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NEAR BAND-EDGE PHOTOCONDUCTIVITY IN HEAVILY DOPED COMPENSATED EPITAXIAL GALLIUM ARSENIDE LAYERS

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The experimental data [1-6] from optical and electrical investigations on heavily doped and strongly compensated gallium arsenide epitaxial layers are in good agreement with the theory [7, 8] taking into account the influence of the correlated impurity distribution on the potential relief. The luminescence and low-temperature conductivity in such objects are studied in detail. Practically there are no investigations on the photoconductivity in heavily doped and compensated with shallow impurities gallium arsenide.

The energy spectrum of heavily doped and compensated semiconductors is quasicontinuous. So one can expect photosensitivity in a wide spectral range from the energy gap to shallow impurities binding energies. Various kinetics of decay of the photoconductivity can take place in the different ranges of the spectra including the long-time relaxations and residual conductivity [9]. The photoconductivity theory [10] based on the idea of the random potential relief has mainly qualitative character.

The epitaxial gallium arsenide layers grown from the liquid phase on substrates with resistivity more than $10^6\ \Omega$. cm are investigated. The layers are simultaneously doped with tellurium and germanium as a shallow donor ($E_D \sim 6$meV) and acceptor ($E_A \sim 40$meV), respectively. The simultaneous doping with Te and Ge allows to obtain a high degree of compensation [2, 4]. There is a potential relief in the samples whose properties are defined by the majority impurity concentration N and correlation in the donors and acceptors distribution in the samples. The latter one defines the linear size R_0 and the root mean

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square (RMS) fluctuation of the impurity potential $\gamma(R_0)$ [8]:

$$\gamma \gtrsim 2\sqrt{\pi} \frac{q^2}{\varepsilon\varepsilon_0 R_0} (2NR_0^3)^{1/2} \tag{1}$$

$$R_0 = (\varepsilon\varepsilon_0 kT/8\pi N q^2)^{1/2} \tag{2}$$

where E is the relative dielectric constant, k = the Boltzmann constant, q = the electron charge, T_0 = the temperature at which the impurity diffusion has been frozen out.

