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PECULARITIES OF PHOTOCONDUCTIVITY OF $TlGaS_2$ SINGLE CRYSTAL DOPED WITH Nd^{3+} IONS

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The photoconductivity (PC) of $TlGaS_2$ single crystal doped with Nd^{3+} ions is studied. At low electric fields ($E\leq 10^2$ V/cm) and low Nd^{3+} concentrations (x=0.001) the PC spectrum has only one maximum at 2.9 eV and its red boundary corresponds to 2.61 eV which coincides with the band gap . At high electric fields ($E\leq 10^3$-10^4 V/cm) , besides the I maximum, the second maximum with $h\nu_2$=2.65eV appears in the PC spectrum for all the compositions with $0<x\leq$ 0.003. The nature of PC on the base of impurity model is discussed.

Key words: photoconductivity, $TlGaS_2$

$TlGaS_2$ is a semiconductor with an indirect band-gap of about 2,46 and 2,55 eV at 300 and 10K respectively[1]. A high photosensitivity in the visible range of spectra makes this crystal useful for optoelectronics[2]. For possible applications in optoelectronic devices in this range much attention has been devoted to the study of the optical and electrical properties of $TlGaS_2$ [3-5]. In this regard, detailed information on the presence of the impurity and defect centers in the crystal is important. $TlGaS_2$ is strongly anisotropic semiconductor where the conductivity in the layer is of several orders of magnitude higher than that normal to the layer. The electronic energy-band structure of this crystal recently has been calculated [6].

In the present report .the results of studying the photoconductivity (PC) spectrum of $[TlGaS_2]_{1-x}[Nd_2S_2]_x$ single crystals (where x=0.001; 0.002; 0.003) at energies of 0.8-3eV and temperatures from 77 to 300 K are discussed The $[TlGaS_2]_{1-x}[Nd_2S_2]_x$ crystals (x=0.001; 0.002; 0.003) have been grown by the Bridgman-Stockbarger method/4/. In the above method the Nd impurities enter into $TlGaS_2$ as the Nd^{3+} ion [7]. The PC spectrum for $TlGaS_2$ crystals with different Nd^{3+} ion concentration (the maximum of Nd_2S_3 concentration is $\approx 10^{19}$ cm^{-3} at 77 K is shown in Fig. 1.

At low electric fields $E\leq 10^2$ V/cm and low Nd^{3+} concentrations (x=0.001) the PC spectrum has only one maximum at 2.9 eV (I maximum) and its red boundary corresponds to 2.61 eV which coincides with the band gap [8,9]. For the composition with x=0.003 the PC spectrum and its maximum towards the long-wavelength region (Fig. 1, curve 3).

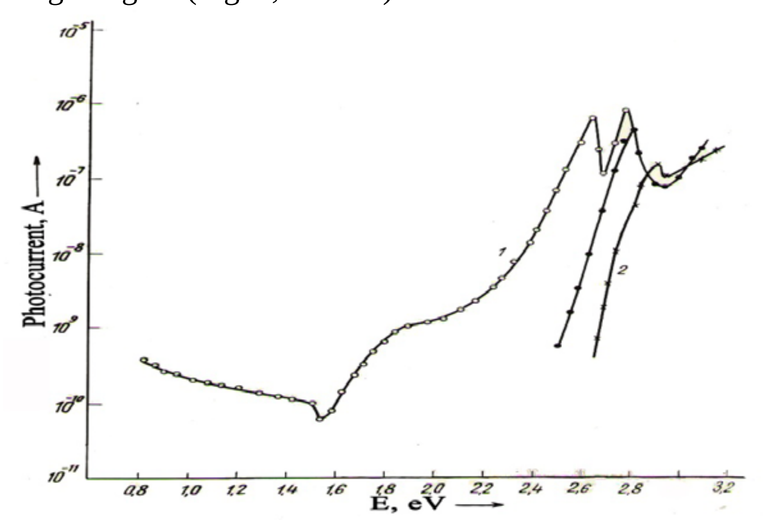

Fig.1. The photocurrent spectrum of $[TlGaS_2]_{1-x}[Nd_2S_2]_x$ single crystals at 77 K at the value of $E=10^2$ V/cm, (x: 1-0; 2-0.001; 3-0.003).

The PC spectrum of the basic compounds $TlGaS_2$ at low electric fields has the two maxima at $h\nu_1$=2.8eV and $h\nu_2$=2.65eV coinciding with the PC spectrum maxima of the composition with x=0.003.

