

Influence of γ-irradiation on kinetic effects in indium-alloyed cadmium antimonide single crystals

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Influence of γ-irradiation on the kinetic parameters of indium-alloyed cadmium antimonide single crystals has been studied. The conductivity and the Hall effect were measured, thus obtaining the dose and temperature dependences for concentration of charge carriers and their mobility. A sharp increase of charge carrier mobility has been found in the crystals irradiated at the doses up to $4\cdot10^{18}$ γ-quanta per cm^2, which is explained by the presence of the "small dose effect ". It is noted that the increase of charge carrier mobility observed in this work is due not to the crystal ordering increase caused by the irradiation but to a decrease in the efficiency of charge carrier dispersion on ionic residues of the impurity during partial charge neutralization by the oppositely charged defects.

Исследовано влияние γ-облучения на кинетические параметры монокристаллов антимонида кадмия, легированных индием. Измерялись удельная проводимость и эффект Холла, что позволило получить дозовые и температурные зависимости концентрации носителей заряда и их подвижности. Обнаружен факт резкого увеличения значений подвижности носителей заряда в облученных кристаллах при дозах облучения до $4\cdot10^{18}$ γ-кв/см^2, которое объясняется наличием "эффекта малых доз". Отмечено, что увеличение подвижности носителей заряда, наблюдаемое в данной работе, возникает не за счет повышения упорядоченности кристаллов при их радиационной обработке, а за счет снижения эффективности рассеяния носителей заряда на ионных остатках примеси при частичной нейтрализации заряда противоположным по знаку зарядом дефектов.

Research of crystal lattice defects and establishment of relationships thereof with physical properties of crystals is of a considerable scientific and practical interest and belongs to the major problems in physics of solids and semiconductors [1]. Irradiation with high energy particles is an efficient and well-controllable method to regulate the ordering degree in solids. The nature of radiation-induced defects and variation character of electrophysical properties of crystals under irradiation is defined by numerous factors depending both on the initial properties of the crystals being irradiated and on the irradiation dose [2]. In this work, the kinetic parameters of indium-alloyed single crystals of cadmium antimonide (CdSb(In)) were studied prior to and after γ-irradiation. The measurements were done on the samples cut out along the main crystallographic directions. The samples were irradiated by ^{60}Co γ quanta at 300 K (the irradiation dose power 500 R/s). Specific conductivity and Hall effect were studied, thus providing the dose and temperature dependences of charge carrier concentration and mobility.

The dose dependences of charge carrier concentration are presented in Fig. 1. As is seen that at room temperature, the concentra-tions are almost dose-independent (Fig. 1, curve *1*) being only a function of the initial impurity concentration [3]. On the contrary, the charge carrier concentration dependence on the irradiation dose at 78 K (Fig. 1, curve *2*)

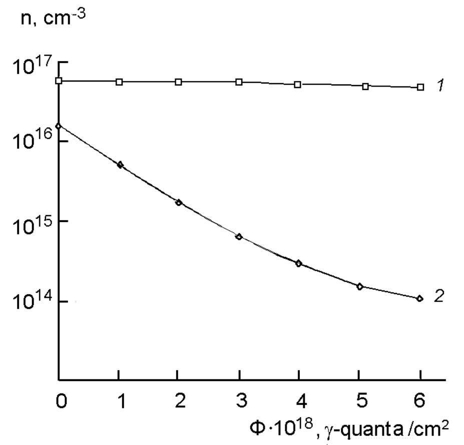

Fig. 1. Dose dependences of charge carrier concentration in CdSb(In) single crystals at 293 K (*1*); and at 78 K (*2*).

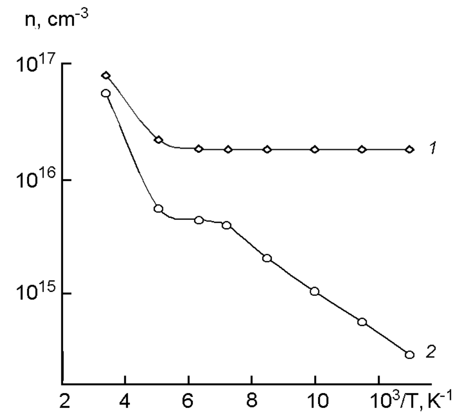

Fig. 2. Temperature dependences of charge carrier concentration in CdSb(In) single crystals prior to irradiation (*1*) and after irradiation at dose $4\cdot10^{18}$ γ-quanta/cm^2 (*2*).

has a more pronounced character. Lowering of concentration, that is, the removal of electrons from the conductivity band, is associated with increase of the radiation defect concentration in the deep level of the CdSb(In) band gap. Basing on the temperature dependences of charge carrier concentration in γ-irradiated crystals (Fig. 2) the energy of that energy level has been determined to be of E_c = 0.3 eV.

