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INFLUENCE OF LASER IRRADIATION ON $Hg_{1-x}Mn_xTe$ PHOTOELECTRICAL PROPERTIES

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ABSTRACT

We have carried out experimental investigation of spectral and temperature dependences of photoconductivity in n-type $Hg_{1-x}Mn_xTe$ ($x = 0.1$) and studied an influence of nanosecond pulses of ruby laser irradiation on such properties. It has been shown that irrdiation of the samples with subthreshold energy densities ($E < E_{th} = 0.18$ J/cm^2) does not cause a change of their photosensitivity and leads to the surface refining from impurity atoms and oxides. A laser treatment of the samples with energy densities $E > E_{th}$ stimulates a rise of the defect number in the crystals that causes a change of the lifetime characteristics and photosensitivity lowering.

Keywords: laser, photoconductivity, recombination, lifetime, $Hg_{1-x}Mn_xTe$.

1. INTRODUCTION

Diluted magnetic semiconductors have in recent years attracted considerable attention of the scientific community. $Hg_{1-x}Mn_xTe$ is one of the most intencively investigated representative of this group of materials. This ternary semiconductor possesses many interesting properties[1] which result because of the spin-spin exchange interection that occurs between the localized magnetic moments associated with the Mn^{2+} ions and the condaction band electrons and valence band holes. Apart from the magnetic-related characteristics, such material exhibits composition-dependent optical and transport properties, much as the nonmagnetic ternary alloys like $Hg_{1-x}Cd_xTe$. A few years ago it was suggested that $Hg_{1-x}Mn_xTe$ could represent an alternative material for IR detector applications.[2] However this alloy system has never been systematically explored in the device context.[3-5] Moreover the possibilities of laser modification of $Hg_{1-x}Mn_xTe$ properties were not so far considered in scientific papers. Therefore it is of interest to investigate an influence of nanosecond laser pulses on photoelectric properties of $Hg_{1-x}Mn_xTe$ crystals.

2. INVESTIGATION METHODS

The single crystal specimens used for the present work were grown by Bridgman method and possessed n-conductivity. After the chemical etching thier liner dimentions were 3×1 mm, the thickness was ~300 μm. As a laser radiation source we used a Q-switched ruby laser ($\lambda = 0.69$ μm) emitting pulses of 20 ns duration with energy density varied in the range $E = 0.03-2.66$ J/cm^2. Indium contacts were disposed on mirrow-smooth surface of the samples. The whole area between contacts was subjected to laser irradiation. An investigation of the spectral dependences of the photoconductivity (PC) signal carried out before and after laser irradiation at T=77 K. The photosensitivity was evaluated by the change of absolute value of the PC signal and factor of its amplification. The nonequilibrum carrier lifetime of the initial and irradiated samples was estimated from the PC relaxation curves at the excitation by Nd-laser pulses under linear lux-ampere characteristic in the temperature range $T = 77-300$ K. The absolute position of the solid solution ($x=0.1$) was determined by a JCXA-733 x-ray microanalyzer. For evaluation of the surface recombination rate we used standard equations based on the analysis of the form of PC spectral distribution.[6]

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3. EXPERIMENTAL RESULTS

Figure 1 shows PC spectra before (curve 1) and after treatment by nanosecond ruby laser pulses with different energy densities (curves 2-5). Spectra have a typical δ-shape with maximum at λ= 7.37 μm (T = 77 K) that corresponds to band gap value (E_g = 0.155 eV) calculated for the present crystal composition (x = 0.1) using formula given in Ref.7:

$$E_g(x,T) = 0.253 + 3.446x + 4.9 \times 10^{-4}T - 2.55 \times 10^{-3}xT.$$

A sharp long-wavelength edge of the spectra was evidence of the uniformity of the

