medium has a relaxation time shorter than the photon lifetime in the resonator. The absence of a signal when the mirrors are misaligned, as well as the pulsation regime, are sufficiently convincing evidence favoring the generation regime.

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INFLUENCE OF INTERACTION OF HOT ELECTRONS WITH QUASIDISCRETE LEVELS ON THE CURRENT-VOLTAGE CHARACTERISTIC OF A SEMICONDUCTOR

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It was shown in [1] that shallow donor impurities in semiconductors have quasi-discrete levels connected with the higher valleys. These levels were observed experimentally [2, 3]. If the energy of such levels relative to the bottom of the main valley is $\varepsilon_d \gg T_0$ (T_0 is the lattice temperature), then as the conduction electrons become heated by the electric field E, their density is reduced as a result of capture by these levels; this can lead to negative differential resistance (NDR).

The current-voltage characteristic is determined by the well known expression:

$$\vec{j} = e n_e < \vec{v} f_{\vec{k}} > , \tag{1}$$

where the symbol < > denotes summation over all the quasimomenta k. The distribution function $f_{\vec{k}}$ is obtained from the system of kinetic equations[1)]

$$\partial f/\partial t + e\vec{E}\, \partial f/\partial \vec{p} = I_{11}(f) + I_{12}(f, n_d), \tag{2}$$

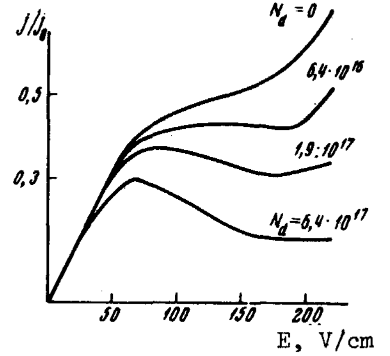
$$\partial n_d/\partial t = \rho_d < f_{\vec{k}} W_{kd} > - n_d < W_{kd} >, \tag{3}$$

$$< f_{\vec{k}} > + n_d = N_e . \tag{4}$$

Here I_{11} is the collision integral, describing the intravalley scattering, I_{12} describes the interaction of the conduction electrons with the quasidiscrete levels, ρ_d is the density of the quasidiscrete levels, n_d is the density of the electrons on these levels, and W_{kd} and W_{dk} are respectively the probabilities of transition of the electron from the state with quasimomentum $\vec{k}$ to the quasidiscrete level and vice versa. The time ratio $\tau/\tau_{dk} \sim I_{12}/I_{11}$ can be used as the small parameter in the solution of the kinetic equations. In the zeroth approximation in this parameter, in the stationary case, the distribution function is determined from (2) accurate to a constant. We assume that the frequency of the electron-electron collisions is sufficiently high, so that the symmetrical part of

1) These equations are valid when $\tau \ll \tau_{dk}$ (τ and τ_{dk} are respectively the times of intravalley scattering and of the transition between the quasidiscrete levels and the main valley). Since $\tau \sim 10^{-13} - 10^{-14}$ sec and, according to our calculations, $\tau_{dk} \sim 10^{-11}$ sec, this condition is satisfied.

Current-voltage characteristics for GaSb at $T_0 = 77°K$ (T_0 = Debye temperature). $j_0 = eN_e(3T_0/m^*)^{1/2}$. N_d - impurity density.



this function is $C\exp(-\varepsilon/T_e)$, where T_e is the electron temperature.

Since it can be shown that the lifetimes of the electron at the quasidiscrete levels, due to electron-phonon interaction and to scattering by the Coulomb potential of the impurity, are respectively of the order of 10^{-11} and 10^{-9} sec, and only phonons with quasimomentum $q \sim k_0$ are effective in the electron-phonon interaction (k_0 is the difference between the quasimomenta of the main minimum and that above it), it becomes necessary to consider one of two cases, either $\varepsilon_d > \hbar\omega_k$ (A) or $\varepsilon_d \le \hbar\omega_{k0}$ (B). Then the expression for the electron density, for the indicated form of the distribution function, is written with the aid of (3) and (4) in the form