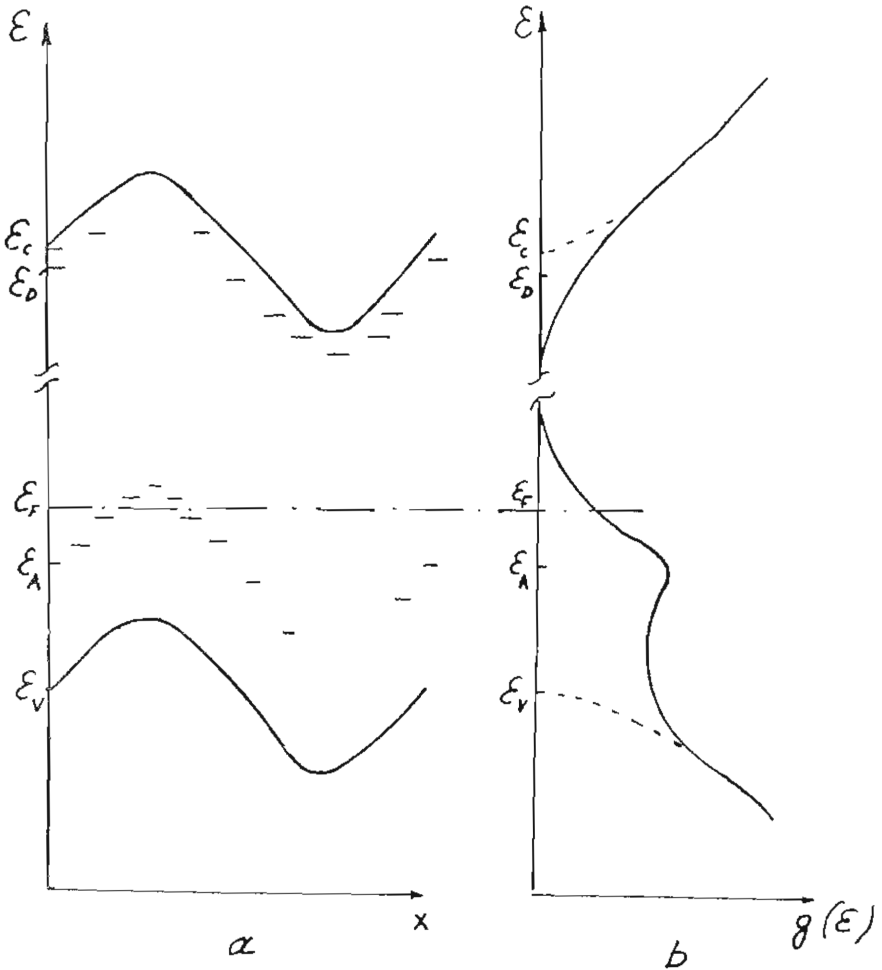

Fig. 1. Supposed energy diagram and spatial average of the density of state g(E) in heavily doped and strongly compensated gallium arsenide.

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In our case $N \simeq 10^{19}cm^{-3}$, $T_0 \simeq 1000K$, $R_0 \simeq 1{,}7.10^{-7}cm$, $\gamma \simeq 75meV$ and the main part of the carriers are localized in potential fluctuations with depth $\gamma > kT$. As it is shown in [4, 5] the conductivity in these samples has an activation and hopping character with parameters in good agreement with the theoretical models in [8, 11].

