LUX-AMPERE CHARACTERISTICS AND PHOTOCURRENT KINETICS IN $Au_3In_5Se_9$ CRYSTALS

N.F. GAHRAMANOV, S.S. SADULOVA
Sumgait Technical University
373208, Sumgait, 43 quarter

Lux-ampere characteristics, kinetics and temperature dependence of the photocurrent for $Au_3In_5Se_9$ compound have been investigated under the light impact and $П$-pulse excitation. The lifetime for non-equilibrium charge carriers has been determined.

INTRODUCTION

Photoconductivity spectra of $Au_3In_5Se_9$ compound at different directions of the electric field have been studied elsewhere [1].

In this paper results of the studies of lux-ampere characteristics (LAC), measured at different energies of incident quanta as well as the kinetics and temperature dependence of photocurrent under the light impact and excitation by $П$-pulses are presented.

We used the method of rectangular modulation of light illumination to determine the non-equilibrium charge carriers lifetime. It is well known [2] that in this case exciting pulses must be classified as on intensity, and their duration in comparison with characteristic relaxation times of the majority and minority charge carriers.

In the measuring installation we have used light pulses of incandescent lamp ($П$-pulse) as exciting source with a few minutes duration and light flash of $3\cdot10^{-6}$s duration by ИСШ-100 lamp. Exciting pulses have been divided in [3,4] on the intensity as follows: short pulses have high intensity (light impact), and long $П$-pulses have low intensity. The chosen pulses allowed to find charge carriers lifetimes determined through slow and quick levels.

RESULTS AND DISCUSSION

Fig.1 presents LAC at different energies of incident quanta, corresponding to different points of the photoconductivity (PC) spectrum. Such choice of excitation energies allows to compare recombination processes in the volume and surface, as quanta, whose energies are higher than the band gap, are absorbed on the surface. It is seen from fig.1, that recombination mechanism for all cases is identical and LAC are sublinear ($n \propto I^{-1/2}$), fulfilling the square, bimolecular recombination mechanism.

From the analysis of LAC one can find only qualitative information on non-equilibrium charge carriers recombination mechanism. In fig.2 (curve 3) PC spectrum is presented at 100 K with 82 Hz frequency of the light intensity modulation. Light pulses had rectangular shape. It is seen from comparison of curves 3 and 2 (without modulation) that in the impurity absorption region the photoconductivity under modulated light is absent, and in other regions spectra have identical run. Difference is only in the fact, that the photocurrent in the range 1.2-1.38 eV under modulated light is higher, and in the 1.5 eV region is lower, than under the permanent illumination. The first difference is characteristic for all high-resistance photosensitive semiconductors [2].

The second difference can be connected with the fact, that quanta with energies higher than ΔE_g are adsorbed near the surface, where a number of localized states is greater than in the volume, i.e. a lifetime for non-equilibrium charge carriers may be calculated, if the amplification coefficient is known [5]. Calculated value for the non-equilibrium charge carriers lifetime is equal to $\tau \approx 10^{-5}$ c.

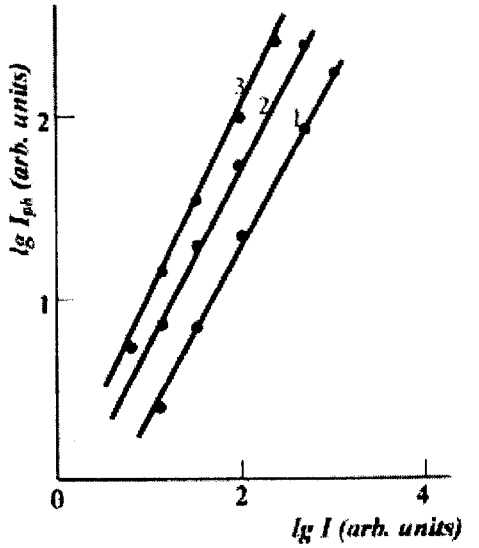

Fig.1 Lux-ampere characteristics of $Au_3In_5Se_9$ compound at different energies of incident quanta $h\nu$, eV: 1-1.1; 2-0.9 and 3-0.8 eV.

