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J. Ackermann, Ch. Dietrich, R. Männer, S. Noehte, K. Schwartz
Universität Mannheim
Seminargebäude A5
D-68131 Mannheim

OPTICAL GRATING STUDIES IN A-AS$_2$S$_3$ FILMS USING SCANNING FORCE MICROSCOPY

S. Noehte[1], J. Ackermann[2], K. Schwartz[3], Ch. Dietrich[1], R. Männer[1,4]

[1]Lehrstuhl für Informatik V, Universität Mannheim, Mannheim, Germany; [2]Gesellschaft für Schwerionenforschung, Darmstadt, Germany; [3]Physikalisches Institut der Universität Heidelberg, Heidelberg, Germany; [4]Interdisziplinäres Zentrum für Wissenschaftliches Rechnen, Universität Heidelberg, Heidelberg, Germany

Abstract

For high quality computer generated holograms As_2S_3-films are used as a real-ime phase recording material . To reach the required quality of optical interconnects it is necessary to expos the exact refractive index change for defined wave front distortions. Different methods were used, as scanning force microscopy (SFM), Mach Zehnder interferometry, confocal laser microscopy and interferometer microscopy to measure the wave front distortion on the pixel level. A computer simulation shows good agreement with the experimental results.

Introduction

Amorphous As_2S_3. (a-As_2S_3.) is a well known holographic recording material. High quality phase holograms with diffraction efficiencies up to 80% can be obtained in real-time. For that a wavelength change is necessary between recording and reconstruction of the holograms. For writing above band gap light (lW = 514 nm), for reading below band gap light (lR = 633 nm) has to be employed. This limits the use of As_2S_3. films for volume holograms, except in the case of plane wave recording. Not restricted by the wavelength change are analog or digital 2D holograms that we use in spatial multiplexed holograms for optical vector matrix multipliers.

Despite the fact that photo induced processes in As_2S_3. are widely studied, the holographic recording parameters of As_2S_3. films have not been investigated yet. Especially the phase shift dependence of lR on the exposure with lW is important for quantitative recording of phase holograms we are interested in. So this work focuses on the analysis of the phase shift as a function of the exposure. Films of different thicknesses were investigated and intensities were varied over four order of magnitude. The recording mechanism is complicated and depends strongly on the initial state of the disordered system [1].

The first method which is described is a direct measurement of the wave front distortion in larger structures. This phase shift measurement uses the technique of a Mach Zehnder interferometer. A HeNe laser beam is expanded by a factor of 25 and splitted into two beams. One part of the beam is transmitted through the a-As_2S_3 film, whereas the intensity of the other part is adjusted by the neutral density filter in order to maximize the contrast of the interference pattern.

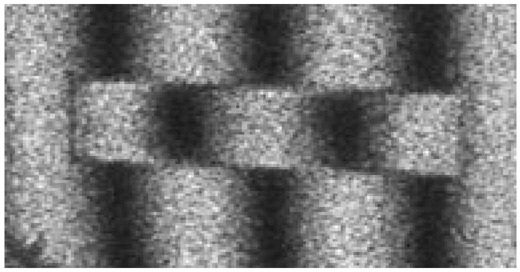

Fig. 1: Interference pattern of an exposed rectangle.

During the exposure of rectangles with different intensities the transmission I_t and the reflection I_r of the writing beam λ_W and the interference pattern of the reading beam λ_R is recorded simultaneously. Two PC's equipped with an ADC board and a frame grabber board resp. are used. Each measurement consists of 200 values for I_r and I_t and 11 pictures of the interference pattern.

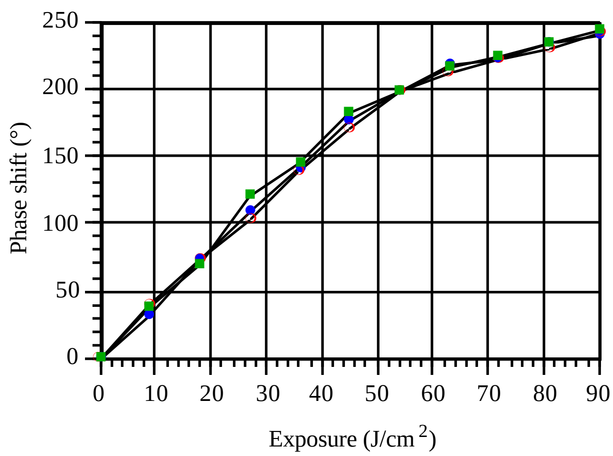

Fig. 2: Phase shift vs exposure (d = 5.2 µm, $I_{\lambda W}$ = 0.1 W/cm^2)

In Fig. 2 the phase modulation during exposure is plotted. It belongs to the 5.2 µm thick film. The maximum phase shift is 240° at 90 J/cm^2. This value corresponds to a change of the refractive index of Δn_{633} = 0.08 for the reading wavelength λ_R. Changes of the film thickness during exposure are small (1-5%) and are ignored here.

