Quantized-Patterning Using Nanoimprinted-Blanks

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Scanning beam lithography (SBL, e.g. EBL) is the work-horse for directly converting designs from a computer CAD file to actual patterns on a substrate. Since it writes in a point-by-point serial manner, SBL has a low throughput and hence is mainly used in making masks for high-throughput pattern duplication methods (e.g. photolithography, EUV, nanoimprint. etc). To remove the low throughput bottleneck, Pease et al proposed and demonstrated "quantum lithography" (QL), a path-changing approach to SBL [1]. In QL, an electron beam itself does not delineate the exact pattern, but rather "tags" certain tiles on a substrate blank that is fully covered with a tile array (the tile array pitch determines the minimum feature size of lithography). QL not only can increase the writing throughput by orders of magnitude, but also can eliminate proximity effects and greatly enhance the precisions of pattern feature and position.

However, a major obstacle in the implementation of QL has been the lack of a low-cost high-throughput method to create the blanks with pre-patterned tile arrays. Here, we report and demonstrate quantum-patterning/lithography using nanoimprinted-blanks (QUN). The wafer-scale blanks fully covered with a square-tile array were fabricated by nanoimprint, etching, and material lift-off. The wafer-scale square-tile-array nanoimprint mold was generated by two cycles of nanoimprint and processing with a grating mold. The tile-array molds were further improved using various technologies, including a self-perfection step to reduce the edge roughness to sub-1 nm. The fabrication of the blanks with square tile array of 200 nm pitch (50 nm node for 4X mask), and sub-9 nm gap and quantized writing of arbitrary patterns on such blanks have been demonstrated. A writing time of 10 X faster than conventional EBL has been achieved. QUN has been used to make nanoimprint molds with arbitrary features. Several ways to scale down the QUN tile size and their advantages in high - throughput writing, as well as pattern feature and position accuracy were studied and will be presented.

[1] Maluf, N.I. and R.F.W. Pease, *Quantum Lithography.* Journal of Vacuum Science & Technology B, 1991. **9**(6): p. 2986-2991

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