Journal of Optoelectronics and Advanced Materials Vol. 5, No. 5, 2003, p. 1361 -1364

NEW APPLICATION OF INORGANIC CHALCOGENIDE PHOTORESISTS IN LIFT-OFF PHOTOLITHOGRAPHY

M. Veinguer*, A. Feigel, B. Sfez, M. Klebanov[a], V. Lyubin[a]

ElectroOptics Department, NRC Soreq, 81800 Yavne, Israel
[a]Department of Physics, Ben-Gurion University, Beer-Sheva 84105, Israel

Chalcogenide glassy photoresist films have been used as photoresist for lift-off photolithography. Fabrication of gratings in layers of highly refractive As-Se-Te films are demonstrated.

(Received July 2, 2003; accepted August 28, 2003)

Keywords: Chalcogenide glassy films, Chalcogenide photoresist, Lift-off photolithography

1. Introduction

Inorganic chalcogenide photoresists (ChP) have several important advantages: very high resolution, photosensitivity in a wide spectral range, and they can be used on both planar and non-planar substrates [1-3]. ChP are used in fabrication of diffractive gratings, IR microlens arrays and photonic-band-gap structures [4-10]. In this paper we demonstrate a novel application of ChP: as a photoresist for lift-off photolithography. This kind of photolithography is used when usual direct photolithography can not be applied, for example when it is difficult to find good etchants for the patterned film or if these etchants damage the substrate.

A problem associated with the lift-off method for high resolution (200 nm and less) is the fabrication of walls with negative slope in organic photoresists, which are usually used in this process. When ChP is used, this problem can be solved due to strong absorption of the exciting radiation in ChP, resulting in distribution of the etching rate across the whole thickness of ChP.

2. Experimental

We used in this work the ChP based on xAsS-yAsSe films, fabricated by vacuum evaporation of bulk xAsS-yAsSe chalcogenide glasses from quartz crucible onto Corning Glass substrates. For better adhesion the substrates were precoated with a special adhesion layer from chalcogenides of Ge group. A two beam interference pattern from an Argon 514 nm laser was used to periodically illuminate the ChP [9, 10]. The intensity of each beam was about 10 mW/cm^2. Their interference was a simple grating pattern with 0.5 µm period. After a certain illumination time, the non-illuminated parts were selectively etched in an amine-based developer down to the substrate. The illumination was strongly dependent on light intensity and the ChP material composition and varied between 2 – 2.5 minutes. After that, a film of the required material (which can not be patterned by the usual photolithography method) is thermally deposited and the remaining fragments of ChP are removed with the aid of a stronger developer, which etches the intensively-irradiated areas of ChP.

*Corresponding author: maya@soreq.gov.il

3. Lift-off process

In Fig. 1 we illustrate schematically different steps of the lift-off photolithographic process.

A holographic pattern is written on the xAsS-yAsSe film (Fig. 1, step1) During the writing process a refractive index and transparency grating is formed in the sample [9].

