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ARRAYS OF MICRO-PRISMS AND MICRO-MIRRORS FOR INFRARED LIGHT BASED ON As_2S_3-As_2Se_3 PHOTORESISTS

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New micro-optical elements, arrays of micro-prisms and micro-mirrors for infra-red light with a wide variation of their parameters were fabricated. These results were obtained with a three-component As-S-Se chalcogenide photoresist and a new efficient amine-based selective developer.

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Keywords: Micro-prism aray, Micro-mirror array, Infrared, As_2S_3-As_2Se_3 photoresist

1. Introduction

Micro-prism and micro-mirror arrays are important elements of modern electro-optics, used for a number of purposes such as optical computing, optical communications, beam coupling or beam combination, for integrated planar optical interconnections etc. Micro-prism and micro-mirror arrays are usually fabricated by photolithography using gray scale photomasks and thick organic photoresists [1-3]. The organic photoresist prisms and mirrors can not be used practically as they are unstable and have very poor optical parameters. Therefore, in practice, the organic photoresist layer is usually deposited onto the surface of a substrate fabricated from robust optical materials, transparent in the spectral range for which the micro-prism or micro-mirror arrays are intended. The mirrors and prisms, obtained in the organic photoresist, are then transferred into robust optical material by anisotropic reactive ion beam etching. In the case of micro-prism and micro-mirror arrays intended for the infra-red range, SiO_2 or GaAs are often used. Such processes of micro-prism and micro-mirror array fabrication are shown schematically in Figs. 1a and 2a.

However anisotropic ion beam etching is a very complicated and expensive process, therefore its elimination would be very desirable in micro-device fabrication. In this paper a new simple micro-prism and micro-mirror array fabrication technology is described in which the ion beam etching step is excluded.

2. Experimental details

This technology is based on the use of chalcogenide glasses that are simultaneously effective photoresists and very good infrared optical materials. The proposed method is based on the direct one step 3D-shaping of a micro-prism and micro-mirror array using a gray scale photolithography process with chalcogenide photoresist (Fig. 1b, 2b). Previously such technology was applied in the fabrication of infrared micro-lens arrays using binary chalcogenide As-S or As-Se photoresists [4-6]. In [7] was demonstrated the use of the As_2S_3 – As_2Se_3 chalcogenides as a photoresist in high resolution lift-off photolithography. For fabrication of micro-prism and micro-mirror arrays of a high quality, it is very important to have very soft contrast characteristics (dependence of remaining photoresist thickness on the dose of irradiation) of the photolithographic

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process, which are characterized by a long quasi-linear section. Three-component $1As_2S_3 \cdot 1As_2Se_3$ photoresist films with thickness of ~ 4 μm were used, together with a selective developer based on ethylenediamine, which allowed for the realization of the necessary soft contrast characteristics of the photolithographic process applying an Xe- source of light. Quasi-linear section of photolithographic process in this case is much longer than in the previously used $As_{50}Se_{50}$ chalcogenide photoresist (Fig. 3). The developer is the negative-type developer characterized by high selectivity, or etching contrast value (ratio of the rates of dissolution of non-irradiated and irradiated areas γ). A γ of ~ 40 is achieved at a moderate radiation intensity of 30 mW/cm^2 at λ = 532 nm.