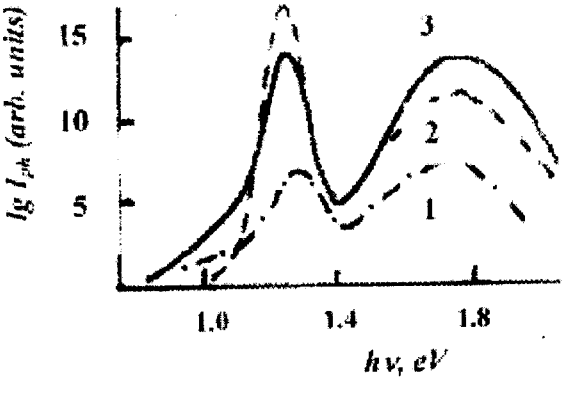

Fig.2 Photocurrent spectrum of $Au_3In_5Se_9$ single crystals under steady-state (1,2) and modulated illumination (3) at dif ferent temperatures, K: 1, 3 – 100, 2 – 300 K.

Non-equilibrium charge carriers lifetime can be determined more precisely from measurements of the photoconductivity kinetics [3]. Dependence of the photocurrent under

the fundamental excitaion of $Au_3In_5Se_9$ single crystals was studied. Energy of exciting quanta was equal to 1.3 eV and the light intensity of Π-pulse was $9 \cdot 10^2$ Lx. This value corresponds to the maximum of the photocurrent in the PC spectrum. Duration of the light pulse Δt many times exceeds the lifetime τ_n of majority charge carriers, i.e. we have the steady-state regime: $\Delta t \gg \tau_n$.

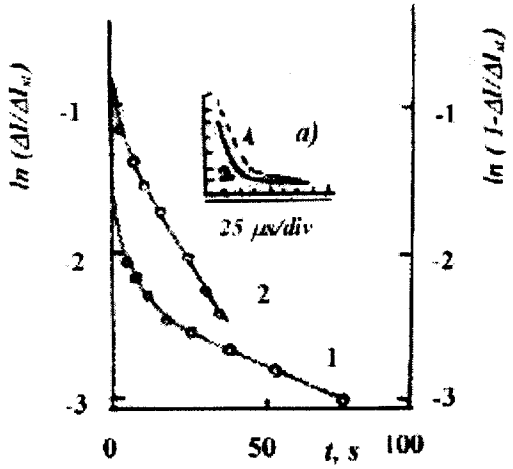

Fig.3 Kinetics of the current in $Au_3In_5Se_9$ compound under the light impact (a) and Π-pulse excitation: 1 – decay and 2 – rise curves.

As have been noted above, $Au_3In_5Se_9$ single crystals possess the high photosensitivity. In such semiconductors for considered levels of the steady-state excitation $\tau_s \ll \tau_r$ (where τ_s and τ_r are lifetimes for the non-equilibrium charge carriers, determined by s- and r- centers, respectively). Rise and decay curves are determined only by the time τ_r from the photocurrent kinetics, i.e. S-section is absent on the decay curve. It means, that owing to the high coefficient of electrons capture by r-centers, steady-state excitation will not lead to appreciable accumulation of holes in these centers.

One can calculate τ_r from dependences ln $(\Delta I/\Delta I_{st})$ and ln $[1-(\Delta I/\Delta I_{st})]$ versus time. fig.3 shows photocurrent decay (1) and rise (2) curves at 300 K. Relaxation time, determined from the slope of the linear section, is equal to 4.2 s.

As it follows from the photocurrent kinetics, a variation of the non-equilibrium charge carriers via slow levels is small in comparison with the total density. Relaxation of the photocurrent is determined mainly by recombination via fast centers.

