Fabrication of seamless three-dimensional roll mold using electron beam direct writing to rotating cylindrical substrate

Jun Taniguchi[1)] and Masao Aratani[1)]

1) Tokyo University of Science, 2641 Yamazaki, Noda, Chiba 278-8510, Japan

Roll to Roll nanoimprint lithography (RTR NIL) is the high throughput production method in the NIL [1, 2]. However, fabrication of roll mold for RTR is difficult because of its cylindrical shape. In order to obtain seamless nano scale mold, we have developed electron beam (EB) direct writing to rotating cylindrical substrate [3]. This method is rotating cylindrical substrate (roll mold substrate) in vacuum ambient and simultaneously EB direct writing to resist which coated on roll mold substrate. In this report, we used Spin-On-Glass (SOG) inorganic EB resist and the control of acceleration voltage electron beam lithography (CAV-EBL) method [4] for three-dimensional (3D) roll mold.

The cylindrical aluminum substrate with 1.0 mm diameter and 30 mm length was used for roll mold substrate. The SOG material (Accuglass 512B; made by Honeywell Co.) which was normally used as interlayer dielectrics was used for positive tone inorganic resist in this study. A buffered hydrofluoric acid (BHF) solution was used for developer. The roll mold substrate was dipped in SOG resist and pull out. After that, this sample was baked at 425 ℃ for 1 hour. The resist thickness was 417 nm. This sample was set in rotating equipment and installed in EB writing machine. Scanning electron microscope (SEM, ESA-2000, Elionix, Co. ltd.) was used for EB writing. This SEM is tungsten filament type electron beam gun, so EB diameter is not fine. The EB direct writing conditions were optimized at each different acceleration voltages (3, 4, 5 kV), EB dose of 1500 μC/cm^2. The rotating speed was 50 rpm and EB diameter was 100nm. Then the EB-exposed area on the SOG film was developed out with BHF solution in 60 s. But it did not etch EB-unexposed area within 120 s which was helpful in fabricating three-dimensional roll molds.

Figure 1 shows the SEM photos of developed SOG pattern on roll mold. Under 1μm line were obtained along circumferential of roll mold substrate. Using this mold, ultraviolet NIL was carried out with 4 J/cm^2 UV dose and PAK-02 photo curable resin (Toyo Gosei Co. ltd.). Figure 2 shows the comparison of roll mold and replicated pattern. Faithful pattern transfer can be obtained. Figure 3 shows AFM images of the replicated pattern height. The different height pattern (3D) replications were obtained using the roll mold fabricated by CAV-EBL.

In conclusion, fabrication process of seamless three-dimensional roll mold for NIL using EB direct writing to rotating cylindrical substrate have been established.

References

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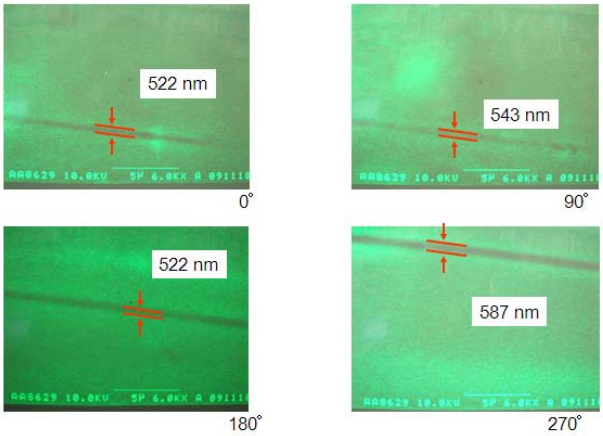
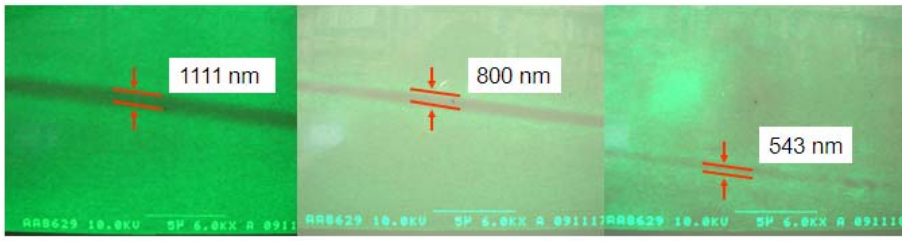
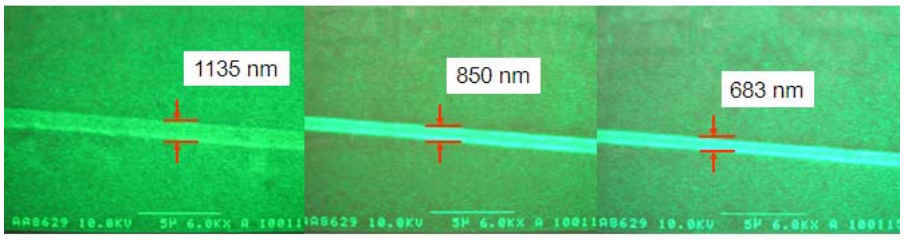


Figure 1 The seamless line pattern on the roll mold.
(EB acceleration voltage: 5kV, EB dose: 1500 μC/cm^2.)



(a) The roll mold



(b) The replicated pattern

Figure 2 The SEM photos of mold and replicated line patterns.

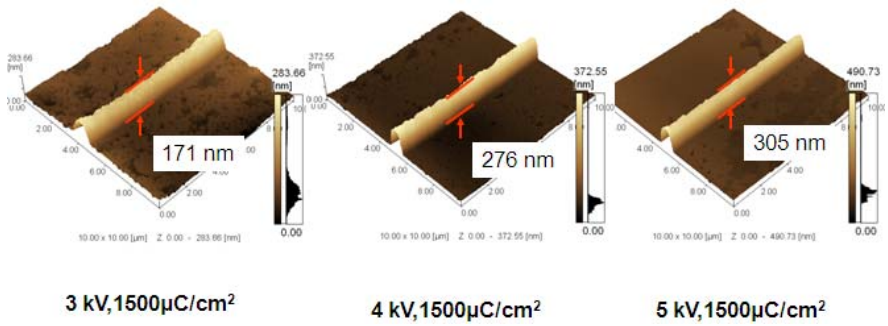


Figure 3 The replicated 3D pattern.