At high electric fields ($E \le 10^3$-10^4 V/cm) besides the I maximum, the second maximum with $h\nu_2$=2.65eV appears in the PC spectrum for all the compositions with $0<x\le 0.003$. With increasing x in the PC spectrum the impurity fraction also increases.

The PC spectrum of $TlGaS_2$ widens to long-wavelength region and a sharp decrease of PC at 1.5 eV followed by its growth is observed (Fig. 2, curve 1).

At 300K PC spectrum of $[TlGaS_2]_{1-x}[Nd_2S_2]_x$ crystals $0<x\le 0.003$ has an impurity region similar to that of $TlGaS_2$. The photosensitivity of the composition with x=0.003 in the short-wavelength region increases by two orders, the PC spectrum maxima correspond to $h\nu_1$=2.8eV and $h\nu_2$=2.65eV.

The observed values of $TlGaS_2$ photoconductivity spectrum maxima at 77 K coincide with their values obtained in [5,6]. The analysis of the obtained results shows that the first maximum at ($h\nu_1$=2.8eV) is attributed to direct band-band transitions, while the second maxima is close to the energy of the exciton absorption [5,6]. The observed wide band of the PC spectrum confirms the existence of a large amount of impurity levels in the $TlGaS_2$ band gap [2] behaving as the acceptor levels and forming wide impurity band.

As seen in Fig. 1 at x=0.001 the photosensitivity of the crystal doped by Nd^{3+} is less as compared to that of the basic crystal. For this composition in the PC spectrum maximum corresponds to energies of the direct transitions (band-band transition) in *$TlGaS_2$*. and the second maximum attributed to the exciton absorption disappears (Fig. 1, curve 2). The decrease of photocurrent and a disappearing of second maximum of the PC spectrum is following by strengthening the maximum in the absorption spectrum /1,2/ that indicates the perfection of the crystal ("cleaning" from impurities, its strengthening) at initial doping by Nd^{3+} ions. The coincidence of a red boundary of the PC spectrum at initial doping by Nd^{3+} ions with the *$TlGaS_2$* band gap confirms the above-mentioned. The further increase of Nd^{3+} concentration (x=0.002) is accompanied by photocurrent increase and the occurrence of the of the impurity photoconductivity. In the case, the intensity of exciton absorption line decreases that confirms the increase of crystal defects and hence, the destruction of free excitons or the formation of the bounded excitons [1, 2].

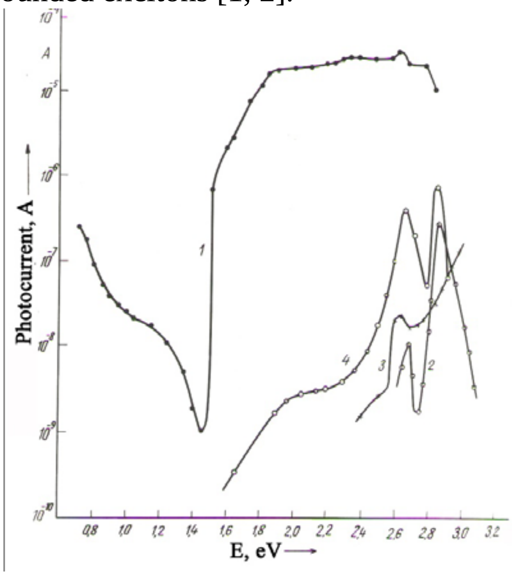

Fig.2. The photocurrent spectrum of *$TlGaS_2$* single crystals at 77 K at the value, of $E=10^4$ V/cm (x: 1-0; 2-0.001; 3-0.002; 4-0.003).

The PC spectrum at 300 K (Fig. 3) also confirms the exciton nature of the second maximum. At x=0.001 and x=0.002 the photosensitivity in the above maximum region is lower than that of the basic crystal (the increase of the exciton line), while at x=0.003 the photosensitivity increases by 1-1.5 orders due to exciton decay. With increase of applied electric field the second maximum attributed to the exciton absorption appears again and it increases as the x value grows (Fig. 2). The comparison of the PC spectrum of the composition with x=0.003 at high electric fields with that of the basic crystal at low fields shows that in the energy region of 1.6-3.0 eV they are identical. A lack of impurity band in the PC spectrum 0.8-1.6 eV in crystals doped shows that when doping by the Nd^{3+} ions, “ the cleaning” of the crystal mainly takes place due to the fact that the deeper impurity levels enter into the complex with Nd^{3+} ions and are not involved into the PC process at low temperatures and fields. Only above a certain value of electric fields and temperatures the above impurities become electrically active.