Complex scanning force microscopy (SFM) investigations were done in As_2S_3-films whitch were exposed with conventionally produced holographic grading and computer generated grading, by a high resolution lithographic system [3]. The light induced structural changes in the amorphous As_2S_3 film have a larger size than the spot diameter of the laser beam. The light induced refractive index change in the phase grating was >0,2 (the initial refractive index is n = 2,4). The optical recording induced a contraction of the amorphous As_2S_3 film (i.e. thickness change) of approximately 5%. The light induced surface relief was studied by SFM, the grating period and the surface structure were revealed.

The microscope has been developed at the Physical Institute of the University of Heidelberg. It is a modification of an earlier version [2]. Using a laser diode and a quadrant photo diode it monitors the motion of the force sensor via light deflection. The images were produced with bar-shaped Si-cantilevers with a force constant of 0.056 N/m and an applied loading force of several nN.

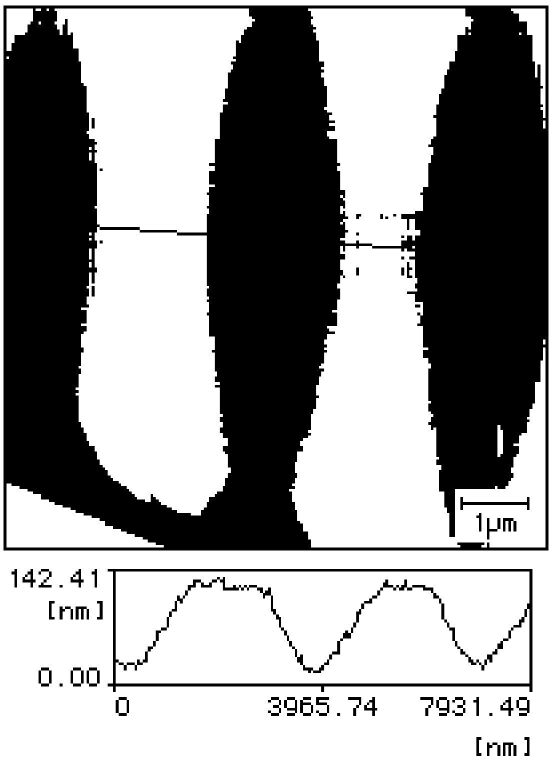

Fig.3 A 9x9 µm^2 SFM scan of a lithographic exposure grating.

Topographic and torsion images have been acquired simultaneously. On the left side an area of about 8 µm^2 of the irradiated As_2S_3 sample is depicted. The structures at the left bottom edge are an artifact of the microscope.

The lower small picture represents a single line scan showing a spacing of the optical grating of 3 µm. The height difference between top and bottom of the sinusoidal curve depends strongly on the difference of exposure - higher laser intensity results in larger height differences.

SFM investigations on a nm-scale revealed the typical structure of an evaporated surface with As_2S_3-clusters having diameters of 15-25 nm and heights of several nm. A remarkable increase of the RMS-roughness of 2±0,5 between the irradiated and non irradiated area could be observed.

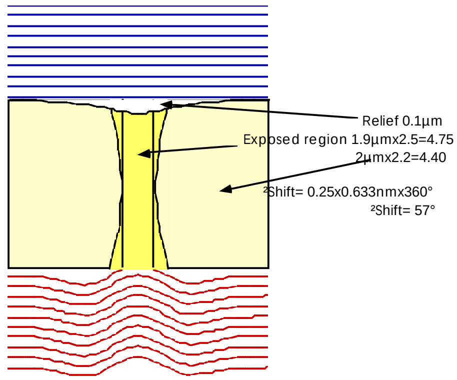

Fig4. Mechanism of wave front distortion at a single pixel.

The relief structure works diametrical to the increasing of the refractive index change in the exposure region of the not anealed As_2S^3 film. The experimental results have shown that a carefully inspection of the mechanism allows a controlled wave front distortion.

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