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High-resolution Reproduction by Cold UV Stamping in Optical Polymeric Films

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1. Introduction

Polymeric materials are of great interest for applications in optical telecommunication such as optical waveguides and optical interconnections due to their easy processing and relatively low cost compared to silica-based materials. In order to use polymer-based optical waveguide devices for optical interconnection and/or access network applications, a low-cost, high throughput and high-resolution lithography technology is necessary for future manufacturing of polymer-based optoelectronic waveguide devices. Several reports have been published on the techniques among which is also the imprint lithography [1] as a potential candidate for constructing such devices.

In this paper, we demonstrate the high-resolution grating pattern on the optical polymeric films based on the "cold UV imprinting" technology. Grating is an essential element of waveguide devices playing an important role as a beam-splitter, a wavelength filter or input-output couplers. By changing the parameters for cold UV imprinting, we investigated condition of the reproduction of replica grating pattern.

2. Experimental Settings

Materials

As the negative type photo-resist material we used a formulation described in [2][3]. In this paper we are going to call it PNME by the capitals of its principal components. It consist of three materials: functional monomer, sensitizer dye, and amine cosynergist. Polyfunctional acrylate monomer was Pentaerythritol triacrylate, the cosynergist was N-methyldiethanolamin, and as dye we used eosin Y (2', 4', 5', 7'- tetrabromofluorescein disodium salt). The concentrations of materials in formulation were following: Eosin Y represented 0.3% of weight, N-methyldiethanolamin represented 8% of weight, and Pentaerythritol triacrylate 91.7%. This formulation is a liquid sensitive to light. Sensitivity of the formulation is highest in the spectral region from 450 to 550 nm, with its peak at 530 nm [3]. After the formulation receives sufficient amount of energy through exposure, a process of gelation or cross-linking of monomers occurs. Depending on the amount of received energy cross-linking can be partial or complete.

The material for master fabrication was ZEP520-A7 from ZEONREX Electronic Chemicals. Spacer material was PMER-N600 from TOK.

Master Fabrication and Spacer Fabrication

Material ZEP520-A7 was spin-coated onto glass substrate. Master structure was then fabricated by electron beam lithography on the thin film. The dose received was 40μC/cm^2. After development by dipping for five minutes and rinsing, grating was created. The last step in master fabrication was hardbake of the grating structure with a thin film of gold on the top at 120°C for 30 minutes. Thus thin film of gold was evaporated onto master structure before hardbake.

The substrate PMER N-HC600 was twice spin-coated onto the glass at 3000 rpm for 60 seconds. After pre-bake at 70°C for 30 minutes the film was covered by a mask. Exposure to UV lamp and development created a spacer of thickness of 14 μm on glass substrate.

Replica Fabrication Process

Figure 1 presents a schematic diagram of replica fabrication. PNME material was enclosed between two glass plates. One glass plate supported master structure. Second glass plate supported spacer. PNME was then exposed to UV light through glass plate supporting spacer. Wavelength of UV light was λ=365nm. Intensity was I = 0.17 mW/cm^2. Time of exposure was t = 6min. After exposure PNME material was partially solidified. Master was then removed and PNME sample was exposed again to UV light for complete solidification.

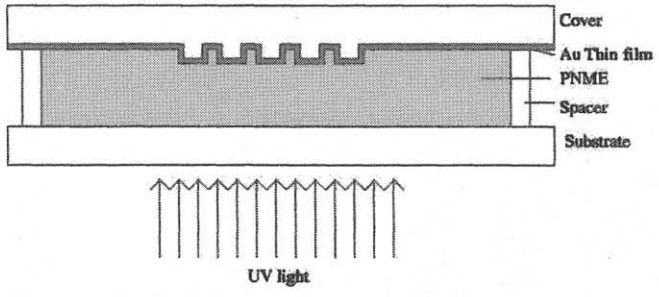

Fig. 1 Schematic diagram for replica fabrication by cold UV embossing.

3. Results

The master structure, figure Fig. 2, was a grating

with period Λ = 520nm. By fabrication process described in previous section we fabricated replica of the master structure. Picture of replica can be seen in Fig. 3. Pictures were taken by Atomic Force Microscope AFM. Considering the grating period and depth, fabricated replica completely corresponds to master structure with high resolution at submicron range. Fabrication technique can be described as cold UV embossing onto liquid negative type photo-resist material. Similar results were obtained also when thin aluminum film was evaporated on top of ZEP material. Master with Al treated surface and its replica can be seen in pictures Fig 4. and Fig 5. respectively.