The dependences of the charge carrier mobility on the γ-irradiation dose ($\mu = f(\Phi)$) are presented in Fig. 3. The experiment evidences the presence of maxima in the dependences at the dose of about the dose area $4\cdot10^{18}$ γ-quanta/cm^2. Increase of the charge carrier mobility in the dose interval to $4\cdot10^{18}$ γ-quanta/cm^2 is connected in our opinion with the radiation-induced defects insertion, which start to arise first near the positive impurity (In) ions, where the probability of their appearance is higher due to the mechanical straining of the lattice [4] near the extrinsic centers. As a result, the "neutralization" of the impurity ions takes place, that causes a degradation of the Rutherford scattering at the partly "neutralized" centers, that is, an increased mobility.

At the further increase of irradiation dose over $4\cdot10^{18}$ γ-quanta/cm^2, a reduction of μ is observed in $\mu = f(\Phi)$ dependence for the liquid nitrogen temperature (Fig. 3, curve *1*), that is explained by the starting scattering on the formed radiation-induced defects. In addition, an insignificant increase in μ with growing irradiation dose at room temperature (Fig. 3, curve *2*) is observed as compared to that at liquid nitrogen temperature. Such behavior of $\mu = f(\Phi)$ dependence is explained in this case by the fact that at higher temperature the radiation-induced defects are ionized and practically do not neutralize the impurity ions, thus causing a relatively small change in $\mu = f(\Phi)$ values in the dose range up to $4\cdot10^{18}$ γ-quanta/cm^2. As to temperature dependences of the charge carrier mobility in CdSb(In) single crystals prior to and after γ-irradiation (Fig. 4), it is seen that near the room temperature, the μ values in the irradiated crystals (Fig. 4, curve *2*) approach essentially the mobility values in the unirradiated crystals (Fig. 4, curve *1*); that fact explains the insignificant relative changes in μ with increasing dose at room temperature.

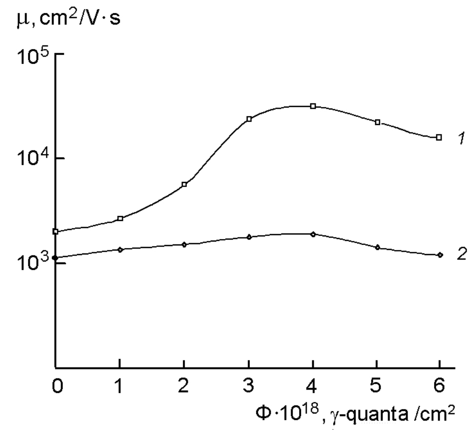

Fig. 3. Dose dependences of charge carrier mobility in CdSb(In) single crystals at 78 K (*1*); and at 293 K (*2*).

Thus, the radiation centers, which are brought into the crystal due to its irradiation, both at room temperature and the liquid nitrogen temperature, y "neutralize" in part the charge of impurity ions, localized at the lattice points. That is why the charge carrier mobility increase observed at this work appears not due to the increase of the crystals ordering resulting from its irradiation, but due to lowering of the charge carrier scattering efficiency on the impurity ions caused by the partial "neutralization" of their charge by the oppositely charged radiation-induced defects. The results obtained and their interpretation are in agreement with similar data presented in the works aimed at silicon and germanium single crystals [4, 5].

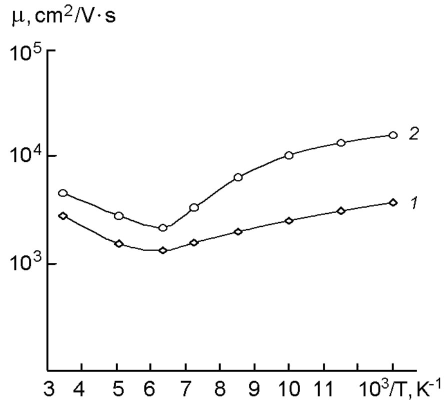

Fig. 4. Temperature dependences of charge carrier concentration in CdSb(In) single crystals prior to irradiation (*1*) and after γ-irradiation (*2*).

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Вплив γ-опромінення на кінетичні ефекти у монокристалах антимоніду кадмію, легованих індієм

Ю.В.Коваль

Досліджено вплив γ-опромінення на кінетичні ефекти у монокристалах антимоніду кадмію, легованих індієм. Вимірювалися питома провідність та ефект Холла, що дозволило отримати дозові та температурні залежності концентрації носіїв заряду та їх рухливості. Помічено різке збільшення значень рухливості в опромінених кристалах при дозах опромінення до $4\cdot10^{18}$ γ-кв/см^2, яке пояснюється наявністю "ефекту малих доз". Відмічено, що зростання рухливості носіїв заряду, що спостерігалося у даній роботі, виникає не за рахунок підвищення досконалості кристалів при їх радіаційній обробці, а за рахунок зниження ефективності розсіяння носіїв заряду на домішкових іонних залишках при частковій нейтралізації заряду протилежним за знаком зарядом дефектів.