# Photonic microstructures generated by intense laser pulses on chalcogenide glass surface

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Using intense laser pulses with femtosecond duration photonic microstructures have been imprinted at the surface of a chalcogenide glass sample of composition As-S and $As_2S_3$. The morphological aspects of the surface after shooting at different pulse energy have been investigated. We have observed strong modifications of the surface when the energy of the pulse was increased. The surface morphology is drastically changed when the pulse energy overcomes 15 mW. The surface topography has been evidenced by atomic force microscopy (AFM).

(Received February 10, 2011; accepted February 24, 2011)

*Keywordss:* Photonc microstructures, $As_2S_3$; Chalcogenide glass; Laser pulses

## 1. Introduction

The photonic microstructures could be used in optoelectronic integrated circuits as elements for separation of the electromagnetic radiation in the infrared wavelength range. The application of photonic structures as optical waveguides resonators dispersive devices and modulators is envisaged. A large interest is paid now to chalcogenide glasses made by combinations of chalcogens (S, Se, Te) with As, Ge and other elements.

There were produced photonic structures built on chalcogenide glasses with laser beams [1]. Indutnyi et al. [2] fabricated submicronic periodic structures by using light irradiation and selective etching starting from interference lithography and a photoresist wit double chalcogenide layers.

Recently it was shown that various 2D and 3D structures can be inscribed on the surface of thin films or bulk arsenic sulphide glass by action of femtosecond laser pulses followed by etching in alkali or amine-based etchants [3, 4].

In this paper we report the results of an experimental study regarding the formation of photonic structures using intense laser pulses shooted on the surface $As_2S_3$ glass plates.

## 2. Experimental

The As-S plates were obtained from bulk glasses by grinding and fine polishing. The glassy structure of the plates has been tested by X-ray diffraction.

The laser irradiation was achieved with a Synergy Pro Ti-sapphire pulsed laser working in femtosecond regime. The laser emission band was situated in the range of 750 – 850 mm and the repetition rate was tens of MHz. the minimum diameter of the laser spot was 1 – 2 um. A Thorlabs Nanomax 300 XYZ table, controlled by computer allows for fine positioning of the laser in order to get various geometrical configurations of the irradiated domain (square lattice of points, hexagonal lattice of points, etc.) imprinted on the glass surface). As a configuration of interest in our study we have built a hexagonal lattice of points.

In order to reveal the morphology of the imprinted region on the glass, we used AFM measurements of the irradiated and not – irradiated domains. AFM micrographs were taken in an apparatus SPMNTEGRA Prima microscope in the semicontact mode. Various imprints have been achieved with laser pulses of different powers in the range 5 mW – 25 mW.

## 3. Results

The not-irradiated surface glass is uniform, smooth without morphological details.

After shooting by intense laser pulses in femtosecond regime, the morphology of the irradiated zones changes as a function of pulse power.

Fig. 1 shows how the structure of the irradiated zone is modified.

It is clearly observed a transition from the column – like structure to hole – like structure when the laser pulse power overcomes a given threshold energy (15 mW)

The height of the columns is around 100 – 200 nm, while the depth of holes reaches 100 – 300 nm.

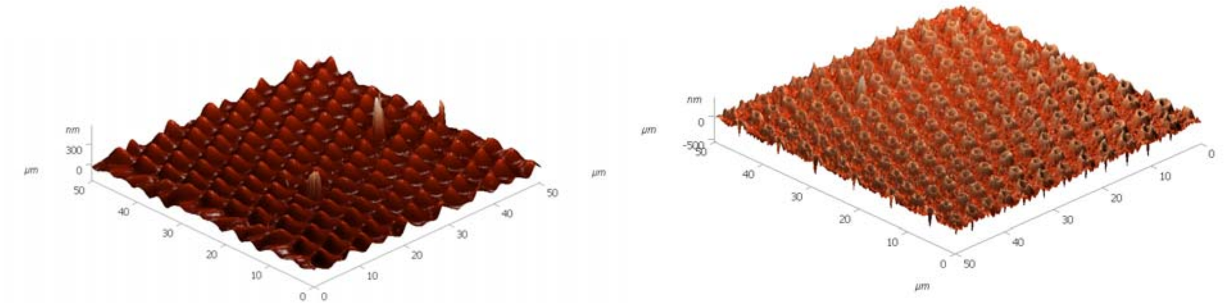

*Fig. 1.*

Details of the structure developed at different laser powers could be seen in Fig 2.