$$n_e = N_e\left[1 + 2/\sqrt{\pi}\,\frac{\rho_d}{\rho(T_e)}\,D\exp\left(-\frac{\epsilon_d + \hbar\omega_{k_0}}{T_e}\right)\right]^{-1}, \tag{5}$$

where

$$\rho(T_e) = \sqrt{2}/\pi^2\,(m^*T_e/\hbar^2)^{3/2}$$

is the number of electron states in the main valley,

$$D = \left(\frac{\epsilon_d + \hbar\omega_{k_0}}{\epsilon_d - \hbar\omega_{k_0}}\right)^{1/2}$$

in case (A), and

$$10^2\left[\left(\frac{\epsilon_d + \hbar\omega_{k_0}}{\epsilon_d}\right)\right]^{1/2}$$

in case (B); N_e is the electron density at $E = 0$. n_0 has a minimum at $T_e = (2/3)(\varepsilon_d + \hbar\omega_{k_0})$. It is natural to expect NDR to occur if the density n_d of the bound electrons of the order of n_e. In case (A) this occurs when $\rho_d \sim 3 \times 10^{20}(m^*/m_0)^{3/2}$ cm^{-3} (for $\varepsilon_d \sim 3\hbar\omega_{k_0}$ ($h\omega_{k_0} \sim (2 - 3) \times 10^2$ °K))[2]. In case (B) the necessary value of ρ_d is decreased by two orders of magnitude and can be readily reached in many semiconductors.

The figure shows the current-voltage characteristics calculated for GaSb doped with Te, for which case (a) is realized ($\varepsilon_d \sim 6 \times 10^{-2}$ eV) and $\rho_d = 8N_d$. We used in the calculations formulas (1) and (5), and also the expression for the drift velocity and Stratton's

[2] Depending on the material, $\rho_d = (2 - 12)N_d$.

equation [4] connecting E with T_e, derived for the case of relaxation by polar optical oscillations.

From the point of view considered here, interest attaches to solid solutions of semiconductors (Ge-Si, various III-V semiconductors), in which variation of the composition makes it possible to choose ε_d such as to realize case (B).

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ORDER-DISORDER TRANSITIONS IN ADSORBED MONATOMIC SODIUM FILMS

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An experimental study of the disorder processes in two-dimensional systems is of interest in connection with the role that they can play in various surface phenomena, and also because it is possible to construct for this case a more rigorous phase-transition theory than for a three-dimensional lattice [1].

By slow-electron diffraction [2], we have observed and investigated order-disorder transitions in sodium films adsorbed on the (110) face of a tungsten crystal. The films were sputtered on the crystal in ultrahigh vacuum ($p < 10^{-10}$ Torr). The technology of obtaining and purifying the sodium is described in [3]. The surface concentration of the adsorbed sodium atoms n_{Na} was determined from its known dependence on the work function of the surface [3]. Since we wished to consider the purely two-dimensional case, we investigated coatings which were certain to be thinner than the close-packed monatomic layer.

Figure 1 shows a series of diffraction patterns corresponding to various sodium concentration. The sputtering of the sodium leads to the appearance of a number of additional (fractional) reflections on the electron diffraction pattern (Figs. 1b - 1d). It is important to note that ordered films are produced when the sodium is sputtered on a crystal cooled with liquid nitrogen, without additional annealing (the sputtering rate was $\sim 10^{12}$ at/cm^{2}sec).

An analysis of the pictures on the basis of the kinematic theory leads to a film structure (Fig. 2) in which the ratio of the number of sodium atoms to the number of surface tungsten atoms n_{Na}/n_W amounts to 1.6, 1.4, and 1.3. The correctness of the analysis of the diffraction patterns is confirmed by the fact that the sodium-atom concentrations for which the corresponding structures are observed are in full agreement with the indicated ratios n_{Na}/n_W (for the (110) face of tungsten, $n_W = 14.1 \times 10^{14}$ cm^{-2}).

Figure 3 shows plots of the additional-reflection intensity against the temperature for the indicated structures. It is clear from Fig. 3 that for each type of structure there is a rather narrow temperature interval in which the reflection intensity, together