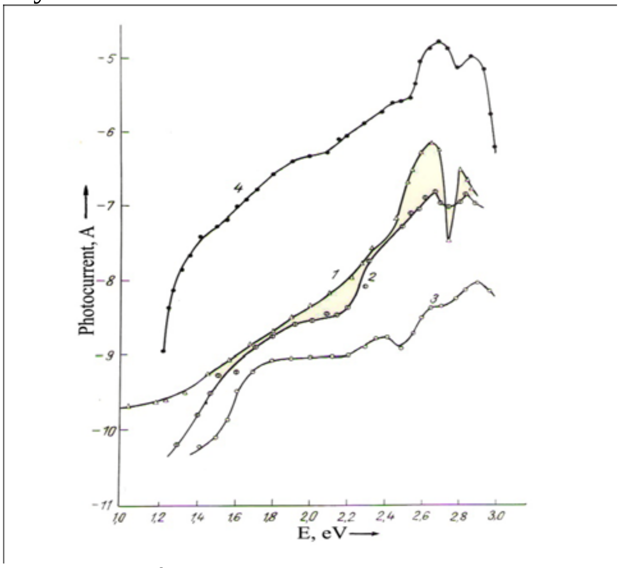

Fig.3. The photocurrent spectrum of $TlGaS_2]_{1-x}[Nd_2S_2]_x$ single crystals at 300 K at the value of E=10^2 V/cm, (x: 1-0; 2-0.001; 3-0.003; 4-0.003).

According to the above given quantitative model, the impurity model, the impurity levels responsible for impurity bands and for forming a complex with rare-earth ions cannot take part in recombination processes at low temperatures. That is why, as expected we do not observe impurity luminescence nor impurity photoconductivity and dark conductivity.

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Gd^{+3} İONLARI İLƏ AŞQARLANMIŞ $TlGaS_2$ LAYLI YARIMKEÇİRİCİSİNİN FOTOKEÇİRİCİLİYİNİN ÖZƏLLİKLƏRİ

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XÜLASƏ

Gd^{+3} ionları ilə aşqarlanmış $TlGaS_2$ laylı yarımkeçiricisinin fotokeçiriciliyi tədqiq olunmuşdur. Zəif elektrik sahələrində (E≤ 10^2 V/sm) və Nd^{3+} ionlarının kiçik konsentrasiyalarında (x=0.001) fotokeçiriciliyin (FK) spektrində işıqlandırma enerjisinin 2,9 eV qiymətində yalnız bir maksimum mövcuddur. Bu maksimumun qırmızı sərhədi isə 2,61 eV enerjiyə təsadüf edir ki, bu da $TlGaS_2$-nin qadağan zolağının eni ilə üst-üstə düşür. Güclü elektrik sahələrində (E≤ 10^3-10^4 V/sm) İ maksimumdan əlavə, *x*-in 0<x≤ 0.003 intervalındakı bütün qiymətlərində $h\nu_2$=2.65 eV enerjisinə uyğun ikinci maksimum da meydana çıxır. FK-in təbiətini izah edən model təklif olunur.

Açar sözlər: fotokeçiricilik**,** $TlGaS_2$

ОСОБЕННОСТИ ФОТОПРОВОДИМОСТИ СЛОИСТОГО ПОЛУПРОВОДНИКА $TlGaS_2$ ЛЕГИРОВАННОГО ИОНАМИ Gd^{+3}

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РЕЗЮМЕ

Исследована фотопроводимость монокристалла $TlGaS_2$ легированного ионами Gd^{+3}. При относительно слабых электрических полях (E≤ 10^2 В/см) и малых концентрациях ионов Nd^{3+} (x=0.001) в спектре фотопроводимости (ФП) имеется только один максимум, при энергии освещения 2.9 эВ, а его красная граница соответствует энергии 2,61 эВ, что совпадает с шириной запрещенной зоны. В сильных электрических полях (E≤ 10^3-10^4 В/см), кроме I максимума в спектре ФП, появляется второй максимум при $h\nu_2$=2.65 эВ, что имеет место для всех значений *x* в интервале 0<x≤ 0.003. Предложена модель для объяснения природы фотопроводимости.

Ключевые слова: фотопроводимость**,** $TlGaS_2$

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