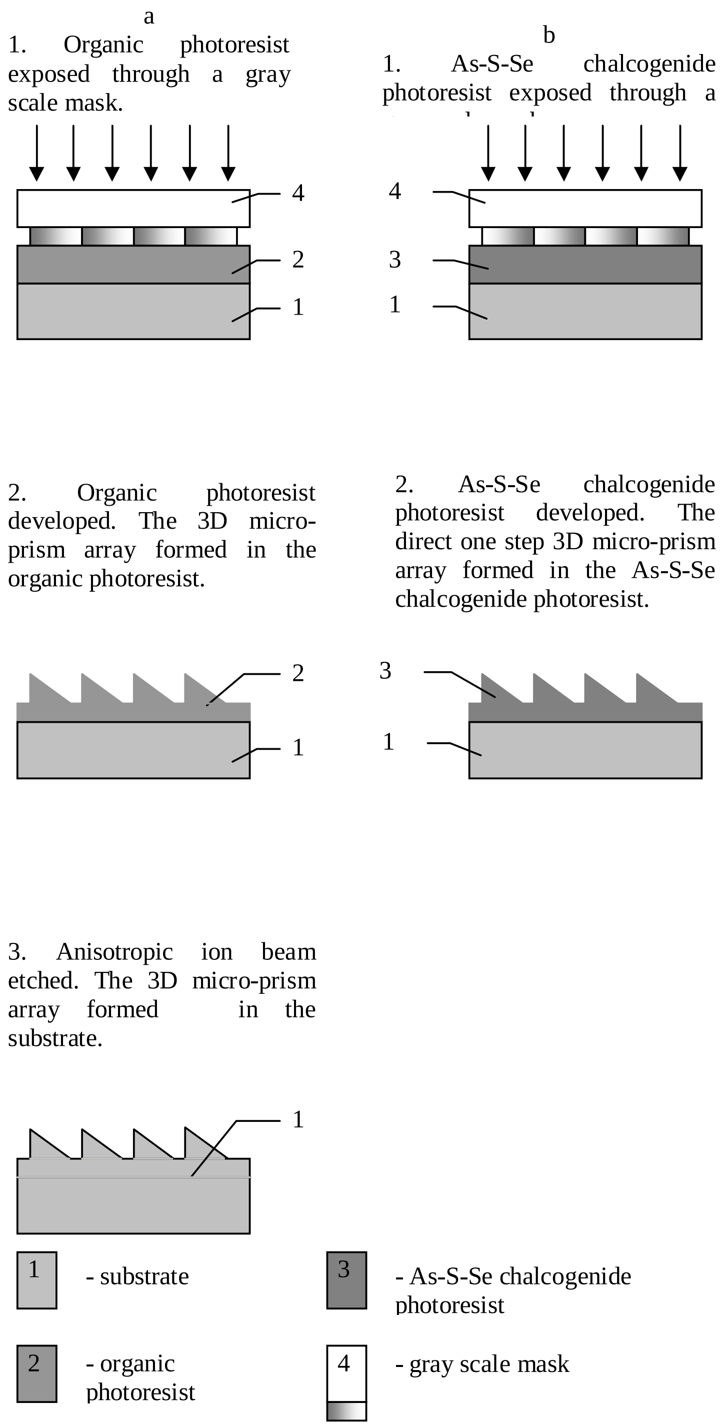

Fig. 1. Micro-prism array fabrication process: a – two step 3D-formation; b – proposed method using a direct one step 3D- formation.

