Journal of Optoelectronics and Advanced Materials Vol. 2, No. 3, September 2000, p. 293-296

SHORT COMMUNICATION

PHOTOCONDUCTIVITY RELAXATION IN As_2Se_3:Sn AND AsSe:Sn AMORPHOUS THIN FILMS

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Photoconductivity relaxation experiments in As-Se chalcogenides doped by tin were performed. The distribution of the localized states in AsSe amorphous thin films is more strongly influenced by tin if compared to the case of the As_2Se_3 amorphous thin films.

(Received February 20, 2000; accepted July 6, 2000)

Keywords: Amorphous chalcogenides, Thin films, Photoconductivity relaxation

Arsenic selenide glassy alloys are well known as high photosensitive materials with a wide range of applications in optoelectronics and information storage systems [1]. Recently, attention was paid to the effect of the metal impurities on the photoconductivity, especially in relation to the structural disorder that is higher in thin amorphous films than in bulk glasses.

Recently, some stationary and non-stationary electrical and photoelectrical characteristics of pure As_2Se_3 and AsSe amorphous thin films, doped with small amount of tin impurity (up to 1% Sn) were reported [2]. It was shown that tin impurity in chalcogenide glasses influences rather the non-stationary than stationary physical characteristics. In the present note some experimental results on long-term photoconductivity relaxation in arsenic selenide (As_2Se_3 and AsSe) amorphous thin films doped with tin impurity up to 3.5 at.% Sn are presented. The films of thickness $L = 1 \div 10$ μm were prepared by "flash" thermal evaporation in vacuum onto glass substrates held at T_{substr} = 100 °C. Aluminium or gold electrodes were used, one of which was transparent.

In Fig. 1 the stationary lux-ampere characteristics for AsSe amorphous thin films with different concentration level of tin impurity are shown. An increase of photoconductivity for doped samples is observed.

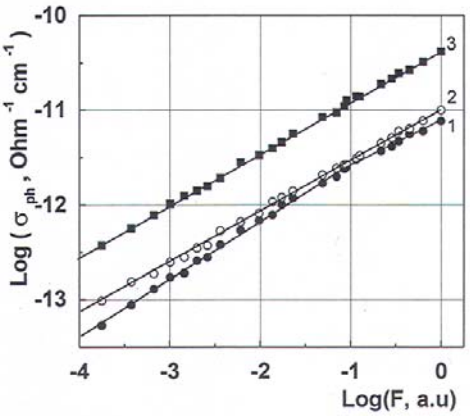

Fig. 1. The lux-ampere characteristics of photoconductivity for AsSe (1), AsSe:Sn_1 (2) and AsSe:Sn_3 (3) thin films at room temperature (T = 290 K) for monochromatic excitation with He-Ne laser (λ = 0.63 μm, $F_0 = 6.5 \times 10^{14}$ $cm^{-2} \cdot s^{-1}$).

The dependence of photoconductivity σ_{ph} upon light intensity F for all samples shows a power-law dependence

$$\sigma_{ph} = AF^{\gamma}, \tag{1}$$

where A is a constant, and the power index γ is situated in the range $0.5 \leq \gamma \leq 1.0$. These results are in agreement with those obtained for AsSe amorphous thin films prepared by thermal and laser evaporation in vacuum [3,4]. The lux-ampere characteristics may be interpreted in the frame of Rose model assuming an exponential distribution of localized states in the band gap of the amorphous semiconductor, and which was applied successfully to other chalcogenide glasses [1].

For photoconductivity transient experiments a He-Ne laser light (λ = 0.63 μm) was used to generate the photocurrent. The relaxation curves were recorded with a time constant not exceeding 0.3 s on an ENDIM 622.02 X-Y plotter using an U5-11 electrometric amplifier. The computer was used for calculations and data processing.

Fig. 2 shows the rise (a) and decay (b) of photoconductivity for AsSe amorphous thin films for different intensities and concentrations of tin impurity in the glass. The rise and decay curves for all investigated samples at various intensities and temperatures are typically for amorphous semiconductors. For rise curves of photocurrent, with increasing of exposure intensity a quasi-stationary region is observed, which is followed by a decreasing one before reaching the stationary value. At highest excitation levels in, the relaxation curves the quasi-stationary domain of photocurrent disappears and an "overshoot" appears, which may be quenched with increasing temperature.

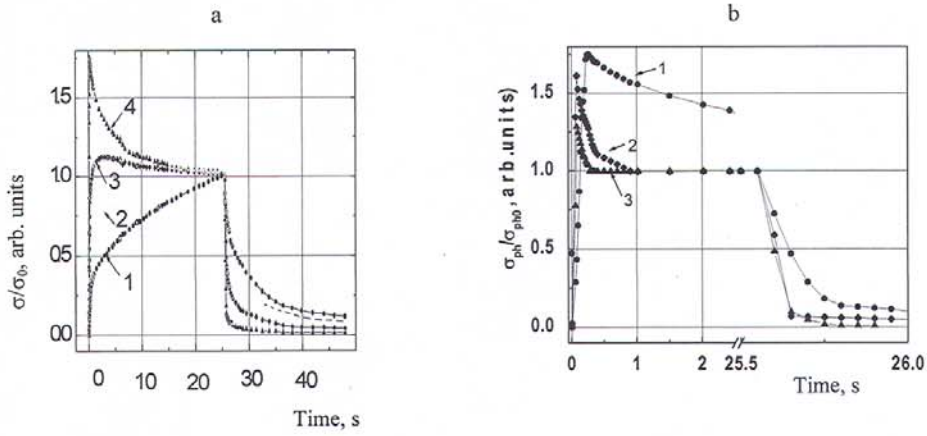

Fig. 2. Photoconductivity relaxation curves in Au-AsSe-Al amorphous thin films under variation of the light intensity (a) F, %: 1 - 0.08; 2 - 0.3; 3 - 2.2; 4 – 100, and for several Sn concentrations (b): AsSe (1), AsSe:Sn_1 (2) and AsSe:Sn_3 (3) at room temperature T = 290 K and laser intensity F = 6.5×10^{14} cm^{-2} s^{-1}.