The supposed energy scheme of the samples under investigations

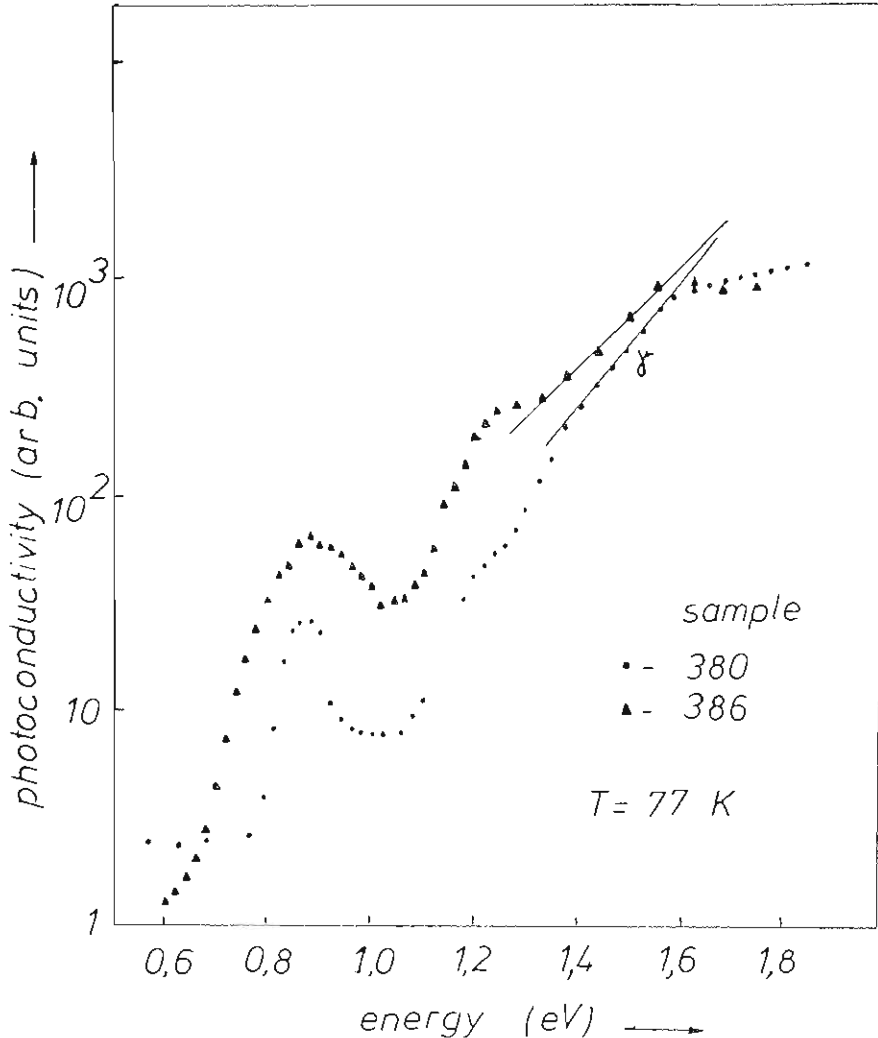

Fig. 2. Photoconductivity spectral distribution at 77 K of heavily doped compensated gallium arsenide epitaxial layers grown from liquid phase.

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and the spatial average of the density of states in the classical approximation are shown on Fig. 1.

The steady-state photoconductivity in the range of 0,5-1,8eV ($\lambda = 2{,}5\text{-}0{,}68\mu m$) and its long-time relaxation are measured. The samples are illuminated with globar and infrared monochromator.

The photoconductivity spectral distribution of two samples at 77K corrected for the energy distribution of the source intensity is shown on Fig. 2. These investigations are preliminary and are carried out on a few samples only. It can be seen that photoconductivity is considerable in the whole investigated range. In our experiments the current after the illumination increases up to 10^3 times.

A maximum at 0,86eV and nearly exponential increase in the short-wavelength range at energies less than the energy gap $Eg = 1{,}513eV$ are observed. At energies more than 1,5eV the photoconductivity rises «slower» than the exponential increase.

The time dependence of the photocurrent in the range of 1-1,5eV at 77K after removing the light is measured. The samples with larger photoconductivity show long-time relaxation of the photocurrent which is transformed into a residual conductivity (Fig. 3). The value of the residual conductivity in the different samples is from 10 to 30 times larger than the conductivity without illumination. By heating to 300K the samples return to the equilibrium state.

The considerable photoconductivity (including the energy range below E_g) is determined by the existence of density of state tails in the energy gap (Fig. 1). The slope of the exponential range of the photoconductivity spectra near 1,4eV determines the characteristic parameter of the exponential density of state tail which is equal to the RMS potential fluctuation γ. The derived value $\gamma = 80\text{-}90meV$ is in good accordance with the calculated value from (1) and with the results from electrical measurements in [4].

The change of the exponential dependence in Fig. 2 at energies more than 1,5eV is probably due to absorption transitions in the free bands. The beginning of this spectral range corresponds to the band edge of undoped gallium arsenide at 77K.

The energy position of the low energy photoconductivity maximum numerically corresponds to the well-known cromium level in gallium arsenide. Probably this maximum is connected with the cromium doped substrate but it cannot be explained with the assumption of Cr-penetration into the layer only.

