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DEPENDENCE OF SPACE-CHARGE REGION CONDUCTIVITY OF NONIDEAL HETEROJUNCTION FROM PHOTOEXCITATION CONDITIONS

It is shown that nonideal CdS-Cu_2S heterojunction illumination results in essential space-charge region width reduction and change of a potential barrier form. It is established that this change is the most expressed near the heteroboundary and occurs even at very small intensity of stimulating light. It is connected with the capture of nonequilibrium charge on local centers, presented in space-charge region. Such change of the form of a potential barrier results in essential change of tunnel hopping conductivity of a spatial charge nonideal heterojunction.

Investigation of the current transport mechanism in heterojunction, used as optical and x-ray images sensors inevitably takes in the account the light influence on their tunnel-jumping conductivity. Impact of light on nonideal heterojunction essentially influences the parameters of its space charge region (SCR) [1], and hence on tunnel-jumping conductivity of SCR, and heterojunction as a whole. As the sensor generated signal strongly depends on heterojunction conductivity, the question about light influence on SCR and so on conductivity is represented as rather significant.

Experimental investigations of light influence on conductivity CdS-Cu_2S heterojunction are described in [2]. It is established, that with the increase of excitation intensity with white or only short-wave ($\lambda \approx$ 520nm) light heterojunction conductivity is essentially increased both on direct and alternating current even in a short-circuited condition, i.e. at constant barrier height. At the same time, photocapacity growth is observed even at light illumination essentially smaller than the solar. Ratio C_{ph}/C_d for some elements achieved 10 and more units that testifies the barrier width reduction. Such phenomenon can result in essential growth tunnel-jumping conductivity in SCR .

In [3] the current transport in heterojunction without illumination was considered, but it was not taken into account the SCR parameters change under light influence. Therefore, the offered model cannot be applied directly to the sensor work description. We shall consider how it is possible quantitatively to take into account the influence of light on jumping current transport in nonideal heterojunction.

For definition SCR heterojunction conductivity it is necessary to set the function Fermi $E_F(x)$ level position in each point x [3]. Conductivity $G_\sigma(x)$ of SCR part is calculated from *0* up to x as the solution of the integral equation. However, the solution of this equation is also determined by the form of a potential barrier $\phi(x)$. For dark heterojunction $\phi(x)$ depends only on submitted bias U and shows the known square-law formula. At heterojunction illumination generated in wide band CdS nonbasic carriers (holes) are captured in SCR on the traps, presented there. We shall assume, that holes are captured by the centers with a single energy level, which concentration is equal N_t. Then, apparently from fig. 1, because of band bending in SCR, the energy distance from level Fermi up to a level of holes traps E_{Ft} (determining their filling degree) essentially depends on coordinate x. It results in non-uniform filling, and concentration of the captured charge (changeable along an x axis) will be determined by expression:

$$p(x) = \Delta p_0 \exp\left[\frac{\varphi_0}{kT}\left(\frac{\omega - x}{\omega}\right)\right] \quad (1)$$

here Δp_0 — the concentration of photoexcited holes in CdS quasineutral region. We shall note, that in formula (1) capture holes centers concentration is absent, because limits of considered here models the capture centers number essentially exceed the number of nonequilibrium holes, i.e. $N_t >> p(x)$ or $E_{Ft} >> kT$. Thus, the dependence of a potential barrier $\phi(x)$ can be defined from Poisson equation:

$$\frac{d^2\varphi(x)}{dx^2} = -\frac{e}{\varepsilon\varepsilon_0}[N_D + p(x)] \quad (2)$$

where N_D — concentration of ionized sallow donors, not compensated completely in CdS, determining barrier width in darkness, when $p(x) \equiv 0$. Captured charge dependence from coordinate x results in a significant deviation of a potential shape of a barrier $\phi(x)$ from the square-law form, characteristic for constant distribution of the charge creating a built-in field. The potential barrier of illuminated heterojunction will be described by expression:

$$\varphi(x) = \frac{\varphi_0 - eU}{1 + \frac{\Delta p}{\alpha N_D}\left(e^\alpha - 1 - \alpha\right)}\left[1 + \frac{x^2}{\omega^2} + \left(\frac{2\Delta p}{\alpha N_D} - 2\right)\frac{x}{\omega} + \right.$$
$$\left. + \frac{2\Delta p}{\alpha^2 N_D}\left(e^\alpha e^{-\alpha\frac{x}{\omega}} - 1 - \alpha\right)\right] + \Delta F_0 \quad (3)$$

where $\alpha = (\phi_0 - EU)/kT$. The parameter Δp, ,ncluded in (3), can be determined knowing the character of distribution of the captured nonequilibrium charge set by the formula (3), and average value of a nonequilibrium charge p'_t, captured on traps in SCR region, which can be determined from photocapacity value (C_{ph}). Having measured heterojunction dark capacity and its photocapacity at various stimulating light intensities under the formula of the flat condenser