For low powers the basical structure between the irradiated points is smooth.

For high powers the surface shows point – like structure, which could be related to the modification of $As_2S_3$ plate in the material structure (probably crystallization) due to energy deposited on the surface.

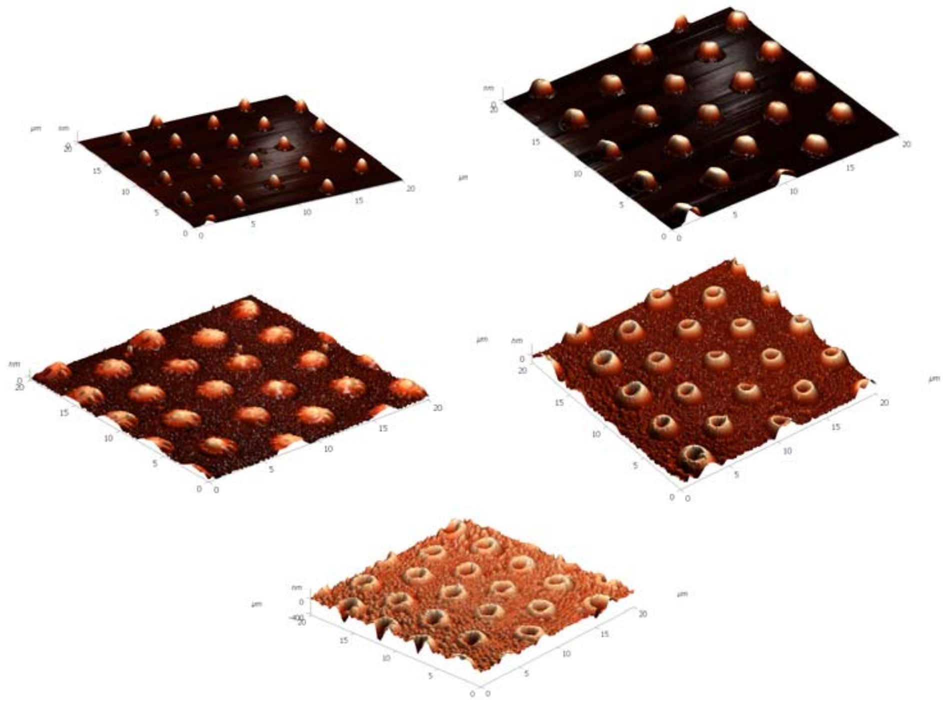

*Fig. 2. (a) 5 mW, (b) 10 mW, (c) 15 mW, (c) 20 mW, (d) 25 mW.*

If the energy of the laser pulse overcomes 0.18 nJ, a power of 15 mW then it is triggered the formation of channels instead of columns of arsenic sulphide materials.

## 4. Discussion

The special effect of laser irradiation in arsenic – sulphide glass is due to the peculiarities of the glass. It is well known the effect of photo-expansion occurring in this glass as a consequence of light irradiation.

Photo expansion is an increase in volume of the glass during irradiation [5].

In the case of $As_2S_3$ the glass expands by ~0.5% due to photostructural changes [6].

Hisakumi and Tanaka [7] reported a 2% expansion when illuminating a piece of $As_2S_3$ glass with 632.2 nm light from a He-Ne laser. The order of magnitude of photo expansion corresponds well to the size of the hill blocks observed on the surface of the laser irradiated area of our bulk glass $As_2S_3$.

However, when the irradiated volume is constrained in an exposed matrix (this is the case of our experiment) stresses at the interface leads to higher volume changes. This phenomenon can explain the formation of big holes as a consequence of the high laser pulse energy.

## 5. Conclusions

We have shown that two-dimensional photonic structures can be inscribed on the surface of a bulk sample of a chalcogenide glass. Special characteristics of the imprints have been revealed by atomic force microscopy.

A transition from the column configuration to the hole configuration has been revealed when the laser pulse power was increased. The threshold of the transition has been established at ~15 mW.

The characteristic feature of the laser imprinted points and modification as a function of irradiation energy was explained on the basis of photo-expansion phenomenon occurring in this chalcogenide glass.

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