# Fabrication of the seamless roll mold using inorganic electron beam resist with post exposure bake

**Noriyuki Unno[1,2)], Jun Taniguchi[1)], Kiyoshi Ishikawa[3)]**

*1)Tokyo University of Science, 2641 Yamazaki, Noda, Chiba 278-8510, Japan*
*2) Research Fellow of the Japan Society for the Promotion of Science, 8 Ichibancho, Chiyoda-ku, Tokyo*
*3)TOKYO OHKA KOGYO CO., LTD 1590 Tabata, Samukawa, Koza, Kanagawa, 253-0014 Japan*

In order to fabricate the next-generation devices, roll-to-roll (RTR) nanoimprint [1] has received a lot of attention because of its very high throughput and high resolution. Generally, a roll mold is obtained by the attachment of a planar replica mold, which is duplicated by a master mold using an electroformed nickel technique [2]. However, the resulting roll mold has seams and this brings about a yield loss of the product. Therefore, we have developed a direct writing method using EB lithography on a rotating cylindrical substrate [3]. In this study, we examined a fabrication method of seamless roll mold using high resolution inorganic EB resist (NIMO-P0701, TOKYO OHKA KOGYO CO., LTD) and a pattern shrink effect by post exposure bake (PEB) [4]. Figure 1 shows the process procedure. First, the roll mold substrate (3 cm diameter, made by brass) was dipped into NIMO-P0701 and then pulled out at a constant speed. Then, the resulting sample was cured at 300 °C for 1 hour. Next, the sample was mounted onto rotating equipment and installed in a scanning electron microscope (SEM) with an EB writing system (ERA-8800FE, Elionix Co.) and the roll substrate was exposed by 10 kV EB while being rotated at a constant speed. The rotational speed was set to ten turns per line pattern. Then, PEB was carried out at 200 °C for 10 minutes. After that, the EB-exposed area of the resist was developed by buffered HF. Subsequently, the sample was coated with an antisticking layer of Optool DSX (Daikin Industries). Then, the RTR nanoimprint was carried out using ultra violet (UV) photocurable resin PAK01 (Toyo Gosei Co., Ltd.)

Figure 2 shows SEM images of obtained patterns at 1000 $\mu C/cm^2$ with or without PEB. The developed pattern without PEB was peeled off because of large proximity effect. In contrast, a line and space pattern (L&S) was obtained with PEB. Figure 3 shows the obtained L&S pattern and its RTR nanoimprint result. Although the obtained PAK01 pattern was shrunk by photo polymerization, the replicated L&S pattern was very smooth and corresponded approximately to the roll mold. Finally, a 170 nm L&S pattern was obtained over 10 cm seamlessly, as shown figure 4.

[1] H. Tan et al., *J. Vac. Sci. Technol. B* **16** (1998) 3926.
[2] V. Velkova et al., *Microelectron. Eng.* **87** (2010) 2139.
[3] J. Taniguchi et al., *J. Vac. Sci. Technol. B* **27** (2009) 2841.
[4] N. Unno et al., *J. Vac. Sci. Technol. B* **26** (2008) 2390.

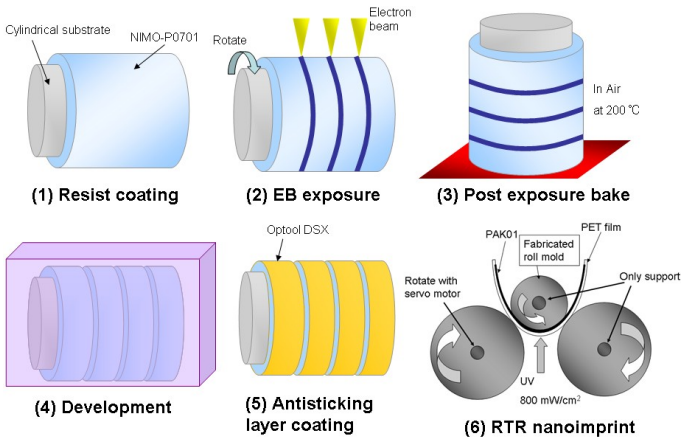


*Fig 1*: The characteristic of line width in various PEB temperatures at 4 kV.

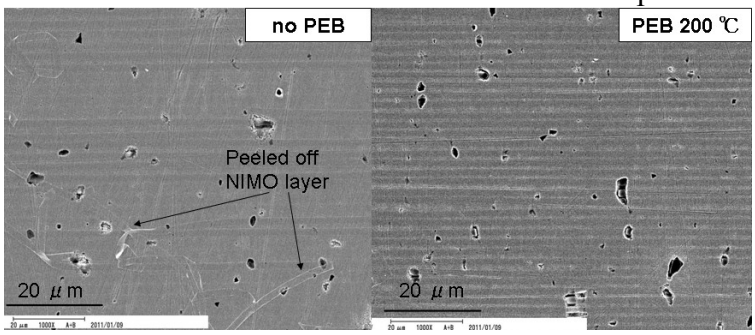


*Fig 2*: SEM images of the developed pattern with or without PEB.

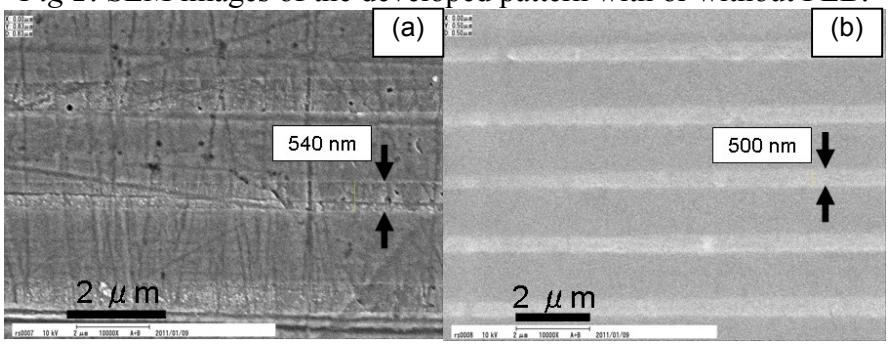


*Fig 3*:SEM image of (a) the roll mold and (b) the RTR nanoimprint result.

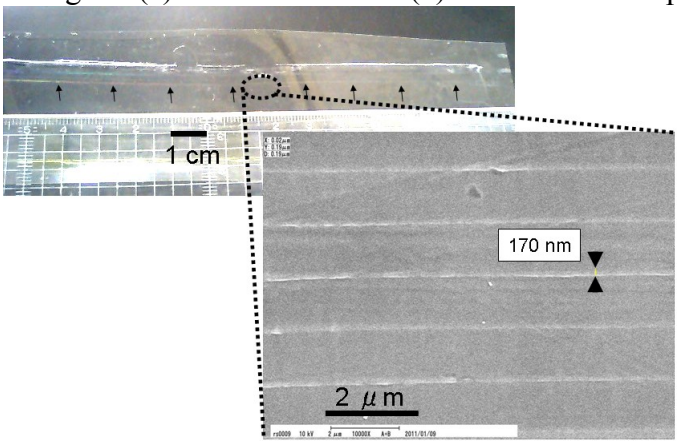


*Fig 4*:SEM image of the finest replicated pattern using RTR nanoimprint.