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Ordering Phenomenon in Highly Doped III-V Semiconductor materials

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The distribution of the energy of heavy doped semiconductors is determined by the interaction processes of charged ions, impurities, intrinsic point defects with matrix atoms. In addition, associative interaction leads to qualitatively new phenomena conditioned by structural complexes at the critical concentrations. A systematic study of the processes of impurity centre self-induced ordering in the matrix III—V semiconductor materials doped with group VI elements has been carried out. Czochralski-grown *GaAs*, *InAs*, and *InSb* single crystals are used. The investigations have been performed in the whole existence region of the compound from slightly doping to the solubility limit.

We studied the doping effects in III—V crystals by methods of free carrier infra-red absorption, the photoluminescence, ultrasonic and calorimetric methods. It has been found that the functional dependences of the number of the characteristic parameters describing these processes lose their regular behaviour at the critical impurity concentrations (3 to 5)$\cdot 10^{18}$ cm^{-3} (e.g., Fig.1 shows the dependence of the edge photoluminescence intensity on the free carrier density in *GaAs*-(*Te*), and Fig.2 demonstrates the departure from the Burstein-Moss effect in *InAs*-(*Te*)). The nonmonotonic nature of the impurity concentration dependences of these parameters was attributed to ordering effects, induced by impurity complexes. This phenomenon changes the traditional notions about impurity properties of the diamond-similar semiconductors. For the explanation of the discovered peculiarities in doped gallium arsenide the thermodynamic model of phase transitions was proposed using the properties of complex formation in this semiconductor compound. It was carried out the theoretical description of interaction of the impurity dipole centres with crystal polarization and elastic strains. Our conclusions were confirmed by the temperature investigations of the ultrasonic wave velocity and molar heat capacity in the *GaAs* sample with carrier density N_e=3$\cdot 10^{18}$ cm^{-3}. The electron microscope investigations showed the two systems of superlattice reflections on the electron microdiffractogram (Fig.3). We considered these dates as the confirmation a transition from statistical distribution centres to an ordered one with the formation of a periodical spacial superstructure.

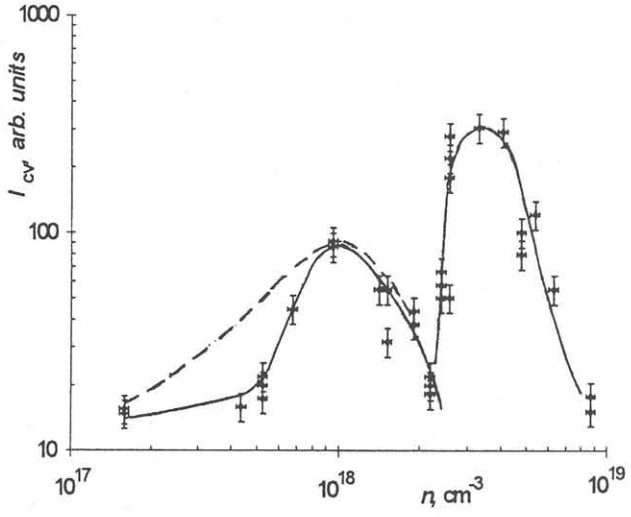

Fig.1 The dependence of the edge photoluminescence intensity on the free carrier density in *GaAs-Te* (77K): the dashed curve is the generalized literature data.

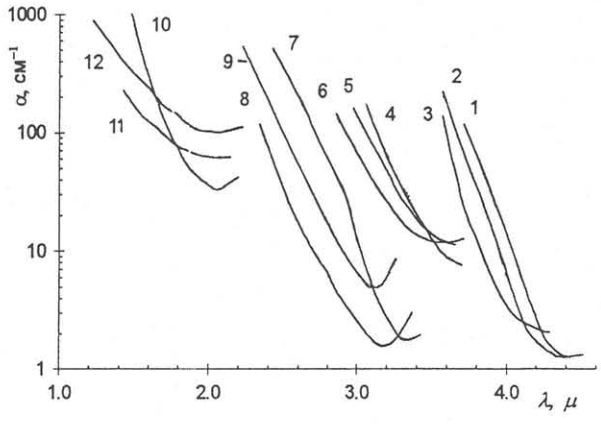

Fig.2 The absorption edge spectra in *InAs-Te* monocrystals (300K) with various doping levels: from 10^{15} cm^{-3} (curve 1) to 10^{20} cm^{-3} (curve 12). The curves 7-9 — the crystals with impurity sublattice ordering.

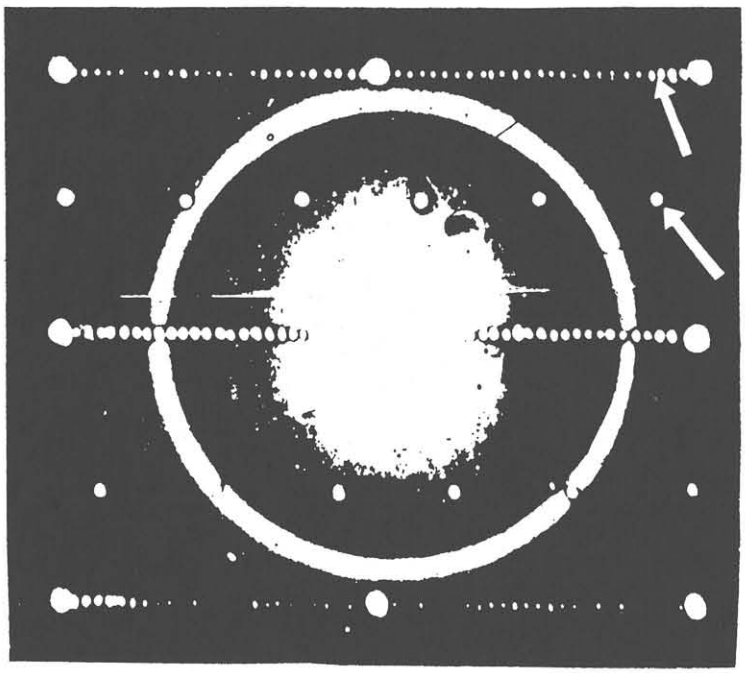

Fig.3 The electron microdifractogram of GaAs-Te monocrystal (n=4·10^{18} cm^{-3}); arrows shows the superlattice reflections.