.

The influence of charged edge dislocation on properties of semiconductors strongly depends, apart from the physical situation, on the interaction between carriers of charge and dislocations [1]. Therefore, the study of the electron capture by dislocations in quantized magnetic fields is interesting from practical point of view.

The present article is devoted to the investigation of the cross-section of electron capture by dislocations in n-type semiconductors in quantized magnetic field. The cross-section of electrons σ was calculated on the basis of the modernized model of an edge dislocation suggested in the paper [2]. According to [2], the deformation potential creates a potential which is able to catch electrons intensively. In this paper the theory of the cascade capture of charge carriers by point attractive centres in quantized magnetic fields is being generalized for semiconductors with edge dislocations in quantized magnetic field.

We consider the temperature range where electrons are being scattered by acoustical phonons in quasi-elastic way, i.e. when $kT \gg \hbar\omega_q \sim (\hbar\Omega ms^2)^{1/2}$ (T is the temperature of lattice, k is Boltzman's constant, $\hbar\omega_q$ is the energy of an acoustical phonon, $\Omega=(eH/mc)$ is the cyclotronic frequency, m is the effective mass of electron, s is the sound velocity). Under these conditions the electron loses its energy little by little, and the capture may be described as the persistent shift from positive energy region to the negative one. The electron is really captured when its energy level is under $E=-kT$.

Now we consider the case when the concentration of dislocations is sufficiently low and there are no crossing among the Ride cylinders of separate dislocations. The dislocations act as independent centres. As it follows from [3], the cross- section of electron capture is defined by the formula

$$\sigma = J/n_0\langle v\rangle \qquad (1)$$

J is the electron flow to the centre of dislocation, n_0 is the equilibrium bulk electron concentration, $\langle v\rangle$ is the thermal velocity of electrons. The flow J is carried out as in the paper [3]. After simple transformations one can get for σ:

$$\sigma = \frac{AkT}{\langle v\rangle}\left(\int_{-\infty}^{0}\frac{dE\,\exp(E/kT)}{B(E)}\right)^{-1} \qquad (2)$$

Here $A = \frac{2\pi}{m}\frac{\hbar^2}{\Omega(kT)^{1/2}}$; kT; $B(E)$ is the diffusional coefficient in the energy space defined by the following formula

$$B(E) = \frac{1}{2kT}\int d\bar{r}\sum_{i,j}W_{ij}(\varepsilon_i-\varepsilon_j)^2\delta(E-\varepsilon-\Phi(\bar{r})) \qquad (3)$$

where $\Phi(\bar{r})$ is the summary potential energy defined by electrical and deformation fields of the edge dislocation [2], the i and j indices mean the totality of the electron's three quantum numbers (n,k_x,k_y), W_{ij} is the transition probability from the i-th quantum state to the j-th one by the interaction with acoustical phonons. In the ultraquantum limit $(n=n'=0)$ the probability defined as follows:

$$W_{ij} = \frac{2\pi}{\hbar}\sum_{\bar{q}}\frac{E_c q\hbar}{2\rho s}\delta_{k_x,k_x'+q_x}\delta_{k_y,k_y'+q_y}\exp\left[-\frac{(q_x^2+q_y^2)r_H^2}{2}\right]\times$$
$$\times\left[N_{\bar{q}}\delta(\varepsilon_j-\varepsilon_i-\hbar\omega_{\bar{q}})+(N_{\bar{q}}+1)\delta(\varepsilon_j-\varepsilon_i+\hbar\omega_{\bar{q}})\right] \qquad (4)$$

where

$$\varepsilon_i = \frac{\hbar k_z^2}{2m}+\hbar\Omega(n+1/2)$$

is the energy of electron for i-th quantum state, $r_H=(\hbar c/eH)^{1/2}$, ρ is crystal density, E_c is the constant of deformation potential, $\bar{q}$ is the phonon wave vector, $N_{\bar{q}}=kT/\hbar\omega_{\bar{q}}$ is the equilibrium distribution function of phonons.

After simple calculations we have:

$$B(E) = \frac{E_c^4 b^2 m\alpha^2}{3\rho\pi^3 U_0^2\hbar}\left(\frac{eH}{\hbar c}\right)^3 e^{-\frac{3|E|}{U_0}}\left(\ln\frac{U_0}{\sqrt{\hbar\Omega ms^2}}+\frac{1}{3}\right)\times$$
$$\times ch\frac{3\sqrt{\hbar\Omega ms^2}}{U_0} \qquad (5)$$

$\alpha=(1-2\nu)/(1-\nu)$, ν is the Poisson's coefficient, b is the value of the Burger's vector. Substituting (5) into (2) we get

$$\sigma(H,T)=\left(\frac{eH}{\hbar c}\right)^2\frac{mb^2E_c^2a^2}{3\pi\rho U_0^3kT}\left(ln\frac{U_0}{\sqrt{\hbar\Omega ms^2}}+\frac{1}{3}\right)\times \times ch\frac{3\sqrt{\hbar\Omega ms^2}}{U_0} \quad (6)$$

It is obvious that the cross-section of capture increases with the increase of magnetic field. As the value of $\sqrt{\hbar\Omega ms^2}/U_0$ is less than 1, therefore σ is growing as H^2.

Now we shall estimate the value $\sqrt{\hbar\Omega ms^2}/U_0$ and define the region of application for the formula (6). If f, H and s have the following values $f\sim0.1$, $H\sim10^5$ c, $s\sim5\cdot10^5$ cm/s then the value $\sqrt{\hbar\Omega ms^2}/U_0$ is equal ~0,1. The value of the magnetic field is defined by the inequality

$$(\hbar\Omega ms^2)^{1/2}<kT\ll\hbar\Omega \quad (7)$$

This equation provides both the quasielasticity of electron scattering by acoustical phonons and quantizing of the magnetic field. The conditions (7) may be rewritten as $1\ll H/H_c<\delta^{-1}$, where $\delta=ms^2/kT$, $H_c=kT/2\mu_0$ ($\mu_0=e\hbar/2mc$ is the effective Bohr magnetone). If we take the value of the parameters $m\sim10^{-28}$g, T=300K then H_c is equal ~250 kc.

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KVANTLAYICI MAQNİT SAHƏSİNDƏ DİSLOKASİYALI YARIMKEÇİRİCİLƏRDƏ ELEKTRONLARIN ZƏBT OLUNMASI

İşdə dislokasiyalı yarımkeçiricilərdə kvantlayıcı maqnit sahələrində elektronların kənar dislokasiya mərkəzlərinə zəbt olunması tədqiq olunur. Pilleverin zəbt nəzəriyyəsi əsasında elektronların zəbt olunmasının effektiv kəsiyi hesablanmışdır. Göstərilmişdir ki, xarici maqnit sahəsinin intensivliyi artdıqca zəbt olunmanın effektiv kəsiyi loqarifmik dəqiqliklə H² ilə mütənasib olaraq artır.

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ЗАХВАТ ЭЛЕКТРОНОВ В ПОЛУПРОВОДНИКАХ С ДИСЛОКАЦИЕЙ В КВАНТУЮЩЕМ МАГНИТНОМ ПОЛЕ

В работе исследован захват электронов инородными дислокационными центрами в полупроводниках с дислокациями в квантующих магнитных полях. Вычислено эффективное сечение захвата электронов на основе теории захвата Пиллавера. Показано, что с увеличением интенсивности внешнего магнитного поля эффективное сечение захвата с логарифмической точностью растет пропорционально H^2.

Дата поступления: 14.02.97

Редактор: Ф.М. Гашимзаде