$$C=\varepsilon\varepsilon_0 S/\omega \quad (4)$$

it is possible easily to determine appropriate to each of these capacities barrier region width ω (C_d, C_{ph}), so also values N_D (C_T) and $p_d(C_d, C_{ph})$. It is obvious, that the size of average captured in SCR nonequilibrium charge is connected with $p(x)$ by the ratio:

$$p_t = \frac{1}{\omega}\int_0^{\omega} p(x)dx\,. \quad (5)$$

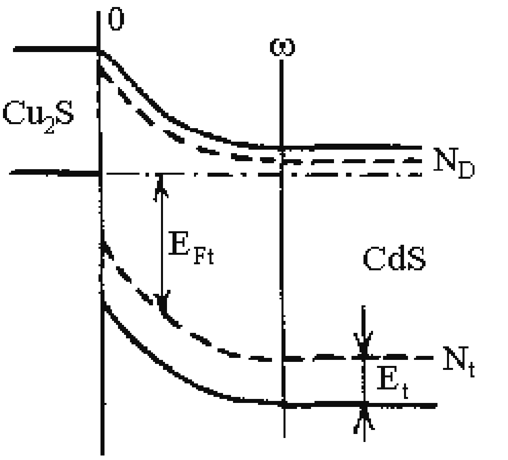

Fig. 1. The zone diagram CdS-Cu_2S heterojunction with hole traps in CdS

It is possible to determine the appropriate value of parameter Δp, included in (3), for each value of stimulating light intensity by means of calculating p_t (C_d, C_{ph}) from (5) with the account (1) for each value of photocapacity C_{ph}.

From the equation (3) it is seen, that at absence of photoexcitation of wide band material, i.e. at $\Delta p = 0$, the expression (3) transforms into the square-law form. However, already at small values Δp there is an essential deviation ϕ *(x)* from a square-law dependence especially near heterojunction where the captured nonequilibrium charge is maximal and ϕ *(x)* gets the character close to exponential. At values Δp appropriate to large capacities, change ϕ *(x)* form also is the most essential in frontier area where $E_F(x)$ has the maximal value and which, hence, has minimal tunnel-jumping conductivity. Thus, function ϕ *(x),* and also E_F *(x)* essentially depend on intensity of illumination and consequently from photocapacity which is easily measured experimentally. As E_F *(x)* determines the values of parameters $R'(E_F)$, $N(E_F)$, $W(E_F)$, which determines tunnel-jumping conductivity mechanism in SCR, the SCR conductivity G_σ essentially depends on a type of function ϕ *(x)* and the stimulating light intensity. It means, that illumination influences not only barrier width reduction on current-transport, but also the change of its form.

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Abstract

It is shown that nonideal CdS-Cu_2S heterojunction illumination results in essential space-charge region width reduction and change of a potential barrier form. It is established that this change is the most expressed near the heteroboundary and occurs even at very small intensity of stimulating light. It is connected with the capture of nonequilibrium charge on local centers, presented in space-charge region. Such change of the form of a potential barrier results in essential change of tunnel hopping conductivity of a spatial charge nonideal heterojunction.

Key word: space — nonideal heterojunction, photoexcitation conditions.

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ЗАВИСИМОСТЬ ПРОВОДИМОСТИ ОБЛАСТИ ПРОСТРАНСТВЕННОГО ЗАРЯДА НЕИДЕАЛЬНОГО ГЕТЕРОПЕРЕХОДА ОТ УСЛОВИЙ ФОТОВОЗБУЖДЕНИЯ

Реферат

Показано, что освещение неидеального гетероперехода CdS-Cu_2S приводит к существенному сокращению ширины области пространственного заряда и изменению формы потенциального барьера. Установлено, что вблизи гетерограницы это изменение максимально выражено и происходит даже при очень небольших интенсивностях возбуждающего света. Это связано с захватом неравновесного заряда на присутствующие в области пространственного заряда локальные центры. Такое изменение формы потенциального барьера приводит к существенному изменению туннельно-прыжковой проводимости области пространственного заряда неидеального гетероперехода.

Ключевые слова: пространственный заряд, неидеальный гетеропереход, условия фотовозбуждения.

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ЗАЛЕЖНІСТЬ ПРОВІДНОСТІ ОБЛАСТІ ПРОСТОРОВОГО ЗАРЯДУ НЕІДЕАЛЬНОГО ГЕТЕРОПЕРЕХОДУ ВІД УМОВ ФОТОЗБУДЖЕННЯ

Резюме

Доведено, що засвітлення неідеального гетеропереходу CdS-Cu_2S викликає важливе скорочення ширини області просторового заряда та зміни форми потенційного бар'єру.

Встановлено, що поблизу гетеромежі ця зміна — максимальна і відбувається при дуже невеликих інтенсивностях збуджуючого світла. Це пов'язано з захопленням нерівноважного заряду на присутні локальні центри. Такі зміни форми потенційного бар'єру викликають суттєві зміни тунельно –стрибкової провідності області просторового заряду неідеального гетеропереходу.

Ключові слова: просторовий заряд, неідальний гетроперехід, умови фотозбудження.