Sub-10-nm pattern transfer and nanoimprint molds.

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The trend towards miniaturization of devices makes high-resolution pattern transfer a necessity, despite this it remains a challenge to fabricate sub-10nm arbitrary pattern nanoimprint molds. Nanoimprint lithography is capable of high-throughput, low cost and high resolution, but it relies on other techniques, such as molecular beam epitaxy (MBE) followed by selective wet etching, to fabricate sub-10-nm molds[1]. These techniques are typically limited in flexibility of pattern design, permitting, for example, only simple periodic linear patterns to be formed. Electron-beam lithography (EBL), on the other hand, is capable of arbitrary pattern design, but the ultimate feature density is generally limited by proximity effects. We have addressed this challenge by using a high contrast EBL process and reactive ion etching (RIE).

The EBL processing was carried out using a Raith 150 tool with negative-tone hydrogen silsesquioxane (HSQ) resist and a salty developer technique[2]. The patterns were then either directly used as a mold for nanoimprint, or their aspect ratio was first increased by pattern transfer into silicon using reactive-ion etching (RIE) with a hydrogen bromide plasma. By optimizing the process conditions, the hydrogen bromide plasma shows a high selectivity between the HSQ hard mask and the silicon. Fig. 1 (a) shows a scanning electron micrograph of a nested-"L" pattern, transferred 130nm deep into silicon with 10nm line-width and 30nm pitch. This demonstration was accomplished by curing the resist prior to etching, removing surface oxide/resist scum using a short, high-voltage etch, and by careful control of the parameters during the etch.

Fig. 1 (b) shows a scanning-electron micrograph of a 25nm pitch dot/line pattern array nanoimprinted into imprint resist using a UV cure wafer bow system[3].These results demonstrate the practicality of processing and pattern-transfer of dense, arbitrary patterns into silicon at the sub-15-nm, and even in some cases at the sub-10-nm scale.

[1] M. D. Austin *et al*, Nanotechnology **16**, 1058 (2005)
[2] J. K. W. Yang, K. K. Berggren, J. Vac. Sci. and Technol. B **25**(6), 2025 (2007)
[3] W. Wu *et al*, Nano Lett. **8**(11), 3865 (2008)

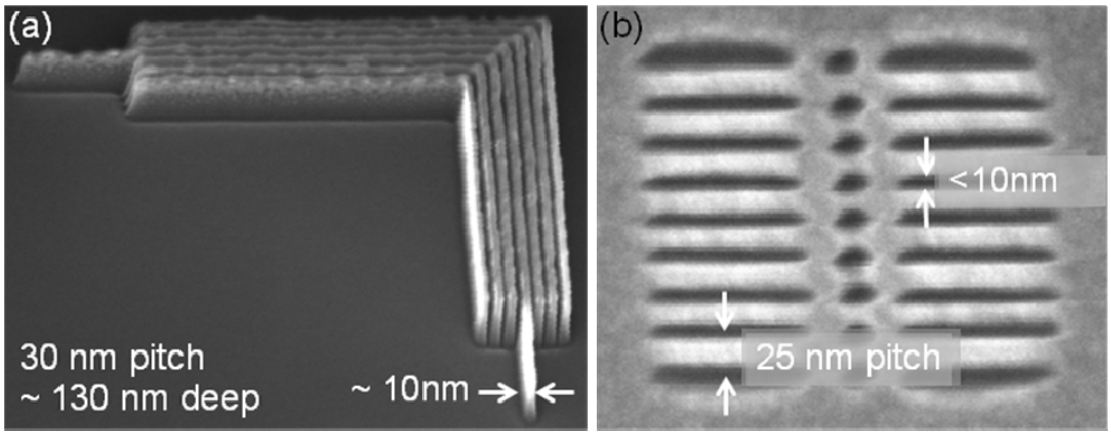

Figure 1. Scanning-electron microscopy images of (a) angled view (45 deg) of 30-nm pitch nested-"L" pattern, transferred 130 nm deep into the silicon substrate using RIE with a HBr plasma, (b) dot/line pattern array imprinted into nanoimprint resist with 2 nm-thick Au/Pd layer added for imaging.