Optics Communications 283 (2010) 1366–1369

Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

Photodarkening of amorphous Se and $Se_{95}Te_5$ films under μs light pulses

E. Flaxer [a,*], M. Klebanov [b], V. Lyubin [b], D. Abrahamoff [c]

[a] Afeka-Tel-Aviv Academic College of Engineering, 69107 Tel-Aviv, Israel
[b] Department of Physics, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel
[c] Dynamic Media Solutions Laboratory, 69512 Tel-Aviv, Israel

ARTICLE INFO

Article history:
Received 31 August 2009
Accepted 1 December 2009

Keywords:
Thin amorphous films
Photodarkening
Pulse photorecording

ABSTRACT

Photodarkening phenomena in the amorphous Se and $Se_{95}Te_5$ films at the μs light pulses irradiation are investigated. The process of photodarkening during each of the individual 1, 10 or 100 μs pulses and also the processes proceeding between successive pulses are recorded and analyzed. The darkened film was shown to restore initial optical properties after some stay in darkness without any additional irradiation or heating. Photodarkening is very strongly dependent on the light pulse fluence.

1. Introduction

Photodarkening (PD) effect in the films of binary chalcogenide glasses (e.g. As_2Se_3, As_2S_3, $GeSe_2$) has been studied by many researchers [1,2 and references therein]. The PD effect in the films of amorphous selenium (a-Se) that is a simplest chalcogenide glass, has previously only been observed under cooling and was not found at room temperature [3–5].

Later, by application of the two beam technique, it was shown that PD in a-Se films can also be induced at room temperature [6,7]. Recently, there has been a growing interest in photoinduced processes in a-Se, due to the expanding field of the application of these films in the very sensitive vidicon camera tubes for television broadcasting as well as for medical X-ray imaging applications [8]. In all previous works the PD in a-Se films was only studied under CW light irradiation and there are no data concerning the behavior of these films under short light pulses. Recently, pulse excitation of binary chalcogenide films showed many peculiarities in the PD process [9,10], therefore it was interesting to study processes of short pulse excitation of PD in the a-Se films. In this letter, we introduce the first results of investigation of PD in a-Se films under the action of μs light pulses.

2. Experimental

We investigated amorphous Se and $Se_{95}Te_5$ films, fabricated by thermal evaporation of glassy Se and $Se_{95}Te_5$ powders on carefully cleaned Corning glass substrates, from quarts crucibles, in a vacuum of $\sim 2 \times 10^{-6}$ Torr. The films had a thickness of 0.5–2.0 μm. PD phenomena in both types of films, under CW and pulse irradiation, were practically similar although $Se_{95}Te_5$ films were more stable and therefore, in many cases, we preferred to study these films only. For excitation, the pulse laser (Stocker Yale Canada Inc), working on the wavelength 650 nm was used. The laser could generate 1.0–100 μs pulses with a frequency of up to 100 Hz. Maximum light intensity was 16 kW/cm^2 at the diameter of the beam of ~7.0 μm.

We observed the shape and amplitude of light pulses transmitted through the studied film on the screen of digital storage oscilloscope (Keithley – PCI-433) and recorded them to the personal computer for analysis. The sampling interval during the measurement was 10 ns. The measurement of the electrical signal value during the pulse was carried out with an accuracy of not less than 0.1%. Magnitude of transmission T was determined as a ratio of fluencies of transmitted and falling pulses. Such a system allowed the observation of the shape and amplitude of each chosen pulse. All experiments were carried out at room temperature.

3. Experimental results

Fig. 1 shows several pulses from a typical series of 1 μs successive pulses of light, transmitted through the $Se_{95}Te_5$ film having a thickness of ~1 μm. Energy fluence of each exciting light pulse is 16 kW/cm^2, whilst the rate of the pulses is 1 Hz. We demonstrate here the 1st, 10th, 50th and 200th pulse. During each pulse we did not observe any visible darkening, however, there is a very

* Corresponding author. Tel.: +972 3 6449344; fax: +972 3 6480944.
E-mail address: flaxer@post.tau.ac.il (E. Flaxer).

0030-4018/$ - see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.optcom.2009.12.007