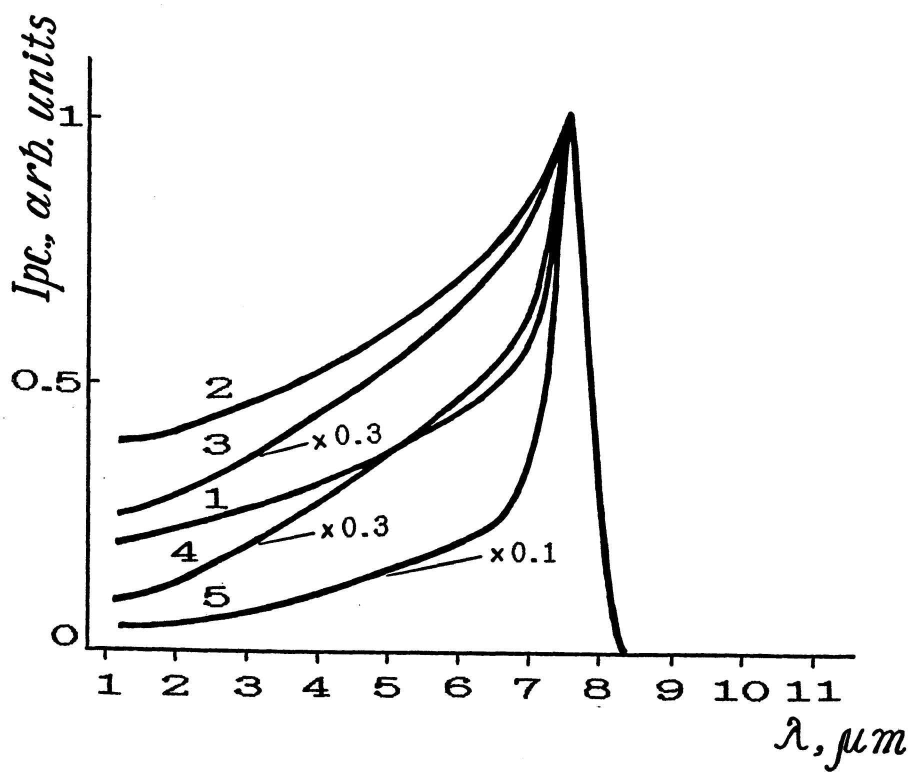

FIG.1. Spectra of the $Hg_{1-x}Mn_xTe$ photoconductivity signal before (1) and after (2-5) laser irradiation with pulses of the following energy density E (J/cm^2): 2) 0.033; 3) 0.18; 4) 1.6; 5) 2.66.

elemental composition. A study of the surface morphology of the samples showed that there is no visible surface demage in the zone of interection with laser radiation pulses of energy densuty E < E_{th} = 0.18 J/cm^2. The photosensitivity of the crystals did not change too (see the table). A rising of the short-wavelength edge of the

N	E, J/cm^2	s, cm/s	PS, arb. units
1	initial	3.33×10^3	1
2	0.03	9.2×10^2	1
3	0.18	1.23×10^3	0.3
4	1.60	3.33×10^3	0.3
5	2.66	2.32×10^4	0.1

Table. The values of the surface recombination rate and photosensitivity (PS) of the samples before and after laser irradiation with different energy densities.

spectra (Fig.1, curve 2) was observed that indicated a reduce of the surface recombination rate (the table) connected with laser cleaning of the surface from impurity atoms and oxide films. After irradiation of the samples with energy densities $E>E_{th}$ an intensity of photosignal decreases in the whole photosensitivity region without change of long-wavelength edge and maximum position (Fig.1, curves 3-5). This result differs from early observed at laser irradiation of $Hg_{1-x}Cd_xTe$ crystals[8] where the short-wavelength shift of red edge of PC spectrum took place and was accounted by a change in the composition of the thin surface layer under the laser irradiation. Our data are evidence of invariable elemental composition of $Hg_{1-x}Mn_xTe$ after irradiation and thus of more stable conection of HgTe in investigated samples. The downfall of the short-wavelength edge of the spectra indicates an increase of the surface recombination rate (the table) caused by creation of structure defects in the nearsurface region of the samples under the action of laser pulses irradiation with $E>E_{th}$.

A treatment of the $Hg_{1-x}Mn_xTe$ crystals by nanosecond laser pulses leads to the visible change in the carrriers density and lifetime. The temperature dependences of carriers lifetime in the initial and irradiated samples adduced in Figure 2 allow to observe the dynamics of laser stimulated defect promotion. Analysis of the data has