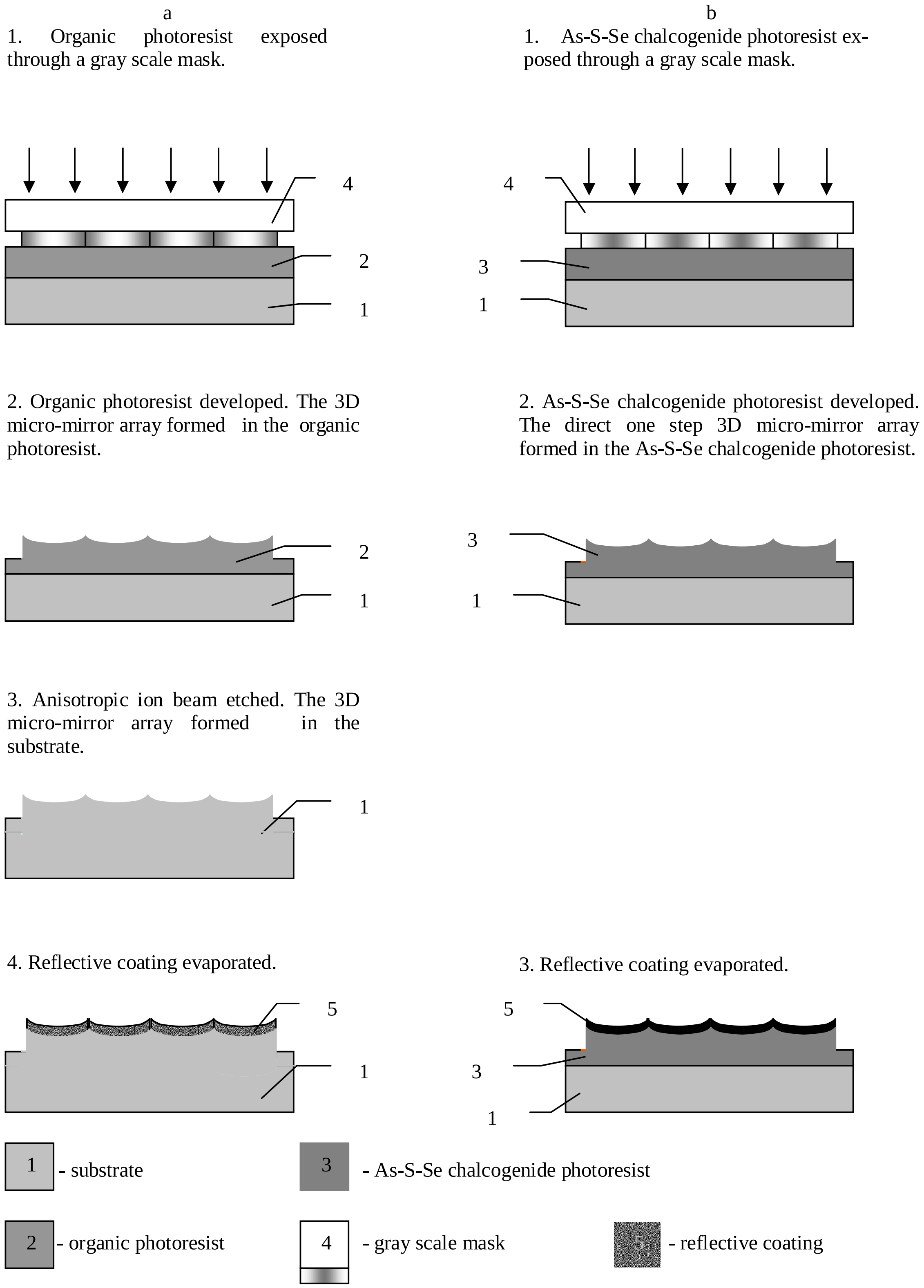

Fig. 2. Micro-mirror array fabrication process: a – two step 3D-formation; b – proposed method using a direct one step 3D- formation.

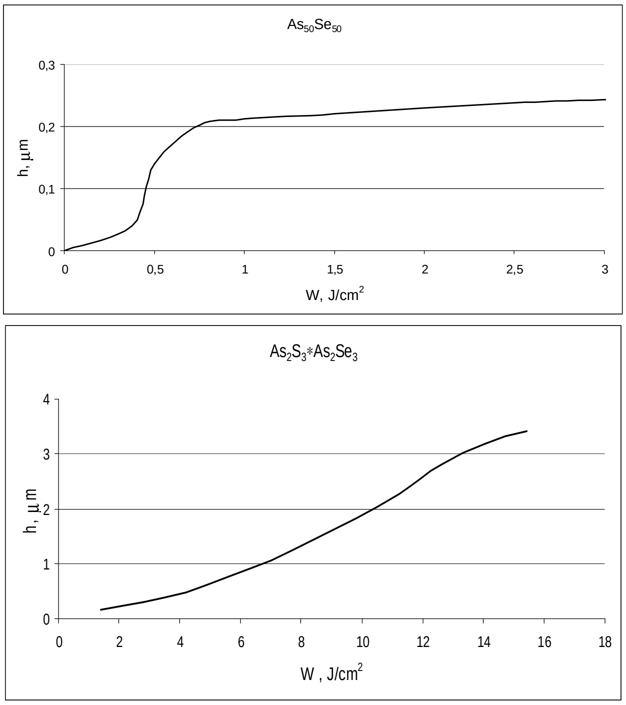

Fig. 3. The contrast characteristics of the $As_{50}Se_{50}$ and $As_2S_3 \cdot As_2Se_3$ chalcogenide photoresists.

3. Experimental results

Using different gray scale photomasks, micro-prisms and micro-mirrors with a wide variation of their geometric parameters were obtained. The micro-prism and micro-mirror arrays obtained were measured using a "Zygo Corporation" (USA) microinterferometer and several are shown in Figs. 4-6. Parameters of several micro-prism and micro-mirror arrays are shown in the Tables 1 and 2.

