Diffractive elements formation in thin amorphous chalcogenide layers

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Diffractive elements have many applications as e.g. gratings, lenses, filters, beam couplers and/or beam combiners and may have advantages over conventional refractive/reflective components as regards weight, cost and ease of manufacture [1]. Quick development of optoelectronics requires the extension of diffractive optical techniques from the visible to the infrared spectral region. Chalcogenide glasses are well known IR transmitting materials and therefore they can be very effectively employed in the production of IR diffractive elements [2]. They also exhibit mainly in the form of thin layers a wide variety of light-induced effects, which enable them to be used as optical imaging or storage media in applications such as holography, integrated optics and VLSI lithography. These effects can be used to produce either embedded or surface-relief structures in thin chalcogenide layers and hence, because of the above mentioned transparency of these materials in the IR spectral region, they can be used to fabricate diffractive elements which are transmissive in the IR [2]. This paper deals with the study of formation of amplitude and phase diffractive gratings in As based chalcogenide thin layers by holographical method.

Bulk As based glasses have been prepared by melting high purity (5N) elements in evacuated quartz ampoules (650-700 ^{o}C, 8 hrs). Thin layers (d_o = 300 – 1300 nm) were prepared in a vacuum (10^{-3} Pa) and at a low evaporation rate (about 1 nm/s).

Classical holographical set up using Ar^+ laser (514 nm, 100 mW/cm^2) as a recording beam source has been used to produce amplitude gratings within As based thin layers. Depending on the configuration of the whole set up gratings with periods 0.4 – 4 m were recorded, exposure time was 30 – 120 seconds. Non-aqueous triethylamine based solvents were employed as etching solvents to transform some of prepared amplitude gratings into relief type phase gratings. The profile of the structures produced by etching as well as the depth of grooves were subsequently checked using AFM and REM techniques. Structure of variously treated thin layers was studied by Raman spectroscopy using a BRUKER ISF55 IR spectrometer with FRA 106 accessory.

It was found, that exposure with Ar^+ laser causes shift in position of short wavelength absorption edge. The magnitude of this phenomenon depends strongly on the composition of thin layers and increases with As content in the layers copositions. Raman spectroscopy confirmed that changes of transmission (and of index of refraction as well) induced by exposure with Ar^+ laser are the results of photo-induced chemical redistribution which leads to higher homogenisation and to increase of polymerisation level. Detailed results will be published elsewhere.

The diffraction efficiencies η_{1T} (defined as the power ratio of the light diffracted into the first transmitted order to the incident light) of prepared amplitude type gratings at λ = 632,8 nm has been up to 3 % for normal incidence. Being exposed by day light for longer period, they have losed their diffraction efficiency as a result of gradual diminishing of gratings due to exposure of those parts of layers which were not exposed during holographical recording, as well.

Therefore we transformed these relatively unstable amplitude gratings into stable relief type ones. It is well known that As based chalcogenide thin layers can be selectively etched in alkaline bases. Application of aqueous solvents usually results in positive type of selective etching (exposed parts of the layer dissolve more quickly). Non aqueous amine based etching solvents can be used to produce negative type of selective etching (unexposed parts dissolve more quickly than exposed) [3].

In the present work we have used for etching of As-S layers non-aqueous triethylamine based solutions. The selectivity of etching of S rich layers in the non-aqueous solutions used was much more higher than that for the stochiometric $As_{40}S_{60}$ and As rich layers. It was found that exposure of the layers with Ar^+ laser postpones significantly the start of dissolution of the exposed material. The dissolution rate is essentially the same during the entire etching of the layers and does not depend on exposure time or on the initial layer thickness.

The great difference of etching time of exposed and unexposed As based thin layers has been used for fabrication of surface-relief diffraction gratings. In principle etching through the whole volume of unexposed parts of even „thick" (1,3 m) thin layers can be achieved. The diffraction efficiency of sinusoidal gratings (Fig. 1) increased remarkably up to 24 - 26 % for a wavelength of 633 nm at normal incidence after etching. For a grating with a period of 2 μm etched into a medium of refractive index 2.45 (index at 633 nm of exposed to saturation $As_{35}S_{65}$) this efficiency is close to the theoretical maximum of 29% for a grating depth of 250 nm for ideal sinusoidal diffraction gratings and of 33 % for binary gratings.
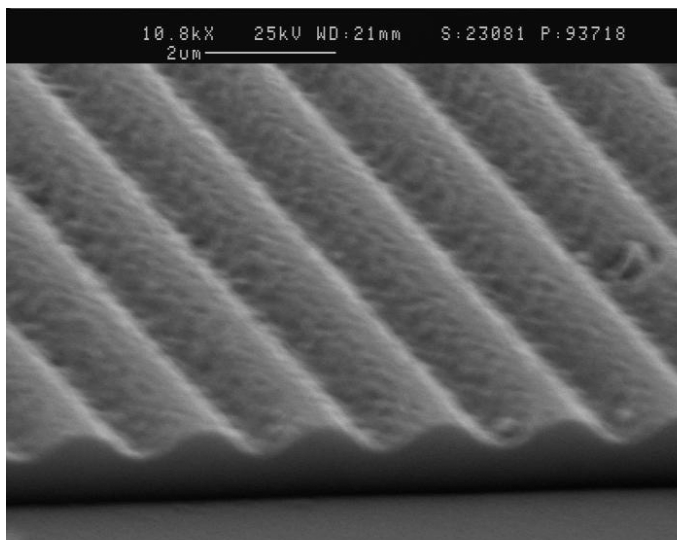

Fig. 1: REM picture of sinusoidal grating (period 2 m) etched into $As_{35}S_{65}$ thin layer.

Optimisation of exposure and etching conditions to produce highly effective diffraction gratings for IR spectral region are in progress.

References

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