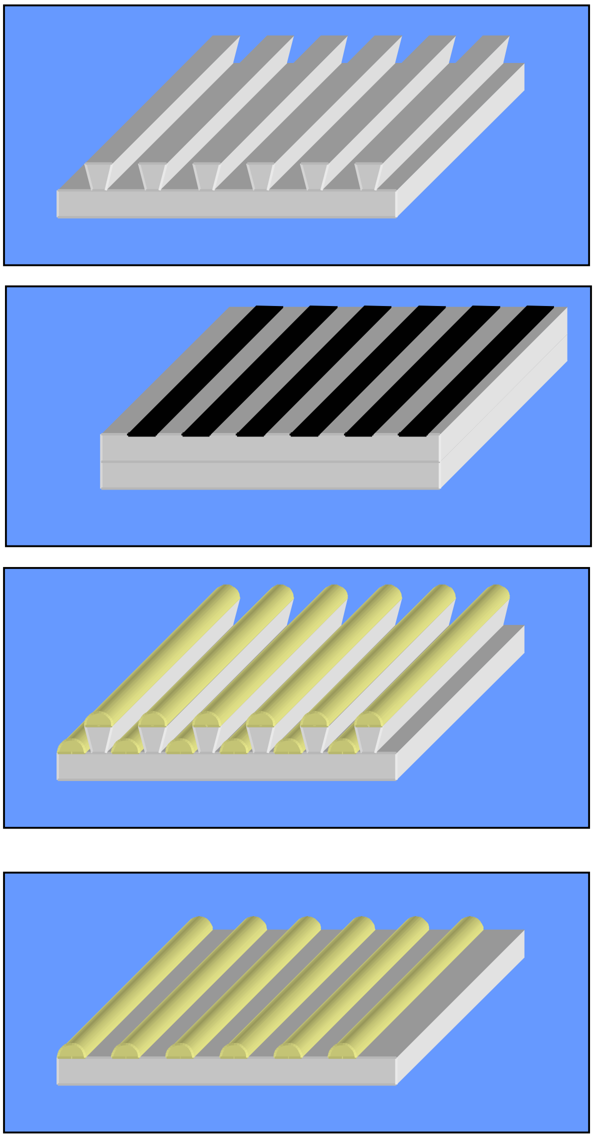
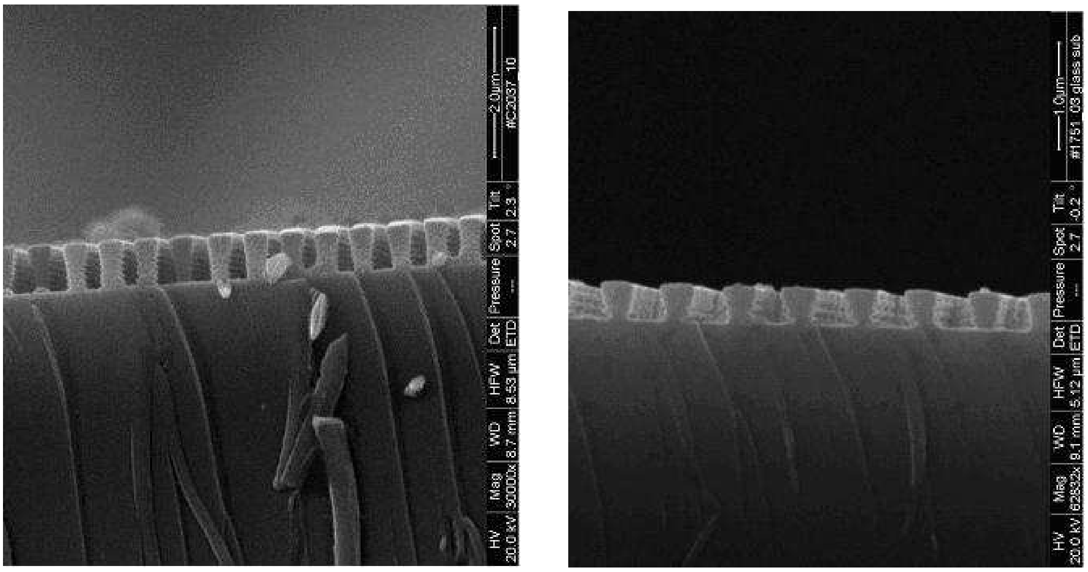


Fig. 1. Complete lift-off photolithographic process of grating fabrication.

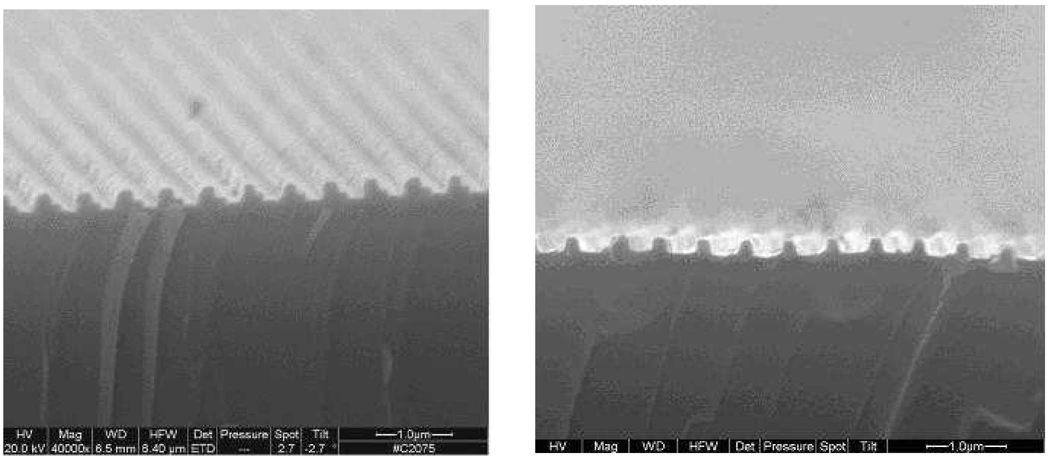
The sample is then dipped in a selective developer for some tens of seconds in order to obtain a thickness grating (Fig. 1, step 2). We took care to obtaine the required negative slope profile for lift-off process. By varying the ChP composition (x and y) together with thickness, radiation intensity and radiation time, etching time and parameters of developer we were able to realize different profiles in the ChP. Fig. 2 shows two profiles obtained in the $(As_2S_3)_2(As_2Se_3)_1$ and $(As_2S_3)_1(As_2Se_3)_1$ ChP films. The grating stripes are etched down to the substrate.