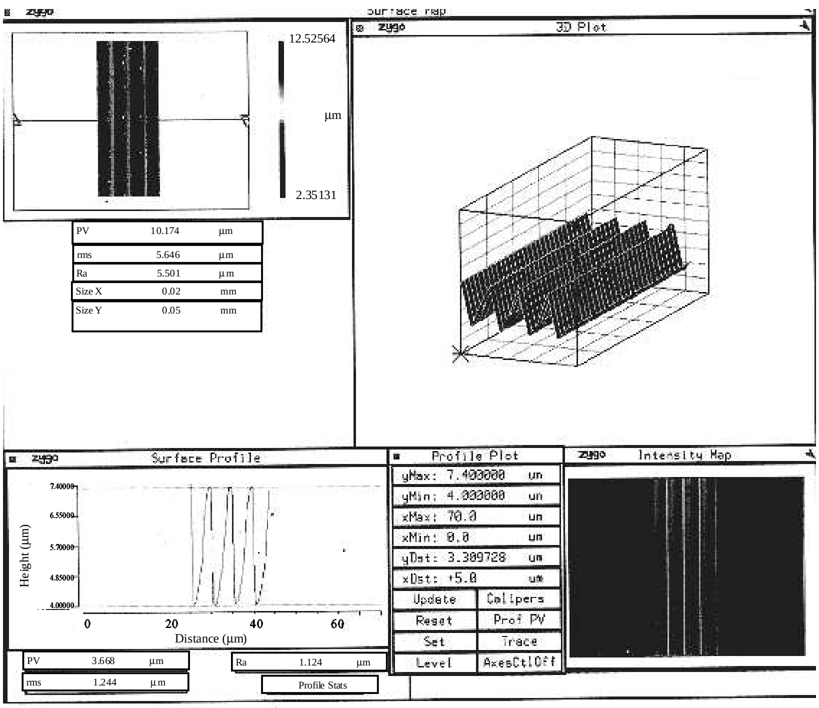

Fig. 4. Micro-prism array with a micro-prism base width of 5 µm.

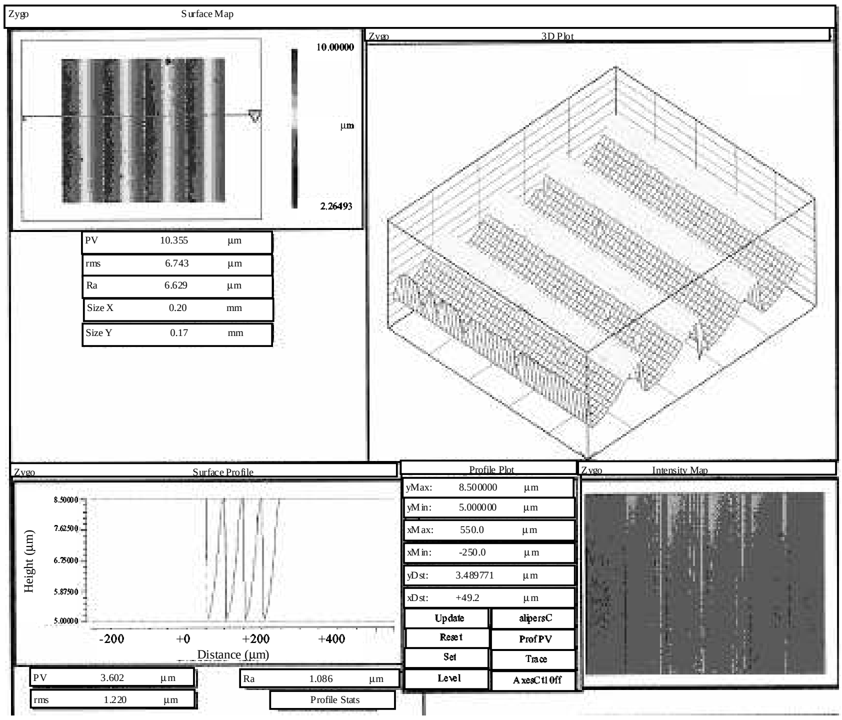

Fig. 5. Micro-prism array with a micro-prism base width of ~ 50 µm.

