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NEW MICRO PROCESS OF PERIODICAL POLYMER STRUCTURE WITH HIGH ASPECT RATIO

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A new procedure for fabricating a periodic structure on a UV polymer at submicron range using holographic interferometry and molding processes is described. First, holographic interference using a He-Cd (325 nm) laser was used to create the master of the periodic line structure on an i-line sub-micron positive photoresist film. A 200 nm nickel thin film was then sputtered onto the positive photoresist. Final line pattern on a UV polymer was formed from casting against the master mold. Initial results show the technique can accurately control the grating's period and depth. A high aspect ratio of grating period (gp) to depth (d) is about 1.35.

1. Introduction

Gratings are used in integrated optics for several purpose, including light wavelength filtering, sensing, optical measuring technique, spectral narrowing of laser output, etc. [1]. Polymer gratings are of great interest for their low cost and simple fabrication. The conventional way of fabricating grating includes the steps of patterning and etching. Typical techniques for patterning gratings on polymers include holographic surface relief grating, electro-beam (e-beam) lithography, laser-beam direct writing, X-ray mask technology, and phase mask lithography. [2] Although an e-beam lithography process provides flexibility and high resolution in defining almost any prescribed pattern, it is limited to very small throughput and has difficulty in obtaining accurate pattern placement. Alternatively, the laser-beam direct writing technique provides the same flexibility for pattern definitions, but the etching profile is highly dependent on the operating wavelength. Thermal effects stemming from the laser ablation also causes unwanted irradiated material that collects around the edge of the etched material. In this study, the grating patterns on the photoresist have been prepared by the holographic interferometric technique. This technique offers distinguished advantages compared to other techniques are that it can easily control the period and depth of gratings, and it is more naturally suitable for the production of high-resolution gratings than other techniques, yielding good uniformity of the grating period with greater ease. In addition, the theoretical limit of the frequency of the interference pattern produced by two intersecting beams is half of the wavelength of the incident beam. Thus, the grating period is limited only by the wavelength of the light source. The materials used as well as the fabrication processes are important factors in manufacturing optical elements for different applications.

The sol-gel hybrid (SGH) materials have shown simple fabrication of grating diffraction by the holographic interferometric technique, but this material cannot be fabricated to obtain the high aspect ratio of grating pattern, and they are brittle material that is hard to be used as any applied applications. [3] In our previous report, [4] polymer diffraction gratings were fabricated using the holographic interferometric technique with a photoresist (Ultra 123) to obtain the high aspect ratio of the grating pattern. We also use a rubber (PDMS) to transfer the pattern. But, an obvious phenomenon is observed that when the depth of the grating was larger than 350 nm, which is accompanied by a grating period smaller than 500 nm, some of the periodic structure of PDMS was stuck together after release from the mold. This sticking effect increased when the aspect ratio increased because the fins are less rigid. Therefore, in this paper we will describe a technique for combining the holographic interferometric and micro-molding process to create a high aspect ratio

grating structure on a polymer surface. This kind of study is still limited elsewhere.

2. Methodology and results

The technique of forming grating patterns on the UV polymer involved three processing steps: First, a grating pattern is holographically exposed using two-beam interference pattern on a positive photoresist film. A 280 nm nickel thin film is then sputtered onto the positive photoresist mold. This mold can be subsequently used to transfer the final gratings pattern onto a UV cure epoxy polymer. The following sections describe the process involved for the grating fabrication.

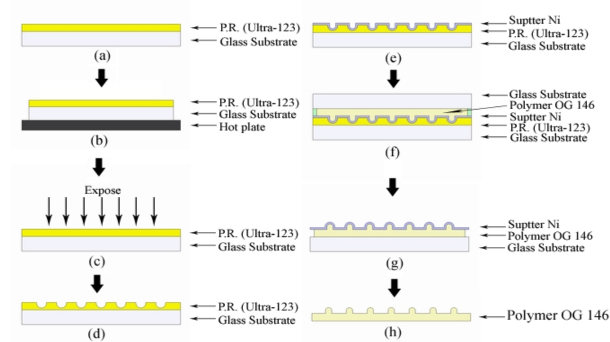


Fig. 1. Schematic illustration of the fabricated polymer gratings in the micro-molding process.