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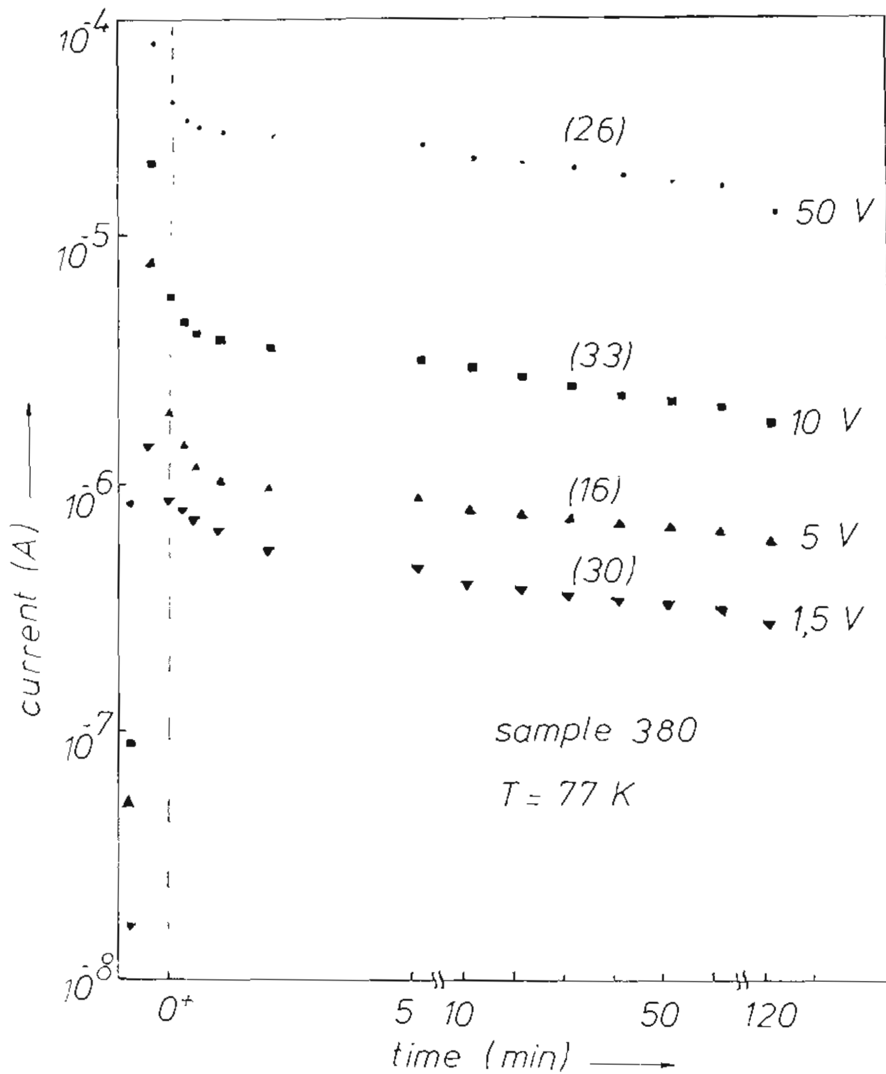

Fig. 3. Time dependence of the photocurrent after switching off the light (at the moment O^{+}) for the sample of Fig. 2.

The long time relaxations and the high residual conductivity can be explained qualitatively with the theory [10] taking into account the energy band bending by the random potential. It is assumed that classical potential relief leads to spatial separation of the generated non-equilibrium carriers. As a result the decay time constant increases

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strongly. These data are in agreement with the experimentally obtained hopping conductivity in these samples [5].

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ΠΕΡΙΛΗΨΗ

ΦΩΤΟΑΓΩΓΙΜΟΤΗΣ ΚΟΝΤΑ ΣΤΗΝ ΑΚΜΗ ΤΑΙΝΙΑΣ ΣΕ ΕΠΙΤΑΞΙΑΚΑ ΕΠΙΠΕΔΑ Ga-As ΜΕ ΙΣΧΥΡΗ ΔΙΑΧΥΣΗ ΠΡΟΣΜΕΙΞΕΩΝ

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Τὰ πειραματικὰ ἀποτελέσματα ἀπὸ ὀπτικὲς καὶ ἠλεκτρικὲς μετρήσεις σὲ ἐπιταξιακὰ ἐπίπεδα Ga-As μὲ ὑψηλὸ βαθμὸ προσμείξεων εἶναι σὲ καλὴ συμφωνία μὲ τὴ θεωρία ποὺ παίρνει ὑπόψη της τὴν ἐπίδραση τῆς συναρτήσεως κατανομῆς τοῦ δυναμικοῦ τῶν προσμείξεων. 'Εδῶ μελετᾶται ἀντίστοιχα ὁ φθορισμὸς καὶ ἡ ἀγωγιμότητα σὲ χαμηλὲς θερμοκρασίες στὸ ἴδιο ὑλικὸ καὶ μὲ τὶς ἴδιες προϋποθέσεις.

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