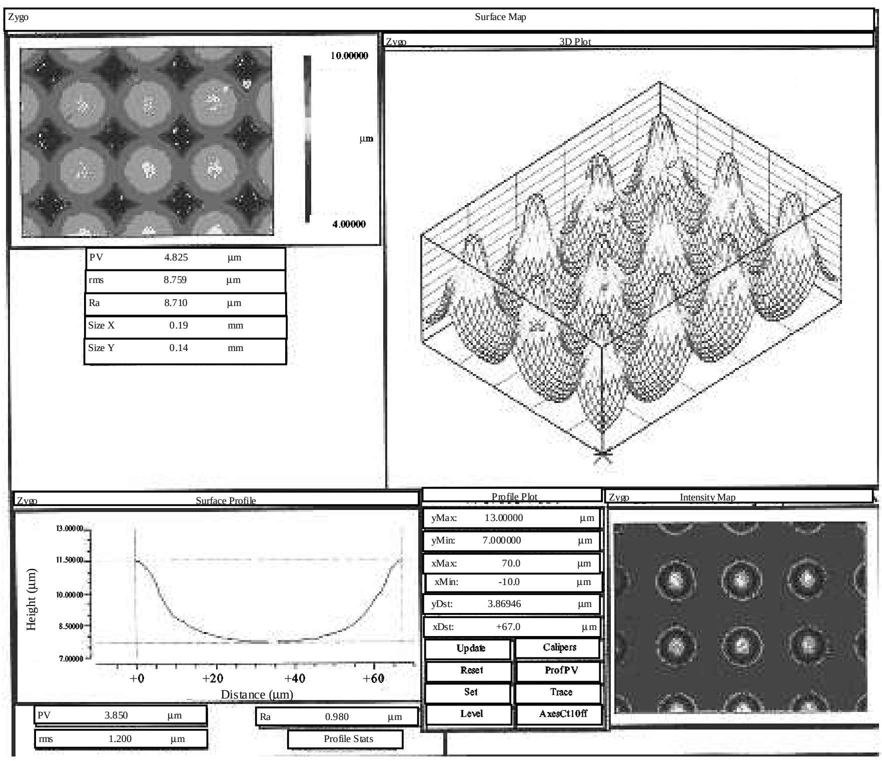

Fig. 6. Square plano-concave micro-mirror array with a diagonal of ~ 67 µm.

The quality of the micro-prism and micro-mirror surface (shape, roughness) was extremely high and the reproducibility of their parameters was also good.

Table 1. Parameters of the right-angled micro-prism arrays fabricated in $1As_2S_3 \cdot 1As_2Se_3$ chalcogenide films.

Parameter	Micro-prism array number			
Micro-prism height	3.31 μm	3.49 μm	3.50 μm	3.47 μm
Micro-prism base width	5.0 μm	49.2 μm	70.0 μm	203 μm
Micro-prism base length	1000 μm	2000 μm	2000 μm	1000 μm
Roughness	0.5 nm	0.5 nm	0.5 nm	0.5 nm
Micro-prism array size	128×8	64×4	64×4	32×1
Fill-factor	100 %	100 %	100 %	100 %

Table 2. Parameters of the array of square plano-concave micro-mirrors fabricated in $1As_2S_3 \cdot 1As_2Se_3$ chalcogenide films.

Dimension of a single square micro-mirror	Diagonal: 67.0 μm
Sag	3.87 μm
Pitch	47.4 μm
Focal length	37 μm
Micro-prism array size	100×100
Fill-factor	100 %

Chalcogenide glasses are characterized by high values of refractive index in the range of 2.3 – 3.2 and therefore the chalcogenide micro-prisms can be used for the coupling of I.R. light beams into optical wave-guides with a high refractive index, particularly, into chalcogenide glass wave-guides [8].

4. Conclusion

In this paper the development of a new simple photolithographic infrared micro-prism and micro-mirror array fabrication technology based on application of chalcogenide photoresists was reported. These results were obtained using a three-component As-S-Se chalcogenide photoresist and a new efficient amine-based selective developer, which together allowed for the realization of soft contrast characteristics of the photolithographic process, using an Xe- source of light. The new technology results in the elimination of the very complicated and expensive ion beam etching step.

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