

Fabrication of the nanoimprint mold using inorganic electron beam resist with post exposure bake

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Nanoimprint lithography (NIL) is a promising method for fabricating nanoscale patterns, because of its low cost and process simplicity. Electron beam lithography (EBL), where the beam diameter is a few nm, is absolutely necessary to fabricate the mold. Normally, EBL is operated at high-acceleration voltage (> 50 kV) because its diameter is smaller than low-acceleration voltage [1]. However, high-acceleration-voltage EBL is lower throughput because of its poor interaction with resist, and the equipment is expensive. Thus, a low-acceleration-voltage EBL system is desired because of higher sensitivity [2] and less expensive equipment. Our previous studies had reported that a low-acceleration-voltage EBL system with inorganic resist can be used to delineate the fine L&S pattern (line-width < 100 nm) [3, 4]. In this study a denser L&S pattern was obtained with post exposure bake (PEB).

NIMO-P0701 (TOKYO OHKA KOGYO CO., LTD), which is composed mainly of siloxane, was employed as inorganic resist. First, NIMO-P0701 was spin-coated on a Si substrate, followed by a 90 s prebake at 300 °C, resulting in a 300 nm film. Any chemically amplified material is not contained in NIMO-P0701 after prebake at 300 °C. Then, ERA-8800FE (ELIONIX Co.) was used for EBL system. A buffered hydrofluoric acid (BHF) solution was used for developer and developing time was 60 s. The developed inorganic resist has enough hardness to be used for mold because this resist structure is almost equivalent to that of quartz. The replicated pattern was obtained by ultraviolet-NIL with PAK-01 (Toyo Gosei Co., Ltd.).

Figure 1 shows the characteristics of the line-width of L&S pattern at 4 kV with or without PEB. Figure 2 shows the SEM images of L&S pattern with varying PEB temperature using $200\mu\text{C}/\text{cm}^2$ EB dose. The higher PEB temperature tended to make L&S pattern finer and more clearly and the proximity effect was practically reduced with PEB compared to it without PEB. Figure 3 and Figure 4 show the obtained L&S pattern (line-width is 40nm, space-width is 45nm) nanoimprint mold with PEB at 300 °C and the replicated pattern. In spite of the large proximity effect compared to high-voltage EBL system, less than 50 nm L&S pattern NIL mold can fabricate using 4 kV EBL system with the anneal effect of PEB.

[1] K. Ishii et al., *Jpn. J. Appl. Phys.* **31** (1992) 744.

[2] A. Olkhovets et al., *J. Vac. Sci. Technol. B* **17** (1999) 1366.

[3] K.Ogino et al., *Microelectron. Eng.* **84**, 1071(2007)

[4] Noriyuki Unno et al., *J. Vac. Sci. Technol. B* **25** (2007) 2361.

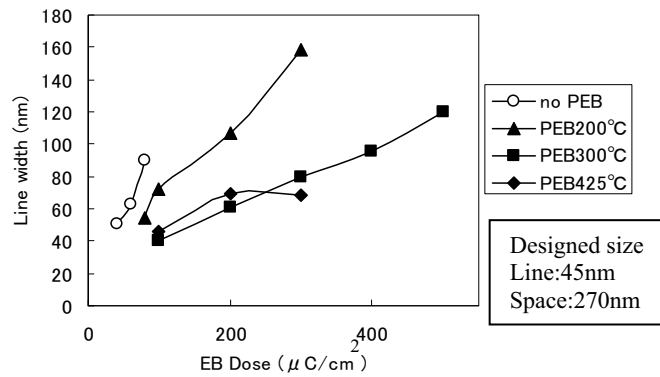


Fig 1: The characteristic of line width in various PEB temperatures at 4 kV.

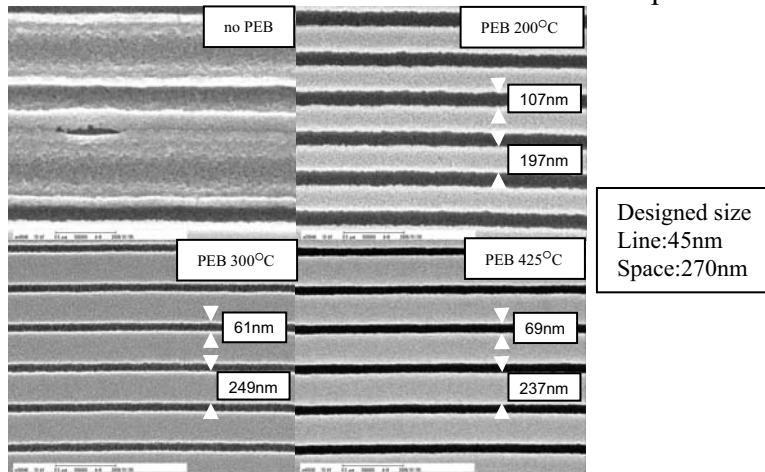


Fig 2: SEM images of the relativity of L&S pattern and PEB temperature.

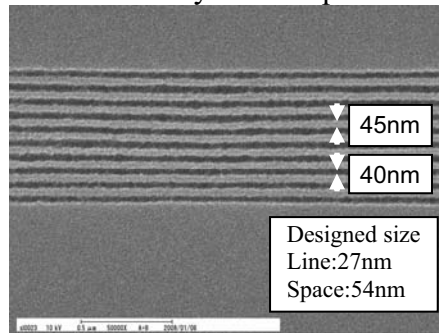


Fig 3: SEM image of L&S pattern mold using $200\mu\text{C}/\text{cm}^2$ EB dose at 4 kV.

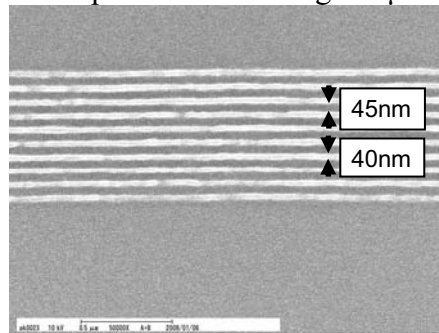


Fig 4: SEM image of replicated pattern using ultraviolet-NIL.