a b

Fig. 2. Electron microscope view of profiles obtained in the $(As_2S_3)_2(As_2Se_3)_1$ (a) and $(As_2S_3)_1(As_2Se_3)_1$ (b) films.

After that the required material (As-Se-Te, etc.) is evaporated in a vacuum of $(2 - 5) \times 10^{-6}$ Torr onto both the clean areas of the Corning Glass substrate and the retained parts of the xAsS-yAsSe film (Fig. 1, step 3). To increase the As-Se-Te film adhesion to the Corning Glass substrate, a thin adhesive layer (100 nm) was deposited on the substrate by the same evaporation method. The sample is then dipped into a stronger developer that is capable to etch the intensively-irradiated parts of the xAsS-yAsSe film. This developer penetrates into the grooves and etches the ChP grating down to the substrate, leaving the evaporated strips of required material on it (Fig. 1, step 4).



a b

Fig. 3. Electron microscope view of gratings obtained in the As-Se-Te.

After realization of the lift-off photolithographic process we fabricated a 200 nm feature size gratings with 100 nm thickness and a 220 nm feature size grating of As-Se-Te layer characterized by a very high refractive index value (n = 3.5 at λ = 514 nm) with 250 nm thickness. These results are illustrated in Fig. 3.

4. Conclusion

In this paper we demonstrated the possibility to use chalcogenide glass as a photoresist in high resolution lift-off photolithography. As example of such a process we have fabricated gratings in As-Se-Te films with high refractive index value.

References

[1] H. Nagai, A. Yoshikawa, Y. Toyoshima, O. Ochi, Y. Mizushima, Appl. Phys. Lett. **28**, 145 (1976).
[2] M. S. Chang, T. W. Hou, J. T. Chen, K. D. Kolwicz, J. N. Zemel, J. Vac. Sci. Technol. **16**, 1973 (1979).
[3] V. M. Lyubin, A. M. Sedikh, N. N. Smirnova, V. P. Shilo, Microelectronica **18**, 523 (1989).
[4] M. Vlcek, P. J. S. Ewen, T. Wagner, J. Non-Cryst. Sol. **227-230**, 743 (1998).
[5] A. V. Stronski, M. Vlcek, A. Sklenar, P. E. Shepeljavi, S. A. Kostyukevich, T. Wagner, J. Non-Cryst. Sol. **266-269**, 973 (2000).
[6] V. Lyubin, M. Klebanov, I. Bar, S. Rosenwaks, N. P. Eisenberg, M. Manevich, J. Vac. Sci. Technol. **B 15**, 823 (1997).
[7] N. P. Eisenberg, M. Maneich, A. Arsh, M. Klebanov, V. Lyubin, J. Optoelectron. Adv. Mater. **4**, 405 (2002).
[8] A. Saitoh, T. Gotoh, K. Tanaka, Opt. Lett. **25**, 1759 (2000).
[9] A. Feigel, Z. Kotler, B. Sfez, A. Arsh, M. Klebanov, V. Lyubin, Appl. Phys. Lett. **77**, 3221 (2000).
[10] A. Feigel, Z. Kotler, B. Sfez, A. Arsh, M. Klebanov, V. Lyubin, Proc SPIE **4277**, 249 (2001).