ELTCTRONIC PROPERTIES OF HIGHLY COMPENSATED SEMICONDUCTORS: HR-GAAS:CR STRUCTURE*

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Using the example of doping the initial industrial n-GaAs with an electron concentration N_d, the conductivity σ of which was compensated by the subsequent introduction of a chromium impurity with a concentration N_{Cr}, creating highly localized centers with levels of allowed states near the middle of the band gap, at $N_{Cr} > N_d$, the electronic properties of semiconductors change significantly.

Semiconductor structures with deep levels, which in GaAs are transition metals of the iron group: V, Cr, Mn, Fe, Co, Ni, are actively used to create a wide range of devices and devices of functional electronics: elements and converters of power pulse electronics, photodetectors of a wide range spectral range, sensors of various external influences, quantum-sensitive detectors of ionizing radiation, matrix image receivers in X-ray and gamma rays, etc.

It is shown that when the conductivity of n-GaAs is compensated by a Cr impurity, two previously unobserved effects are observed: the formation of structures with extremely high resistivity exceeding the resistance of the native semiconductor (ρ_i), $\rho_{max} > \rho_i$, and a long lifetime of nonequilibrium electrons (τ_n), which we called HR-GaAs:Cr structures, HR-High Resistivity. This abbreviation has become established in the literature and is the hallmark of Tomsk State University.

It has been calculated and experimentally shown that when the condition of maximum compensation of n-GaAs conductivity by chromium impurity is met and the equilibrium concentration reaches the values $n = n_i/b^{(1/2)}$, and $p = n_i/b^{(-1/2)}$, where ni is the intrinsic concentration, and b = μn/μp is the ratio of the mobilities of electrons and holes, ρmax is 3-4 times higher than ρi and reaches 3·109 Ohm·cm.

It is shown that the random nature of the distribution of small donor impurity atoms of low concentration in the initial n-GaAs and the localized state of deep acceptor chromium atoms in the highly compensated HR-GaAs:Cr structure leads to the need to take into account electron-electron interactions even at extremely low electron concentrations. As a result, large-scale fluctuations of the band potential are formed in strongly compensated HR-GaAs:Cr. The screening of fluctuations is weak and nonlinear due to the low concentration of electrons (holes). The usual screening theory, based on the linearization of the Poisson equation, equivalent to the assumption of weak electron density inhomogeneity, turns out to be inapplicable [1].

Since in an equilibrium thermodynamic system (crystal) the level of chemical potential is leveled, the band pattern takes on a corrugated appearance [1]. Electrons and holes in their bands turn out to be spatially separated by a potential barrier to recombination ΔE. The lifetime of nonequilibrium carriers (τ_n) increases according to the law: $\tau_n = \tau_o \cdot \exp(\Delta E/kT)$, where τo is the lifetime in the original n-GaAs. The effect of a gigantic (tens of times) increase in lifetime can be observed only in highly compensated GaAs. It has been experimentally shown that in the HR-GaAs:Cr structure the value of ΔE ≈ 0.15 eV, and the lifetime even at 300 K increases to $\sim 10^{-7}$ s.

REFERENCES

[1] Шкловский Б.И., Эфрос А.Л., Электронные характеристики легированных полупроводников. М.: Наука, 1979, 216 с.

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