ON THE PROBLEM OF THE DOPING EFFECT ON PHOTOELECTRIC MEMORY IN INDIUM SELENIDE SINGLE CRYSTALS

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The dysprosium doping effect on photoelectric memory in indium selenide single crystals has been investigated. It has been found that in InSe:Dy crystals with N_{Dy} determined at relatively low temperatures in a wide range of the change of light intensity the residual photoconductivity value remains constant and depends only on the wavelenght. The spectral memory effect has been observed. At low intensities the total absorbed light is responsible only for the residual photoconductivity, i.e. the accumulation of the weak light signals occurs.

The main characteristics of the above phenomena have been studied. Both of them are shown to be well explained on the base of the barrier model proposed for the materials investigated.

In early works [1-4] there was found that the monocrystallic InSe films are semiconductors with a wide variety of properties including also extraordinary ones. Taking into account their great perspective for science and technics we have studied the influence of doping of these materials by rare-earth elements on their electronic properties [5-7]. The present paper deals with the rare phenomenon discovered by us while investigating InSe:Dy photoelectric properties. Particularly, there was found that in InSe:Dy with the fixed impurity percentage concentration (N_{Dy}) at the relatively low temperatures the residual photoconductivity [1] value does not depend on the light intensity (Φ) varying in the wide range, but it is defined only by the light wavelenght (λ). This phenomenon is great importance, both from practical and scientific points of view, as the obtained results may be used for creating detectors and "color" storage elements of light radiation and also for clarifying the mechanism of electronic phenomena in partially disordered semiconductors in general, and in A^3B^6 layered crystals, in particular.

The measurement was carried out in a wide temperature region (from 75K up to 300K), the wavelenght (from 0.35 μ to 2.60 μ) and the light intensities (up to 10^2 lux) in InSe monocrystallic films doped by Dy (N_{Dy} = 0; 10^{-5}; 10^{-4}; 10^{-3}; $5 \cdot 10^{-3}$; 10^{-2} at. %).

It has been found that on illuminating the considered material by the light from fundamental absorption region ($0.35\ \mu \le \lambda \le 1.30\ \mu$) at temperature below 350K there the residual photoconductivity is observed, the magnitude (ΔI_{rph}), recurrence and relaxation time (τ_{rph}) of which depends on T, light intensity and wavelenght, and also on N_{Dy}.

More interesting, we think, that there are results obtained on investigating the luxary dependence $\Delta I_{rph}(\Phi)$ of residual photoconductivity. Particularly, unlike the ordinary photoconductivity case, behaviour of the $\Delta I_{rph}(\Phi)$ curves is determined by light wavelenght. In the deep fundamental absorption region this dependence abbeys the gradual low and at the very low intensities the whole absorbable light is consumed for residual photoconductivity excitation, providing InSe:Dy to be perspective material for creating weak light signal accumulators in this region of spectrum. With the further increase of Φ the share of ΔI_{rph} in the general photoconductivity I_{ph} decreases.

In the fundamental absorption edge region ($0.95\mu \le \lambda \le 1.20\mu$) with relatively high Φ the magnitude of ΔI_{rph} appears to be almost independent from Φ in the wide range of changing it and, thus, the spectral or "color" storages take place (Fig.1). On erasing the residual photoconductivity ΔI_{rph1} obtained after ceasing of the external excitation with the λ_1 wavelength light, and creating a new residual photoconductivity ΔI_{rph2} corresponded to wavelength λ_2 ($\lambda_2 > \lambda_1$), it appears that $\Delta I_{rph2} < \Delta I_{rph1}$. Besides, it has been obtained that on illuminating the sample at first by the λ_1 wavelength light, and then without erasing the created residual photoconductivity (ΔI_{rph1}), illuminate the sample by the λ_2 wavelength light, then the level of the residual conductivity does not change, in the reverse order of the illumination (at first λ_2, then λ_1), the residual photoconductivity increases from ΔI_{rph2} to ΔI_{rph1}.

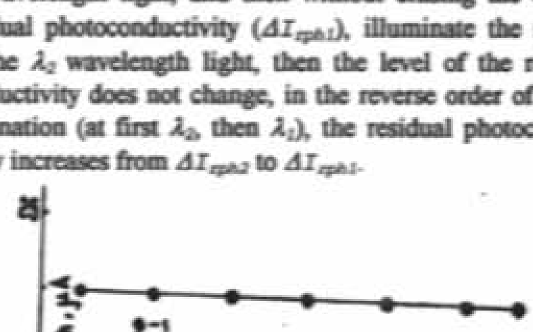

Fig. Dependence of ΔI_{rph} of lightintensity in various wave lengths in monocrystals of InSe:Dy with $N_{Dy} = 10^{-3}$ at.%. λ, μ: 1-0,975; 2-1,00; 3-1,10. T=77K.

