

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

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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. Usually roll mold was fabricated by rolling up the Ni plating foil with nano pattern or lathe turning with small cutting edge tool. However, the former method generates seam and the latter method defines the resolution by tool's cutting edge. In order to obtain seamless nano scale mold, we have developed electron beam (EB) direct writing to rotating cylindrical substrate. 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 (Figure 1.).

The cylindrical brass substrate with 32 mm diameter and 30 mm length was used for roll mold substrate. Polymethylmethacrylate (PMMA) resin was used for positive type EB resist. The roll mold substrate was dipped in PMMA resist and pull out. After that, this sample was baked at 180 °C for 20 minutes and resulted in 360 nm resist thickness. 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 condition as follows: acceleration voltage of 10 kV, EB current of 0.53 nA, beam diameter of 300 nm, EB dose of 100 μ C/cm², and rotating speed of 2 rpm. After the EB lithography, this sample was developed. Figure 2 shows the SEM photos of developed PMMA pattern on roll mold substrate at every 90 °. Seamless and continuous line and space patterns were obtained along circumferential of roll mold substrate. Using this mold, ultraviolet NIL was carried out with 4 J/cm² UV dose and PAK-02 photo curable resin (Toyo Gosei Co. Ltd.). Figure 3 shows the replicated pattern on plastic films. Therefore, fabrication process of seamless and continuous roll mold for NIL using EB direct writing to rotating cylindrical substrate have been established. In addition, fabricated roll mold is use for RTR UV-NIL.

[1] H. Tan, A. Gilbertson and S.Y. Chou, *J. Vac. Sci. Technol. B* **16** (1998) 3926.

[2] S. H. Ahn, J.S. Kima and L. J.y Guo, *J. Vac. Sci. Technol. B* **25** (2007) 2388.

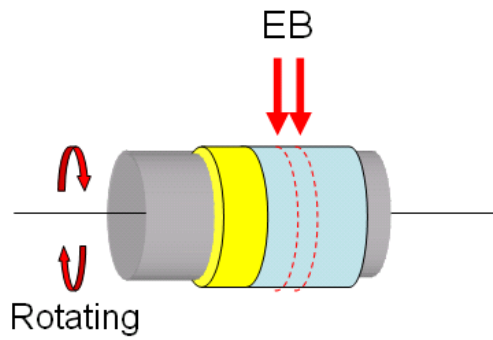


Fig 1: Electron beam direct writing to rotating roll mold.

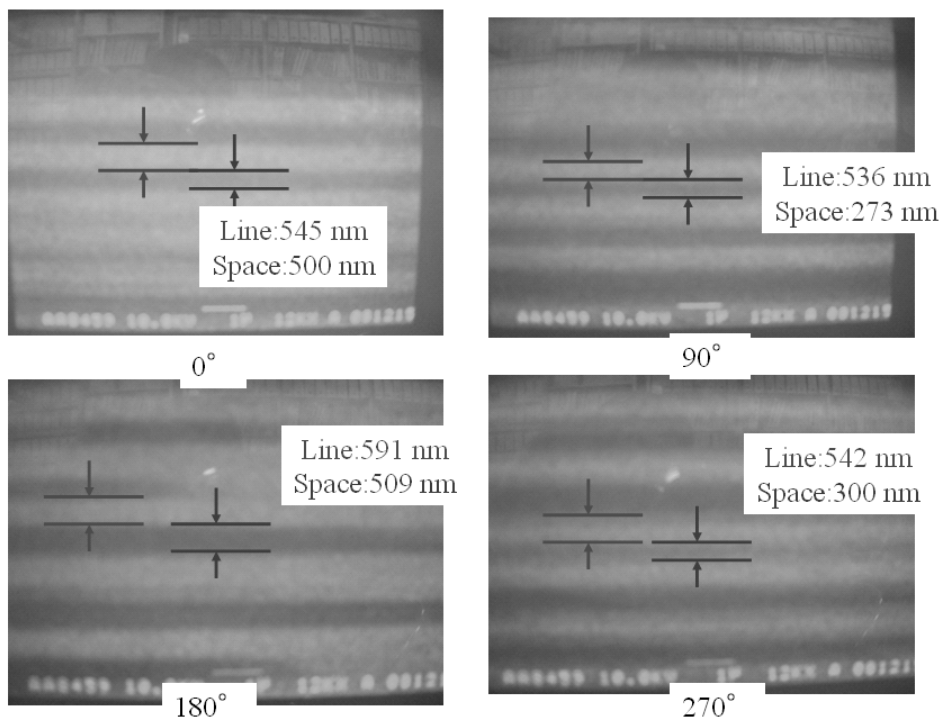


Fig 2: SEM photos of the developed PMMA pattern on roll mold substrate.

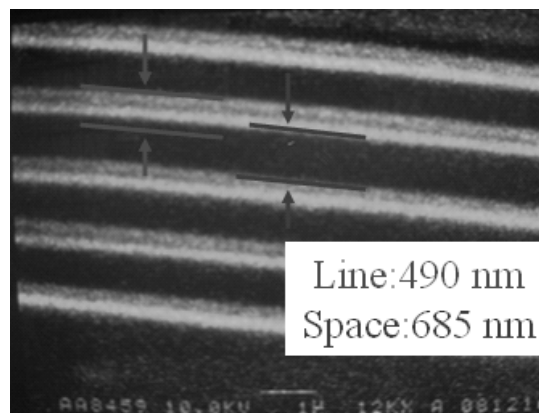


Fig 3: SEM photo of replicated pattern using Fig.2 mold.