# Chalcogenide Glass Photoresists for Grayscale Patterning

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# Chalcogenide Glass Photoresists for Grayscale Patterning

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**Abstract.** Ability to use **c**halcogenide glass thin films as photoresists for one step gray scale lithography is demonstrated. It is shown that the chalcogenide photoresists can be used to fabricate gray scale patterns such as array of microlens, which can find their application in IR optics. The direct application of the patterned resisits reduces the cost and time of fabrication as well.

**Keywords:** Maskless, Grayscale lithography, Chalcogenide glasses, Microlens.
**PACS:** 42.70 Ce, 42.70 Km, 42.82Cr

## INTRODUCTION

Amorphous chalcogenide glasses have recently become promising material for a variety of applications in infrared optics (IR), many of which are based on photo-induced affects that these materials exhibit [1-2]. One of the most interesting properties of amorphous chalcogenide thin films is the change in chemical resistance to various solvents by exposure to light of appropriate wavelength and intensity which implies the usefulness of these materials as inorganic photoresists in optical lithography [3]. These inorganic photoresists have several advantages over polymer based organic photoresists since they have smaller fundamental structural units and strong covalent bonds. Deposition of chalcogenide glasses is also simple; thermal evaporation and sputtering can be used for the deposition on large homogeneous areas with low concentration of defects. It is also important to note that the pre-baking and post baking steps of polymer based lithography are completely eliminated. Photoresists property, together with high transmission in IR region can be used in the area of medical tomography, optical communication and micro imaging [1-3]. Microlenses and micro lens arrays are critical optical elements for these applications due to the adaptive optical properties available with these structures. But a reliable and high resolution fabrication technique is required to reproducibly construct high quality lenses without defects. Using conventional techniques of lithography obtaining the truly curved structures required for optical structures is not possible. Many researches have fabricated 3D structures using inorganic photoresists by different methods such as Gap Micro-Lithography, Proximity lithography and half tone photo-masks [2-3]. In this present paper, we investigated use of chalcogenide glasses as a photoresists material for the lithography.

## EXPERIMENTAL

Amorphous thin films of $As_{40}Se_{60}$ were prepared by commercially available bulk chalcogenide glasses from VITRON GmbH Germany by thermal evaporation method onto pre cleaned glass substrates at room temperature by rotating substrate. The deposition rate of the thin films was kept ~10nm/s. The deposition was done typically in a vacuum of $2x10^{-6}$ Torr. Thickness and uniformity of the deposited films was measured by using mechanical profilometer. The UV irradiation of the films was done by mercury lamp with the power density ~15 $mW/cm^{-2}$ attached with a Maskless Lithography System SF-100 from Intelligent Micropatterning LLC (St. Petersburg, FL) using a grayscale software mask designed in Microsoft Bitmap software programme.

## RESULT AND DISCUSSION

Chalcogenide thin films undergo photo-structural changes when exposed to UV light. Exposed area of the films selectively protected from the etchant in proportion to the irradiation dose. Gray scale

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lithography is based on the fact that not only exposure time, but light intensity too affects the etching rate.

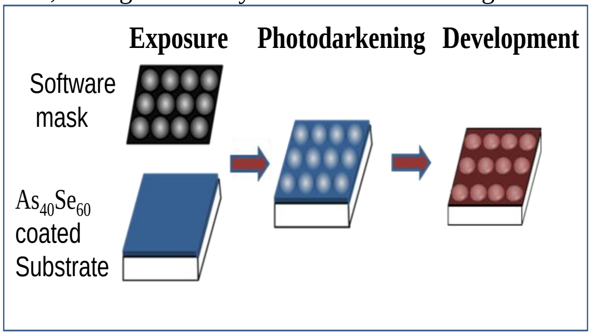


**FIGURE 1**. Schematic used for the Gray scale lithography.

We have employed the technique of grayscale maskless lithography where the light intensity incident on the photoresists is scaled down by a grayscale value that ranges from 0(black) to 255(white). The x-y patterning is achieved by creating computer generated images with regions varying in grayscale value. Microlens arrays have been patterned on chalcogenide glass coated substrates by an array of concentric circles of decreasing grayscale value from the center. Fig. 1 shows the schematic of the maskless gray scale lithography for microlens patterning.