We have also investigated the temperature and impurity percentage concentration dependence of spectral storages of the considered materials. It has been found that the effect decreases with the temperature increasing. The spectral storages effect brightness nonmonotoneously depends on impurity percentage concentration - at the relatively small values of N_{Dy} the brightness increases with increasing of N_{Dy}, passing over the maximum at $N_{Dy} \cong 10^{-3}$ at. %, and then decreases at $N_{Dy} > 5 \cdot 10^{-3}$ at. %.

The obtained results can be well explained in the frame of suggested barrier model for materials under consideration. According to this model InSe:Dy crystals consist of low ohmic matrix (LO) with a chaotic replacement of high ohmic

(H0) regions in it. On the boundary of these regions there exist recombining barriers with the heights depending on various external and intracrystal factors. In high ohmic inclusions deep capture levels have been localized [3]. While illuminating such crystals by the light from the deep fundamental absorption region the generated electron-hole pairs are divided by the internal recombining barrier fields, so electrons are accumulated in conduction band of L0, and holes - in valence band of H0. Optical straightening of energy bands does not appear in low intensities of the falling light. Therefore, almost all generated electrons and holesremain in the respective bands for a long time and create residual photoconductivity, accumulation of weak light signals storages take place.

Observation of "color " storages is also satisfactorily explained in the frame of the above suggested energy model for the materials under the consideration. Particularly, it is supposed that while illuminating by the light from the fundamental absorption edge region, electron - hole pairs are generated with the deficience of energy of free electron - hole pairs by means of tunneling of them through recombination barriers. As in such cases the tunneling transparence coefficient (*D*) is determined by the charge carrier energy, the magnitude of the residual photoconductivity will depend on the wavelength, but not the intensity of the falling light. As a result, the magnitude of ΔI_{rph} will depend on λ.

Weakening of the effect of the "color" storages and accumulation of weak light signals with temperature may rather be conditioned by the reduction of the recombining barriers role at higher temperatures, and their nonmonotoneous dependence on Dy percentage concentration - by the barrier's height nonmonotoneous dependence on the impurity percentage concentration.

Summarizing the obtained results the model suggested for their interpretation it may be said that in InSe:Dy at the certain values of temperature, impurity percentage concentration, light wavelength and intensity, the weak light signal accumulation and spectral or "color" storages take place. Both of the phenomena in materials under the consideration are conditioned by the partial non-ordering of crystals and localization in their high ohmic inclusions of deep energy capture levels. In such structures the above described effects are excited by the influence of light by means of tunneling through recombining barriers and in effective space division of non-equilibrium electron-hole pairs respectively.

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AŞQARLANMANIN İNDİUM-SELEN MONOKRİSTALLARINDA FOTOELEKTRİK YADDAŞ HADİSƏSİNƏ TƏ'SİRİ HAQQINDA

InSe kristallarında fotoelektrik hadisəsinə Dy aşqarlarının tə'siri öyrənilib. Bu zaman daxil edilmiş disprozium aşqarlarının konsentrasiyasının müəyyən qiymətlərində alçaq temperaturlar diapazonunda qalıq fotokeçiriciliyin qiyməti işığın intensivliyinin geniş intervalda dəyişməsində ondan asılı olmur, yalnız dalğa uzunluğundan asılı olaraq dəyişir. Bu hadisə spektral yaddaş hadisəsi adlanır. İşığın intensivliyinin kiçik qiymətlərində isə kristala tə'sir edən işığın hamısı yalnız qalıq fotokeçiriciliyi yaratmağa sərf olunur - zəif işıq siqnallarının toplanması baş verir.

Hər iki hadisə bu kristallar üçün təklif olunan çəpər modeli əsasında izah olunur.

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К ВОПРОСУ О ВЛИЯНИИ ЛЕГИРОВАНИЯ НА ЭФФЕКТ ФОТОЭЛЕКТРИЧЕСКОЙ ПАМЯТИ В МОНОКРИСТАЛЛАХ СЕЛЕНИДА ИНДИЯ

Исследовано влияние легирования диспрозием на эффект фотоэлектрической памяти в монокристаллах селенида-индия. Установлено, что в кристаллах InSe:Dy с определенной N_{Dy} при относительно низких температурах в широком диапазоне изменения интенсивности света величина остаточной фотопроводимости остается постоянной и зависит лишь от длины волны - наблюдается эффект спектральной памяти. При малых интенсивностях весь поглощенный свет создает лишь остаточную фотопроводимость - происходит накопление слабых световых сигналов.

Изучены основные характеристики этих явлений. Показано, что оба они хорошо объясняются с единых позиций на основе предложенной для изучаемых материалов барьерной модели.

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