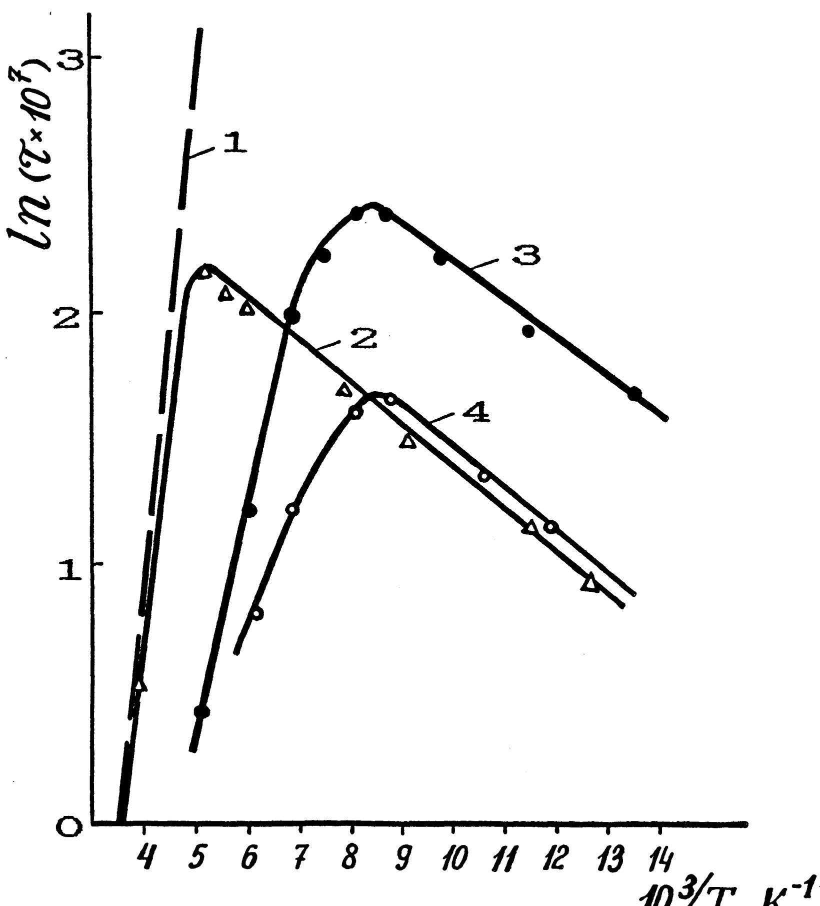

FIG.2. Temperature characteristics of carriers lifetime of the initial samples (1 - theoretical curve, 2 - experimental) and irradiated (3,4) with energy densities $E(J/cm^2)$: 3) 0.033; 4) 0.18.

shown that in the initial crystals the Auger recombination determines carriers lifetime at T = 195-300 K (Fig.2, curve 2). The theoretical curve for Auger-process (curve 1 in Fig.2) is obtained using equations given in Ref.2. A good agreement with theoretical and experimental data is observed. For the irradiated samples the temperature bound of the Auger-process occuring shifted to T = 125 K (Fig.2, curves 3,4). At lower temperatures the recombination occurs via acceptor levels with activation energy E_a = 12 meV in both initial and irradiated samples (Fig.2, curves 2-4). Considerable decrease of the carriers lifetime takes place both on the surface and in the volume of the samples (Fig.2, curve 4) at the same time when the intensity of laser pulses exceeds a melting threshold that was caused by increase in number of laser stimulated defects in the crystals. This fact is supposedly a main reason of the photosensitivity reducing.

4. CONCLUTIONS

Irradiation of the crystals of $Hg_{1-x}Mn_xTe$ by ruby laser pulses with subthreshold energy densities does not cause a change of the samples photosensitivity and leads to the surface refining and therefore to decrease of the surface recombination rate and increase of the carriers lifetime.

A laser treatment of the samples with energy densities $E>E_{th}$ stimulates a rise of defect number in the crystals that displays in the change of the lifetime characteristics and photosensitivity lowering.

Invariable position of the maximum and long-wavelength edge of the photoconductivity spectra under the influence of nanosecond laser pulses on $Hg_{1-x}Mn_xTe$ crystals testifies to the constancy of the solid solution component composition and thus to more stable connection of Hg-Te in this material.

5. REFERENCES

1. J.K.Furdyna, "Diluted magnetic semiconductors" J. Appl. Phys., Vol.64., N4., pp.R29-R64, 1988.
2. A.Rogalsky, " $Hg_{1-x}Cd_xTe$ as a new infrared detector material", Infrared Phys., Vol.31., N2., pp.117-164, 1991.
3. Gelmont B.L., Golonska R.R., Vahabova E.M. et al., "Photoconductivity and photoluminescence in HgMnTe in magnetic fildes", Sov. Phys. Semicond., Vol.20., N1, pp.73-79, 1986.
4. J.Wrodel, F.Kuchar and R.Meisels, Acta phys. pol.A. Vol.67, p.369, 1985.
5. T.I.Hazarenkova, E.A.Salkov, N.V.Sochinskii et al., "Photoconductivity of n-$Hg_{1-x}Mn_xTe$ epitaxial layers", Fiz. and Tekh. Poluprovodn., Vol.23, N7, pp.1309-1311, 1989.
6. R.A.Lafft, H.Y.Fan, "Carrier Lifetime in Indium Antimonide", Phys. Rev., Vol.121, N1, pp.53-62, 1961.
7. J.Kanievski and A.Mishelski, Solid St. Com., Vol.41, p.959, 1982.
8. Virt I.S., Lyubchenko A.V., Mozol P.E., Gnatyuk V.A., "Peculiarities of electrophysic and photoelectric properties of HgCdTe monocrystals subjected to laser irradiation", Sov. Phys. Semicond. Vol. 23, N 8, pp.862-864, 1989.