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Computer generated hologram-ROM fabrication and duplication by EBL and UV-NIL

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ABSTRACT

High speed and large capacity read only memory (ROM) is strongly required for the increasing data size of pictures, videos and other files. Computer generated hologram-ROM (CGH-ROM) has the potential possibility to meet these demands and is receiving a lot of attention as the next generation ROM. However, CGH-ROM is difficult to produce in large volume at low cost because it requires a nano-scale precision structure as well as nano-steps. Therefore, in order to fabricate the complex and high-precision pattern cost-effectively, the authors employed ultraviolet nanoimprint lithography (UV-NIL). The three-dimensional (3D) CGH-ROM master mould was fabricated by electron beam lithography (EBL). In this study, the thickness of the residual layer under the CGH pattern was examined. The result showed the target reconstruction image of the CGH-ROM was obtained regardless of a residual layer thickness. Furthermore, the authors have succeeded in fabrication of a CGH-ROM with a 300 nm step width and demonstrated its reconstruction.

1. Introduction

The resolution of digital contents such as pictures, videos, and various data files has been increasing steadily year by year. Because of low running cost and high throughput, the read-only memory (ROM) optical disk, generally fabricated by plastic injection moulding, is a suitable medium for the rapid and widespread distribution of digital contents. The storage capacity of ROM has been increasing though the contribution of improvements in the track pitch size, the read-out wavelength, and the numerical apertures (NA) of lenses. For instance, Compact Disc (CD) has a read out wavelengths of 785 nm, a track pitch of 1.60 μm and NA of 0.45; the corresponding values for Digital Versatile Disc (DVD) are 655 nm, 0.74 μm, and 0.60, and those of Blu-ray Disc (BD) are 405 nm, 0.32 μm, and 0.85. As a result, the recording densities of CD, DVD, and BD per single layer are 0.41, 2.77, and 14.73 Gbit/in^2 [1,2]. However, it is difficult to decrease the wavelength any further because an ultraviolet-range laser is absorbed by the plastic substrate of the optical disk. In addition, the higher NA lens produces the shallower depth of focus, so that, the smoother surface roughness is required for the disc. While a vibration also becomes a major issue. Although a multi-layer medium is typically used to raise the recording density, the fabrication cost is higher than one of a single-layer medium.

For these reasons, holographic memory [3] is considered to be the next-generation ROM, which is expected to achieve upward of 1 Tbit/in^2 recording density. In the case of holographic memory, the data is read from a block area, so the readout speed is greater than that of a conventional optical disk, which is read by line by line. Moreover, recording techniques, such as angle [4] and shift multiplexing [5], have been reported to increase the recording density. Additionally, it is possible to duplicate the relief-type hologram [6] using nanoimprint lithography (NIL) [7] since this hologram pattern is formed on the surface of the medium. The main problem is that, the fabrication of a master mould over a large area using the optical system is difficult because the optical interference is very sensitive to vibration of the system and the optical axis deviation.

To fabricate the master mould without the environmental disturbance, the computer-generated hologram ROM (CGH-ROM) [8–10] has received a lot of attention. In the case of CGH-ROM, a page of data was converted into a hologram by iterative calculation with arbitrary wave front [11]. Using the calculated result, the master mould, which consists of nanoscale three-dimensional (3D) patterns, was fabricated by electron beam lithography (EBL) [12,13]. Since the control of pattern depths on a nano-scale was very difficult, the step width previously reported was mainly over

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1 μm. If the step width is 1 μm and a step can represent a 1 bit data, the recoding density without the multiple-technique is only 0.645 Gbit/in^2. Thus, a finer step width is necessary to obtain the higher density.

By using an inorganic electron beam (EB) resist and NIL, we have developed a CGH-ROM fabrication process without lift-off and etching process [14]. However, in order to obtain the CGH-ROM pattern over the 12 cm disk area with small residual layer thickness (RLT) [15] variations, a high precision NIL stage and a mirrored surface substrate are required, resulting in very high cost. In this study, therefore, we examined the effect of the RLT under the CGH-ROM and compared each reconstruction images for different RLTs. As a result, it becomes clear that the target reconstruction image of the CGH-ROM was obtained regardless of a residual layer thickness. Moreover, we have succeeded in reconstruction of a duplicated CGH-ROM with a 300 nm step width, which is smaller than the read out wave length of 405 nm.