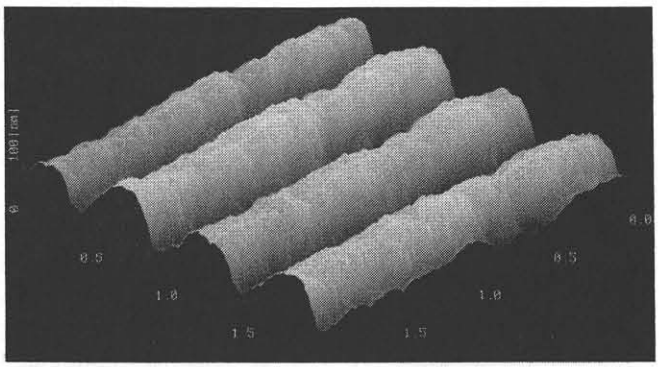

Fig. 1 Master structure fabricated on ZEP thin film onto which Au film was evaporated.

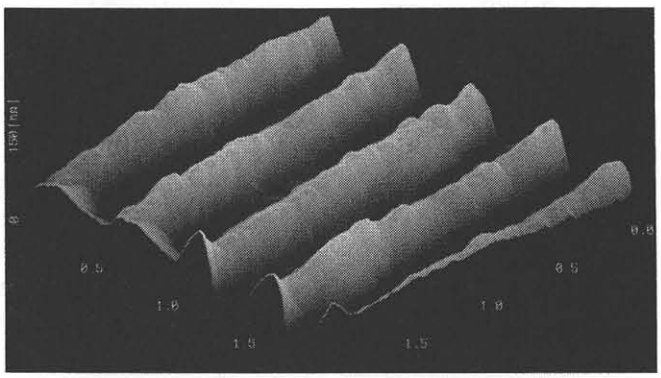

Fig. 2 Replica from Au master structure.

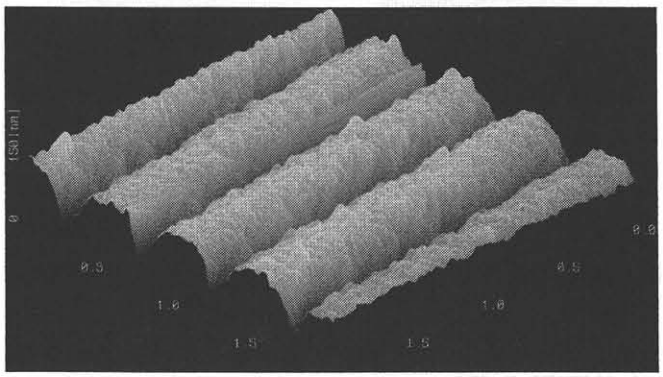

Fig. 4 Master structure fabricated on ZEP thin film onto which Al film was evaporated

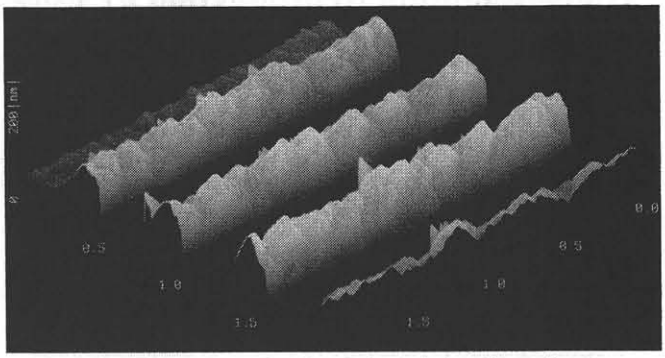

Fig. 5 Replica structure in PMNE formulation from Al master.

4. Discussion

Similar method of fabrication was reported by Masanori Komuro et al,[4]. However, in our method surface of master structure was treated so that adhesion between replica material and master does not occur. We chose to treat surface of master structure by deposition of thin metallic film. We were led to this treatment by preliminary experiments which included direct ZEP – PNME interface, or glass – PNME interface, or glass with deposited thin Al film – PNME interface embossing. These preliminary experiments led either to peeling of PNME off the substrate or sticking of small Al areas to PNME material. It was found out that adhesion of different layers plays a vital role in precise replica fabrication. Additionally, in pictures showing master with aluminum coating and its replica, small bumps on surface of master grating can be seen, which presumably could represent droplets of aluminum. This unevenness can be also observed on the surface of the replica. Such observation could lead us to the conclusion that resolution possibilities of this method of reproduction could be much higher up to nanometer-size.

Acknowledgments

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