The master grating patterns on a positive photoresist (Ultra123, Microchem. Corp. MA) were holographically exposed using a two-beam interferometer technique (Fig. 1 (a)-(d)). The detailes of the process was described in previous reports. [4] Based on our results, it was found that the grating period and the corresponding depth of the grating pattern can be accurately controlled down to an error rate of less than 1%. We also found that a high aspect ratio of almost 1:1 between the depth and the period of the grating structure could be obtained using this process. The profiles of the grating were measured by atomic force microscope (AFM). Fig. 2 showed the AFM result of the photoresist with the grating period of 505 nm and the grating depth of 333 nm.

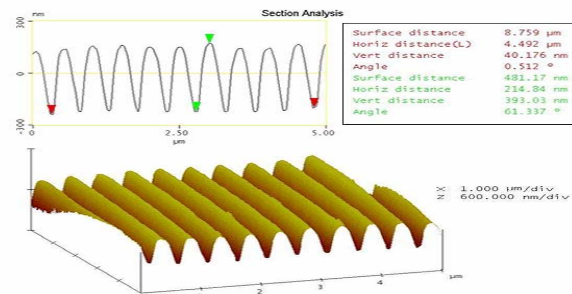
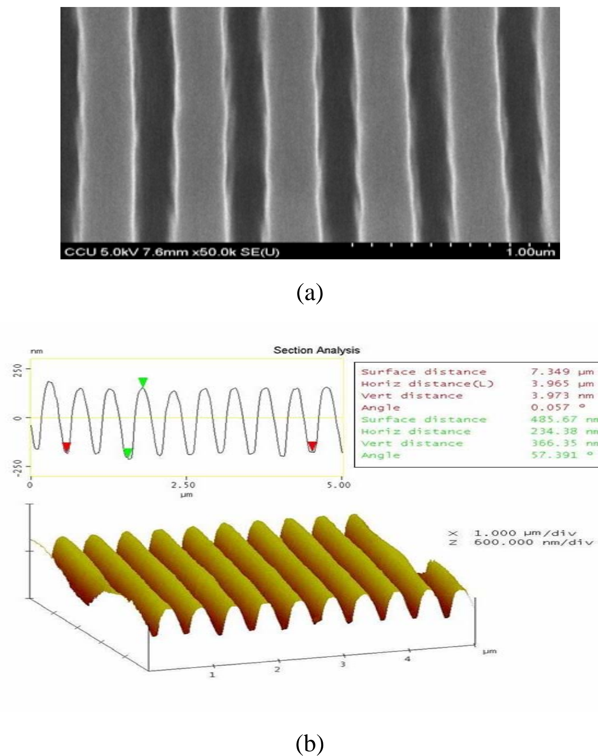


Fig. 2. AFM morphology of the micro-molding gratings with positive photoresist (505 nm grating period and 393 nm grating depth).

A nickel thin film was then sputtered onto the positive photoresist mold by a RF sputter for 5 minutues (Fig. 1(e)). The power source is 50 W, and the pressure is controlled under 5×10^{-3} Torr. The thickness of nickel is about 280 nm. The final pattern was transferred onto a UV cure epoxy substrate from the positive photoresist mold, which was sputtered on nickel, using an injected molding process (Fig. 1 (f)-(h)). The fabrication procedure is described as follows. A spacer with thickness 400 μm was placed between the mold and a thin Pyrex glass slide. The mold was supported by another Pyrex glass slide to create a support for the positive photoresist mold. After

injecting the precursed UV polymer (OG146, EPOXY TECHNOLOGY Inc.)**,** which has a relatively low viscosity (82 CPS), into the opening between the mold and the glass slide using a fine tip syringe, the liquid solution automatically spread and filled up the space between the mold and slide due to capillary effects. A UV curing lamp with a wavelength range of 300-400 nm was used to crosslink the polymer at an intensity of 100 mw/cm^2 for 1 to 2 minutes. After the polymer is fully cured, the sample was put into the acetone solution to remove the positive photoresist. The sample was then put into $FeCl_3$ solution to remove nickel, and the final gratings are formed on the UV polymer. The AFM and SEM micrographs of the gratings on UV polymer show that the high aspect ratio periodical structure can be obtained by the above fabricated process (as shown in Fig. 3).



(a)

(b)

Fig. 3. SEM and AFM grating micrographs on PC polymer (a) SEM (b) AFM (494 nm grating period and 366 nm grating depth).

3. Conclusion

We have successfully demonstrated a new process to produce submicron gratings by using both electroplating-molding and holographic interference techniques. A large aspect ratio of 1.35 on the grating pattern could be obtained, and consist reproduction of the grating on a polycarbonate polymer also has been produced. The grating period (gp) and depth (d) on the polymer gratings exhibit small difference from the original designed grating pattern. This process shows great potential for production of any kind of periodical grating structure.

References

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