For AsSe:Sn amorphous thin films tin impurity decreases the magnitude of the "overshoot" and moves it to shorter times, whereas in As_2Se_3 thin films the "overshoot" is absent or is very small and is clearly observed in As_2Se_3:Sn_3, especially at higher temperatures. For AsSe:Sn amorphous thin films the increase of the temperature diminishes the magnitude of the "overshoot" and above T = 345 K the photoconductivity almost instantaneously reaches its stationary value.

Fig. 3 shows the photoconductivity relaxation curves for As_2Se_3:Sn amorphous thin films at several intensities (a) and temperatures (b). It is remarkable, that increasing of temperature essentially decreases the rise and decay time. It must be pointed out that the rise and decay time also depends on the film composition and concentration of tin impurity.

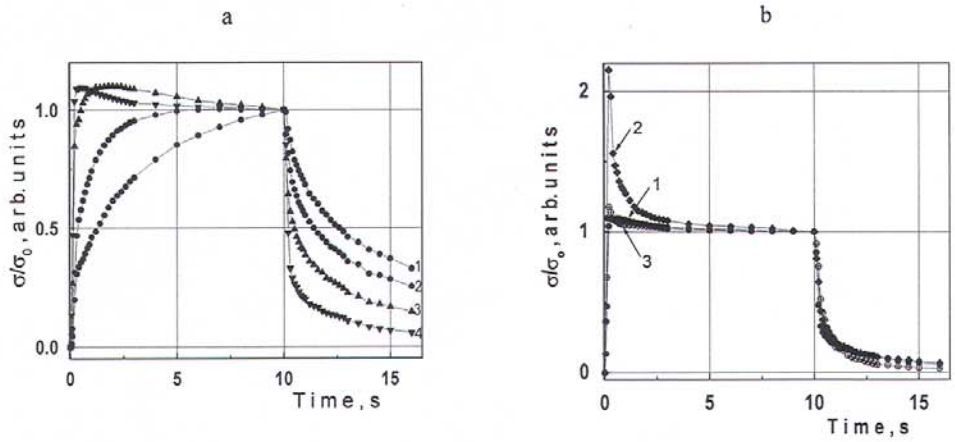

Fig. 3. Photoconductivity relaxation curves for As_2Se_3:$Sn_{3.5}$ thin films. a) for different light intensities F, %: 1 - 0.08; 2 - 1; 3 - 13; 4 - 100. (b) for different temperatures T,K: 1 - 290; 2 - 323; 3 - 346.

Taking into account a broad dispersion of recombination lifetimes due to multiple trapping of excess carriers in exponentially energy-distributed gap states $N(E)$ of amorphous material:

$$N(E)=(N_t/E_0)\ exp(-E/E_0) \tag{2}$$

the different regions of the relaxation curves of photoconductivity may be described analytically with the dispersion parameter $\alpha = kT/E_0$ [5]. For the initial portions of the relaxation curves the photocurrent regions rise and decay are governed by capture processes (the recombination is delayed). Then the rise and decay of photocurrent are determined by the expressions: $I_{ph} \sim G_0 \cdot t^{\alpha}$ and $I_{ph} = I_{ph0} \cdot t^{(1-\alpha)}$, respectively [5].

In our case the dispersion parameter α was determined from the power-law parts of the experimental relaxation curves for a rise and decay regions of the photocurrent plotted in double-logarithmic co-ordinates. Using the experimentally calculated values of the dispersion parameter α, the parameter of localized states distribution, E_0, was estimated. E_0 is nearly constant for As_2Se_3:Sn amorphous thin films, and increases from E_0 = 0.037 eV for AsSe up to E_0 = 0.078 eV for AsSe:Sn_3 thin films (Table 1).

Table 1. Some parameters for AsSe:Sn and As_2Se_3:Sn amorphous thin films calculated from the photoconductivity relaxation curves.

Glass composition	Temperature, T K	$\alpha = kT/E_0$	E_0, eV	T_0, K
AsSe	289	0.67	0.037	429
AsSe:Sn_1	289	0.57	0.044	510
AsSe:Sn_3	300	0.33	0.078	904
As_2Se_3	288	0.54	0.046	533
As_2Se_3:Sn_1	290	0.70	0.036	417
As_2Se_3:$Sn_{3.5}$	293	0.55	0.046	533

According to eqn. (2), the parameter E_0 describes the distribution of localized states. The obtained results means that this distribution in AsSe is more strongly influenced by tin impurity than in the case of As_2Se_3 amorphous thin films. Thus the photoconductivity relaxation experiments at

different intensities and temperatures provide essentially new information on electronic spectrum in amorphous materials.

The obtained experimental results for AsSe:Sn and As_2Se_3:Sn amorphous thin films are in good agreement with the data obtained from electrical and optical measurements [6]. The photoconductivity relaxation data in combination with electrical and optical results may be useful for a better understanding of the impurity effect on the physical processes in amorphous semiconductors, as well as for elaboration of photonic devices and recording media based on amorphous thin film structures.

Acknowledgement

I express my sincere thanks to Drs. M. Iovu, S. Shutov and M. Popescu for helpful discussions.

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