Surface relief formation on As-S-Ge thin films after e-beam recording

Revutska Liubov[1], Shylenko O.I.[2], Stronski A.V.[3], Komanicky V.[2], Bilanych V.S.[4]

[1]National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Kyiv, Ukraine.

E-mail: liubov.revutska@gmail.com.

[2]Pavol Jozef Safarik University, Kosice, Slovakia.

[3]V. Lashkaryov Institute of Semiconductor Physics of the NAS of Ukraine, Kyiv, Ukraine.

[4]Uzhgorod National University,Uzhgorod, Ukraine.

- **Chalcogenide glasses (CG) are attractive materials for applications in the modern nanotechnology due to portfolio of remarkable properties as IR transparency, low-photon energy, quasi-stability, high non-linear optical properties, etc. CG are extensively applied as infrared elements and devices for optoelectronics, holography and information storage media.**

In present work we studied direct (without selective etching) surface relief formation of optical elements periodic nanostructures on $As_3S_{77}Ge_{20}$ films using electron beam lithography, evolution of surface nanostructures height and shape in dependence on exposure keeping in mind that direct one step grating recording simplifies greatly the fabrication processes of the optical elements.

- **Thin films $As_3S_{77}Ge_{20}$ of ~8.3 μm thickness were prepared by thermal vacuum evaporation of $As_4S_{66}Ge_{30}$ bulk glass onto sapphire substrates. .**
- **The films were irradiated by an electron beam using SEM (Tescan, model VEGA).**
- **The accelerating voltage V=30 kV, spot size B=640 nm, and the electron beam current I=19 nA.**
- **The exposure dose G varied from 12 mC·cm^{-2} to 12 C·cm^{-2}. Square matrices of 100 microns in size were made of a certain number of points. The distance between the points was 6.6 μm and 10 μm.**

Formed nanostructures with a height of approximately 100 nm were detected in $As_3S_{77}Ge_{20}$ films after e-beam irradiation.
The cones on the surfaces of the films have Gaussian profiles.

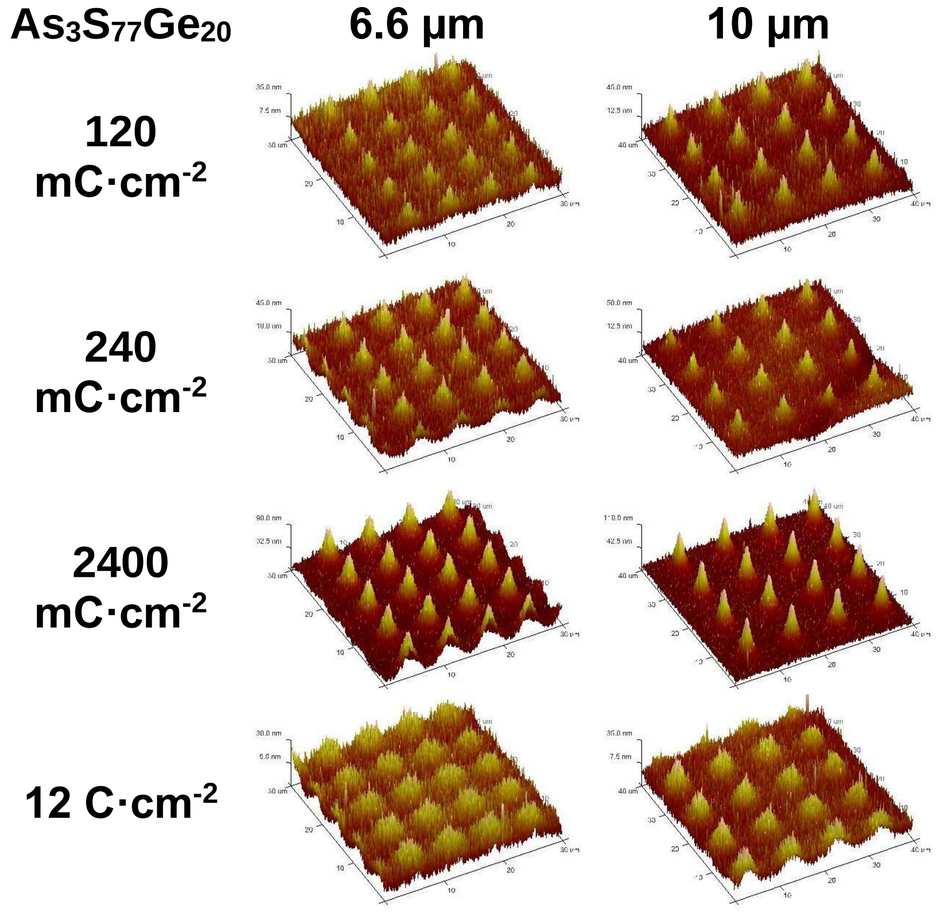

Table 1. AFM images of surface relief on $As_3S_{77}Ge_{20}$ films after e-beam exposure[1].

