# Sub-100nm three-dimensional nano imprint lithography

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Low acceleration voltage electron beam lithography (EBL) system is desired because of higher sensitivity and less expensive of equipment. Low acceleration voltage EBL system is also useful for fabrication of three-dimensional (3D) nano imprint lithography (NIL) mold, since irruption depth of electrons depends on acceleration voltage [1]. Inorganic resists are desired because of resolution. Organic resists are too high sensitivity and large molecular size to delineate fine line and space (L&S) pattern. Though various inorganic resist were reported [2], they are not enough throughput because of low sensitivity. Therefore, Accuglass 512B (made by Honeywell Co., Ltd.), which is a kind of Spin-On-Glass (SOG) materials, was used for positive tone EB resist.

At first, SOG was spin-coated on a Si substrate and pre-baked at 425°C for 1hour resulting in a 450nm film. Then, ERA-8800FE (ELIONIX Co.) was used for EBL system with several pA of beam current and about 10 nm beam diameter. A buffered hydrofluoric acid (BHF) solution was used for developer and developing time was 2 minutes. Our previous report showed that developed depth of standoff line pattern (line width > 100 nm) was able to be controlled by changing acceleration voltages [1], so 3D NIL mold was able to be fabricated by this process. The replicated pattern was obtained by UV-NIL with photo-curable resin PAK-01 (made by Toyo Gosei Co., Ltd.)

This research was aimed at control of developed depth in finer pattern (line width < 100 nm) by optimized acceleration voltage, EB dose and designed value of L & S width. At first, finer standoff line pattern was delineated at various low acceleration voltages (1~2 kV) and then developed depth was controlled. Next, the characteristics of line width in fine L&S pattern were investigated at 2 kV. Using optimized EB dose and designed L&S pattern, the finest L&S pattern was delineated and imprinted.

Finer standoff line pattern is shown in Fig. 1. Widths of lines were around 50nm. Fig. 1 shows that controlled developed depth in finer pattern by changing acceleration voltages. Fig. 2 shows that the dose dependence of the enlargement ratio (observed value / designed value) at various L & S pattern. Line width depended on EB dose and finer line width tended to have large enlargement ratio because of forward electron scattering. The finest L & S pattern is shown in Fig. 3, which was delineated at 2kV, 200μC/$cm^2$. Line width is 80nm, space width is 140nm. Imprinted finest L&S pattern which used this mold is shown in Fig. 4 and imprinted patterns corresponded to mold designs.

[1] Jun Taniguchi et al., Appl. Sur. Science 238 (2004) 324
[2] J. Fujita et al., Appl. Phys. Lett. 66 (22)

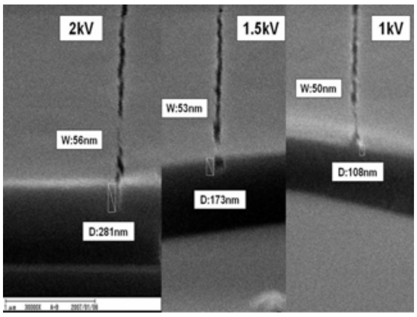


*Fig 1*: Control of acceleration voltage electron beam lithography.

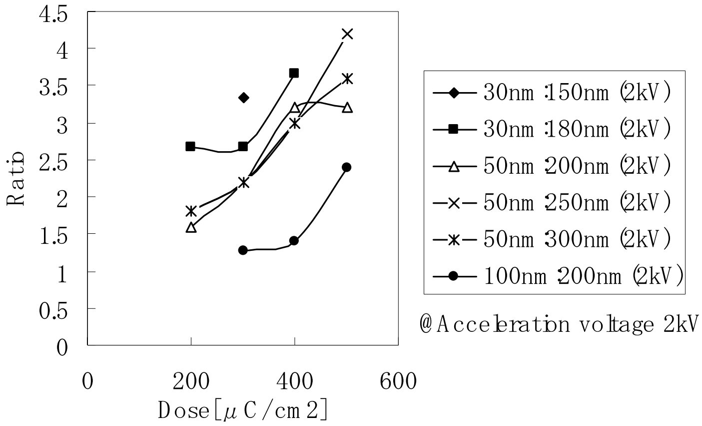


*Fig 2*: The characteristic of line width in various L&S patterns.

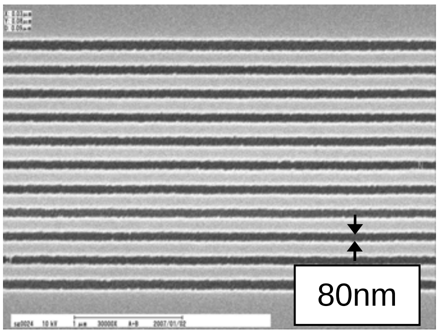


*Fig 3*:SEM image of L&S pattern mold at using 200μC/$cm^2$ EB dose.

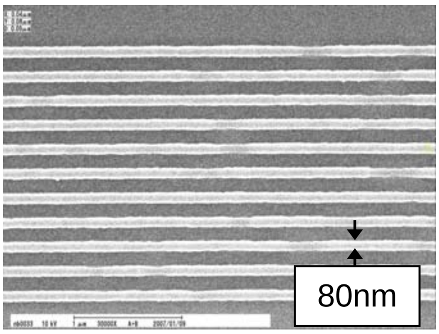


*Fig 4*:SEM image of replicated pattern on photo-curable resin.