Relaxation time, characterized by these centers, was determined from the photocurrent kinetics under the excitation by short-term pulses of light (light impact). Duration of light pulses for ИСШ-100 lamp is equal to 3 μs. Kinetics of relaxation of the "light impact" excitation is represented on fig.3a. Relaxation time, determined as time, in which an amplitude of the photocurrent decreases by e-times, is equal to $4 \cdot 10^{-6}$s. Lifetime for non-equilibrium charge carriers excitation by light, absorbed near surface, was estimated from the PC measurements. This value is $\sim 10^{-5}$s and does not correlate with the relaxation time of fast centers. However it confirms the assumption made at interpretation of results of PC spectrum measurements under steady-state and modulated illumination. We supposed there that the volume lifetime for non-equilibrium charge carriers appreciably lower than surface one. Calculated lifetime, determined from curves of non-equilibrium conductivity at different Π-pulses excitation levels for $Au_3In_5Se_9$ specimens, in practice does not depend on the light intensity (maximum intensity was not higher than 10^3 Lx at the experiment).

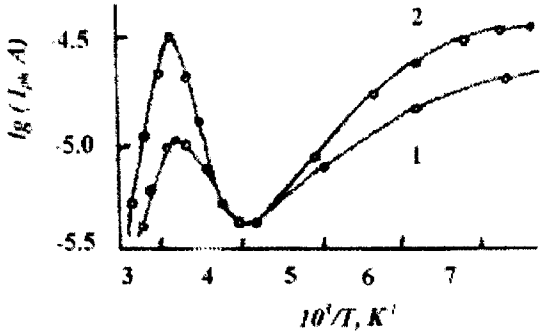

Fig.4 Temperature dependence of the current in $Au_3In_5Se_9$ compound for two light intensities: $I_2 > I_1$.

Temperature dependence of the photocurrent $I_{ph}(T)$ is shown on fig.4 at different excitation levels in photosensitive $Au_3In_5Se_9$ specimens for two intensities. It has the complicated shape and its interpretation requires taking into consideration temperature dependences of the concentration and mobility of non-equilibrium charge carriers. Photocurrent decreases in temperature ranges 130-250 K and 320-350 K. Drop of the photocurrent in the region 320-350 K apparently is caused by the thermal quenching of PC, observed in photosensitive semiconductors [4]. This assumption is based on the change of $I_{ph}(T)$ curves course under different optical excitation levels. The region of temperature quenching of PC (TQPC) shifts to higher temperatures with increase of excitation intensity. However, multiplicity of TQPC is so small, that in practice it is very hard to determine energetic positions of photosensitive centers. Comparison of the photocurrent decay in the range 130-250 K with the temperature dependence of the charge carriers mobility allows to assume, that decrease of I_{ph} in the specified range results from decrease of the mobility with the temperature growth.

[1] *N.F. Gakhramanov.* Scientific Reports of the Sumgayit State University, 2001, №1, pp. 20-24.

[2] *S.M. Ryvkin.* Photoelectrical Phenomena in Semiconductors. Moscow, Fizmatgiz, 1963, p.494.

[3] *E.I.Androvin, Ye.M.Kuznetsova.* Doklady AN SSSR, 1962, v. 1476, №4, pp.813-816

[4] *R.Bube.* In "Photoconductivity in Solids". 1962, Moscow, p.409.

[5] *N.M.Kolchanova, D.N.Nasledov.* 1966, FTT, v.8, №4, p.1907-1914.

N.F. GAHRAMANOV, S.S. SADULOVA

N.F. Qəhrəmanov, S.S. Sadulova

$Au_3In_5Se_9$ KRİSTALLARININ LÜKS-AMPER XARAKTERİSTİKALARI VƏ FOTOCƏRƏYANIN KİNETİKASI

İşdə $Au_3In_5Se_9$ birləşməsinin LAX, fotocərəyanın kinetikası və temperaturdan asılılığı işıq zərbəsi və Π –şəkilli işıq impulsunun təsiri şəraitində öyrənilmişdir. Tarazlıqda olmayan əsas yükdaşıyıcılarının yaşama müddəti təyin olunmuşdur.

Н.Ф. Кахраманов, С.С. Садулова

ЛЮКС-АМПЕРНЫЕ ХАРАКТЕРИСТИКИ И КИНЕТИКА ФОТОТОКА В КРИСТАЛЛАХ $Au_3In_5Se_9$

В работе исследованы ЛАХ, кинетика и температурная зависимость фототока соединения $Au_3In_5Se_9$ при световом ударе и возбуждении Π-импульсами. Определено время жизни неравновесных носителей заряда.

Received: 18.04.01