- **The formation of surface relief is due to structural changes in the film and the emergence of a *space charge region (SCR)* [2] during the interaction of the film and the electron beam.**
- **The initial and inversion doses of relief formation on this film have found (from Fig. 2).**

***d* = 6,6 μm pitch: G_0 = 9,60 mC·cm^{-2}, G_i = 31,18 C·cm^{-2}.**
***d* = 10 μm pitch: G_0= 6,98 mC·cm^{-2}, G_i = 36,19 C·cm^{-2}. `**

- **The dependences at increasing interval (16 mC·cm^{-2} – 1200 mC·cm^{-2}) for *d* = 6,6 μm and *d* = 10 μm were fitted by exponential function (Fig. 3).**
- **Relaxation times that determined as a result of this approximation are τ_1 = (641,35 ± 110,42) ms for *d* = 6,6 μm and τ_1 = (458,95 ± 210,71) ms for *d* = 10 μm.**

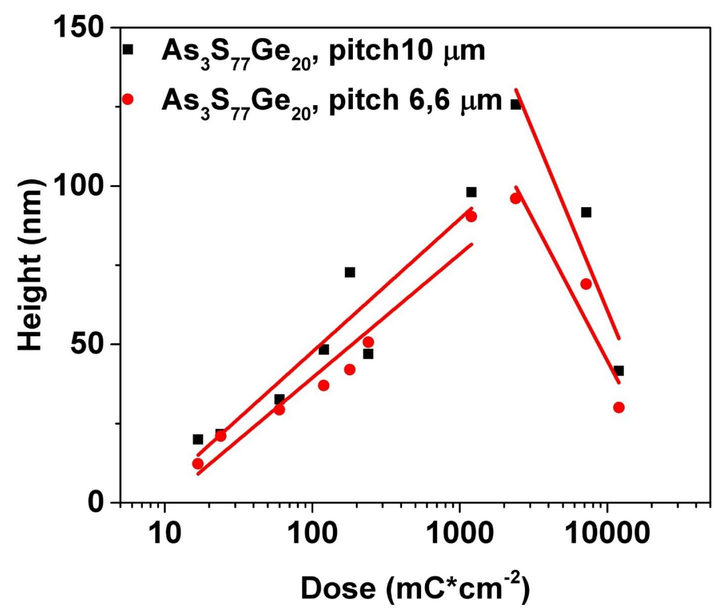

Fig. 2. Linear approximation of the dependence of the surface relief height of the $As_3S_{77}Ge_{20}$ films on the irradiation dose for matrix periods 6,6 μm and 10 μm [1].

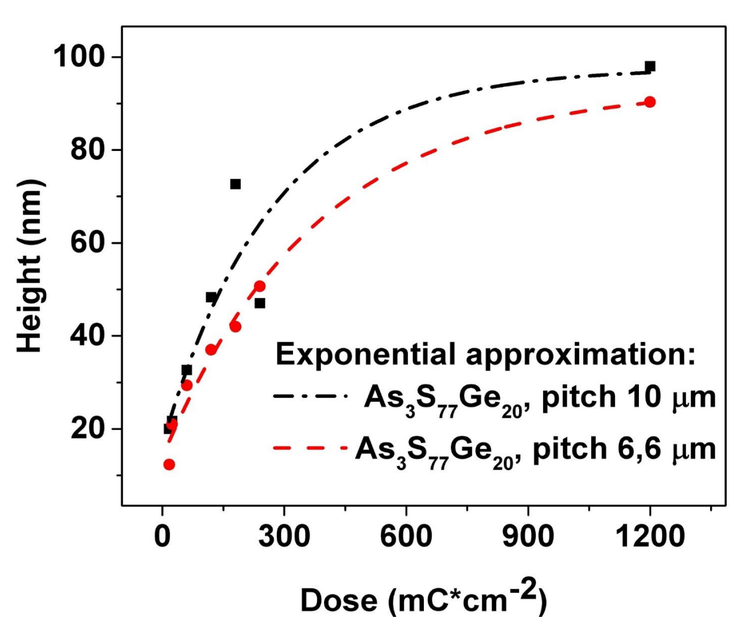

Fig. 3. Exponential approximation of the dependences for the interval 16 mC·cm^{-2} – 1200 mC·cm^{-2} [1].

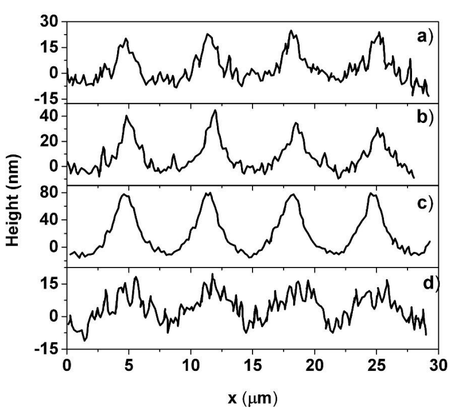

Fig. 1. Profile of recorded surface relief on $As_3S_{77}Ge_{20}$ film after e-beam exposure:
a – 120 mC·cm^{-2};
b – 240 mC·cm^{-2};
c – 2400 mC·cm^{-2};
d – 12 C·cm^{-2}.
Distance between dots – 6.6 μm [1].

1. L. Revutska *et al.*, "The formation of surface nanostructures on As-S-Ge chalcogenide film after e-beam exposure" *KPI Science News*, p. 48-53, 2020.
2. V. Kuzma *et al.*, "Study of dependence of electron beam induced surface relief formation on Ge- As-Se thin films on the film elemental composition," *J. Non. Cryst. Solids*, 2019.

Our investigations have demonstrated that studied $As_3S_{77}Ge_{20}$ composition is suitable for e-beam recording. The formation of cones with Gaussian profile on the surfaces of the films was detected after electron irradiation. Exposition dependent height evolution of surface nanostructures has been detected. These results show that $As_3S_{77}Ge_{20}$ films can be used for fabrication of the optical elements.

This work has been supported by National Scholarship Programme of the Slovak Republic for the Support of Mobility of Students, PhD Students, University Teachers, Researchers and Artists SAIA.