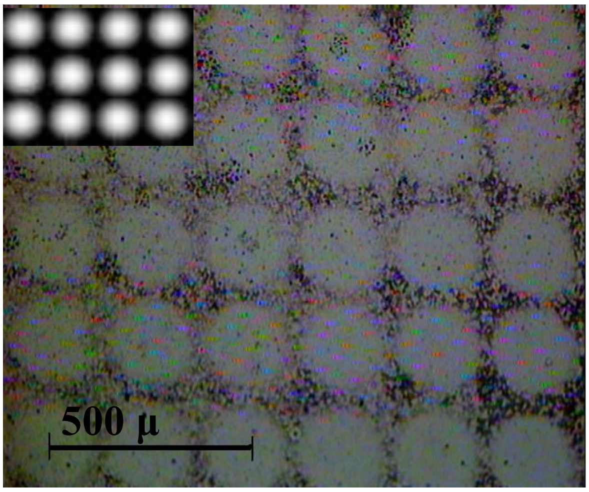


**FIGURE 2**. Fabricated array of microlens in chalcogenide photoresists (Inset shows grayscale software mask used).

Fig. 2 shows the bright field microscope image of array of microlenses fabricated in the chalcogenide photoresists using gray scale lithography. Here the exposed parts of the samples which were proportionally more resistant to the amine based solvents have remained while the unexposed regions were etched away on developing in the amine solution for 2-3 minutes. The etch depth of the developed structures were measured using mechanical profiler and found ~600 nm at the centre of the microlenses. The mechanism of the selective wet etching of $As_2Se_3$ thin films in amine solution is based on the different dissolution rates of the $AsSe_3$ primides, fragments of the Se-Se homopolar bonds and $As_4Se_3$ structural units with As-As- homopolar bonds. Fig. 3 shows Raman spectra of the exposed and unexposed thin films of the $As_2Se_3$ thin films. Raman spectroscopy measurements shows that with increasing time of UV exposure, homo-polar bond peaks at 188, 265 and 280 $cm^{-1}$ disappear or decrease in intensity while the hetero-polar bond peaks at 228 and 236 cm-1 increase in intensity. As the homopolar bond concentration decreases after irradiation, the etch resistance to amine solution increases in that region [3].

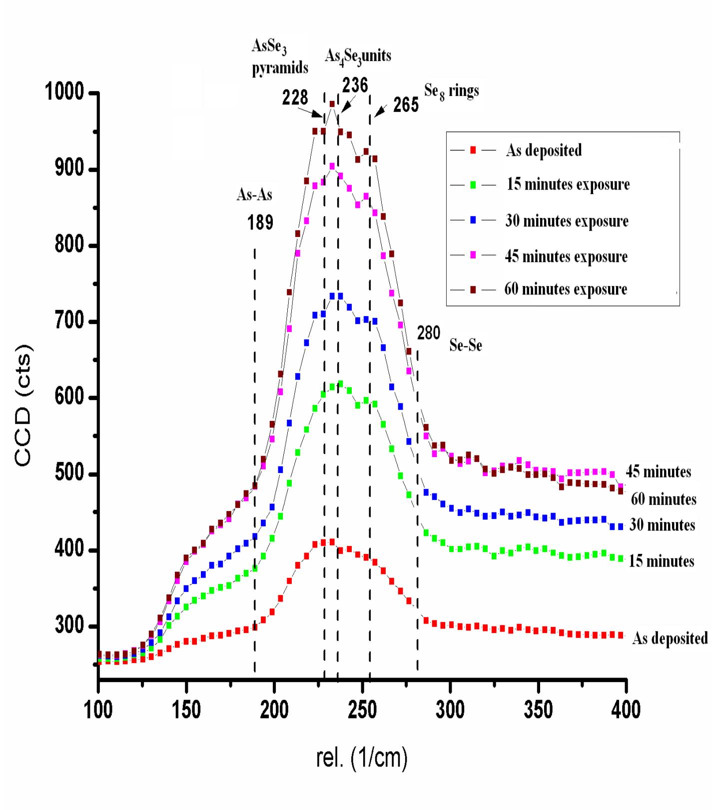


**FIGURE3.** Raman spectra of the exposed and unexposed $As_2Se_3$ thin films.

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