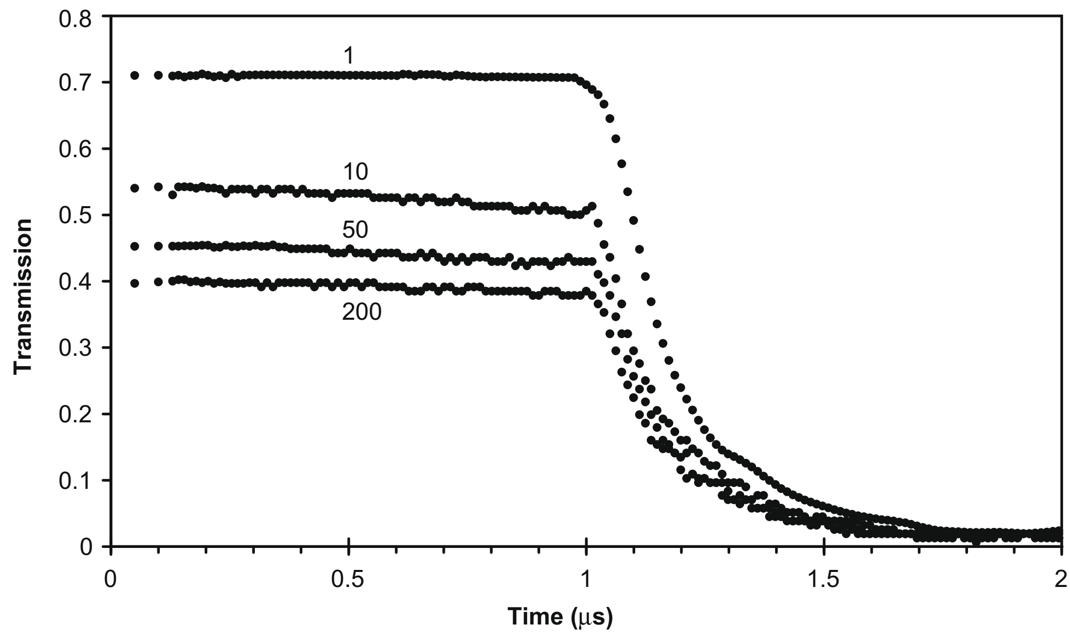

Fig. 1. Series of successive 1 μs pulses of light with intensity of 16 kW/cm^2 transmitted through the $Se_{95}Te_5$ film with a thickness of 1 μm. Ordinal numbers of pulses are shown near each pulse.

essential accumulation of darkening at irradiation with the series of light pulses. This accumulation is especially strongly expressed during the first ten pulses, gradually decreasing later.

Fig. 2 shows several similar successive pulses of transmitted light with a diminished fluence of each pulse to 12 kW/cm^2, keeping the same pulse rate of 1 Hz. Here the 1st, 10th and 100th pulses (as well as all following pulses) are indistinguishable, meaning that even at so small a decrease of the light pulse fluence the PD is practically not observed.

In Fig. 3 we demonstrate a typical PD of the a-Se film with a thickness of ~1 μm after absorption of a series of 1 μs pulses with the pulses rate of 1 Hz. It is seen that the successive pulses cause gradual darkening. The light interruption after 200 and 250 pulses is accompanied by the increase of the film transparency (in the Fig. 3 the light was interrupted for 1 min and a more prolonged interruption led to a stronger transparency increase, until the full bleaching of the film). Following pulse irradiation after the light interruption indicated continuation of PD.

Unlike the situation with short light pulses, irradiation of films with longer light pulses in the μs range showed darkening during the pulse. Such an effect is illustrated in Fig. 4 for the case of a series of 10 μs pulses excited the $Se_{95}Te_5$ film having thickness of ~0.7 μm. It is seen, that during each of the pulses, transparency of the film is essentially diminished. At the start of 50th and 300th pulses, the transparency of the film was aspiring to the initial transparency, while the PD of the film is gradually increased. The light interruption after 3 min, for 300th pulses, is accompanied by the practically complete restoration of initial film transparency.

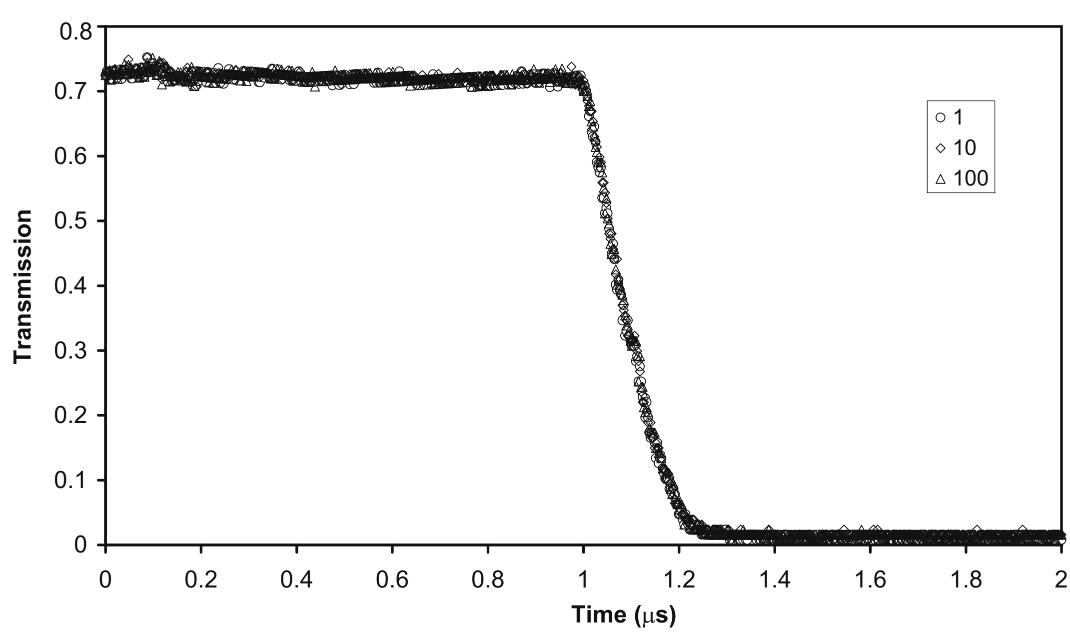

Fig. 2. Series of successive 1 μs light pulses with intensity of 12 kW/cm^2 transmitted through the $Se_{95}Te_5$ film with a thickness of 1 μm. Ordinal numbers of pulses are shown in the frame.