2. Experimental method

Fig. 1 shows the fabrication process for the CGH-ROM via EBL. NIMO-P0701 (Tokyo Ohka Kogyo Co., Ltd., Tokyo), which is based on spin-on glass, was used as the positive-type EB resist [16]. The thickness of the resist on a silicon wafer was about 1 μm. A buffered hydrofluoric acid solution [50% hydrofluoricacid (35 mL/L) and 40% NH_4F (18.75 mL/L)] was used as the developer. The sample was installed in a scanning electron microscope (SEM) with an EB writing system (ERA-8800FE; Elionix Co., Tokyo). Then, the sample was exposed three times to changing EB doses [17] and design patterns without moving the SEM stage. The acceleration voltage and current of EB were 10 kV and 50 pA, respectively. The reflective-type CGH pattern was previously prepared by means of the Gerchberg–Saxton algorithm in conjunction with the angular spectrum method [10,18,19]. The calculated depths of the CGH were converted into four tones: three design bitmap patterns and one unprocessed area. After EB exposure, the sample was developed for 60 sec. By using the master CGH pattern mould, an inverted mould was duplicated by ultra violet NIL (UV-NIL) onto a Polyester film (COSMOSHINE A4300; Toyobo Co., Osaka) substrate. In this case, we used PAK-01CL (Toyo Gosei Co., Tokyo) as a UV-curable resin because of its high performance [20]. Finally, the CGH pattern was transferred onto a silicon wafer via NIL with the inverted mould. When UV-NIL carried out, the sample was coated with a release agent (Optool DSX; Daikin Industries Co., Tokyo). To control the RLT under CGH-ROM, we employed the spin-coating technique and the obtained RLTs were 3.5, 4.6 and 7.7 μm. The height of the sample was examined with an atomic force microscope (AFM) (SPM-9600; Shimadzu Co., Kyoto). Fig. 2 show the relationships between the EB doses and the developed pattern depth. The depths of each step pattern were controlled using by this relationships and the target depths of 97.4, 194.7,

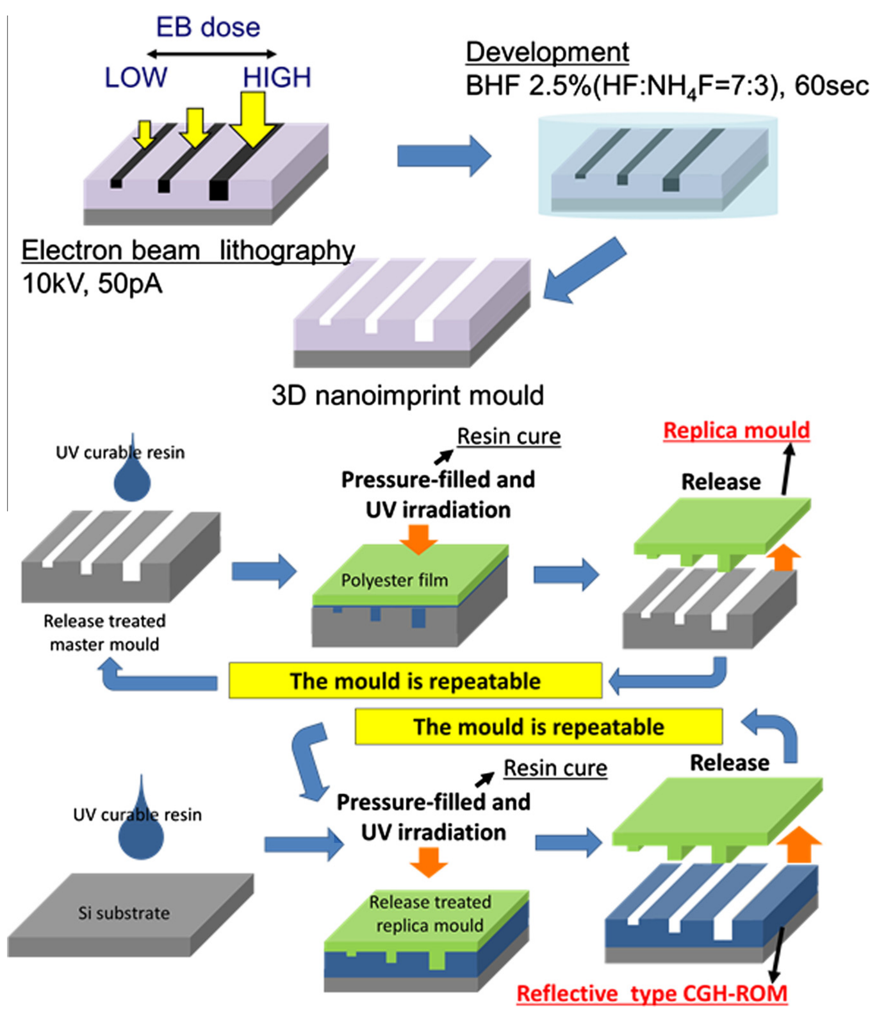

Fig. 1. The method of fabrication and duplication with CGH-ROM.