Stitching periodic submicron fringes by utilizing step-and-align interference lithography (SAIL)

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Optical interference lithography is one of the most powerful techniques to fabricate large-area periodic submicron patterns. It has been reported that two coherent expanded spherical waves could lead to large-area interference fringes on a substrate with one exposure[1], and scanning two small coherent beams on a substrate could also generate a large-area submicron pattern[2]. This paper demonstrates a method to form continuous submicron gratings by exposing successively a unit area filled with interference fringes. Two neighboring exposed areas were stitched together by utilizing step-and-align interference lithography (SAIL) to yield seamless gratings.

The SAIL system was consisted of a vertical two-beam interference lithography module and precision dual-actuator motion stages orientated by displacement interferometers, making large-area 2D submicron patterning possible. An Ar^+ laser operating at 363.8 nm was used as exposure light source. A beam shaper could be used to convert a Gaussian beam to a uniform beam with designated shape such as square or triangle[3] before two-beam interference. Here as an illustration, we used a thin stainless steel mask with a square transparent zone (8 x 8 mm^2) to serve as beam shaper and to intercept the central flat-top region of an expanded Gaussian beam to produce quasi uniform square beam. Two beams with such shape were optically interfered and proximity printed on a Si wafer coated with photoresist (PR) to form a unit of submicron pattern. Then after each exposure the Si wafer would be positioned accurately by the dual-actuator motion stages to the next zone to be stitched together. The positioning precision was in-situ measured and adjusted by three displacement interferometers (X, Y, and Yaw angle).

Figure 1 shows the photographs of the gratings on 4” Si wafers with different stitching directions. The grating structures at different positions after dry etching are shown in Fig. 2. There were different duty cycles at different regions. Since the intensity of the exposure beam was quasi uniform, the dosage would be doubled at the stitching area and the structures with positive PR would become thinner. Thus the linewidths of gratings in stitching regions transformed to Si wafers were also smaller than those in only one exposure areas. The results illustrate that the seamless gratings could be obtained by our SAIL system.

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References

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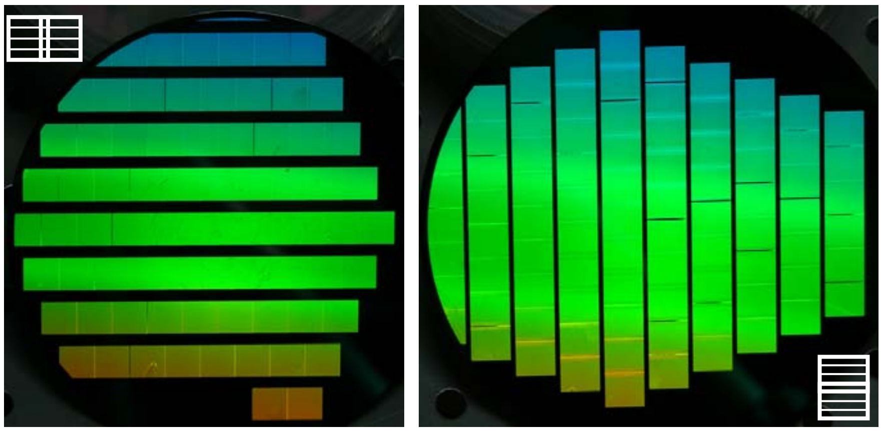
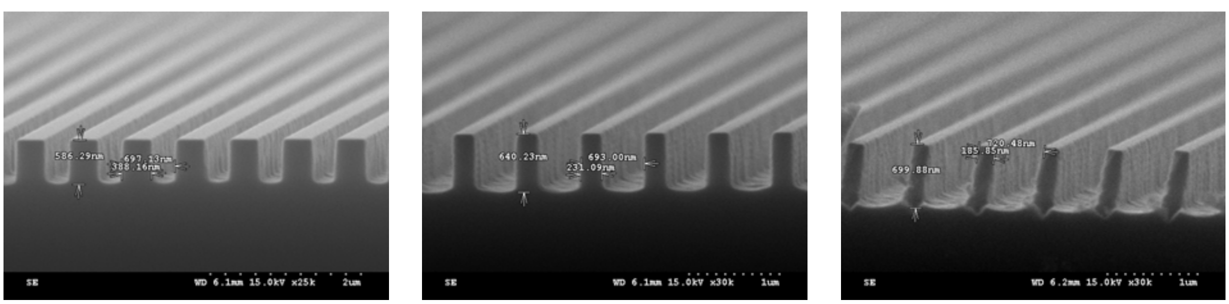


Fig. 1 Photographs show continuous submicron gratings (period 690 nm) over 4-inch Si wafers. The stitching directions are vertical (left) and horizontal (right) to the k-vector of the gratings



(a) (b) (c)

Fig. 2 Micrographs show the Si gratings at different regions after dry etching. (a) single exposure area; (b) single exposure area plus one DC intensity owing to the blocking of one oblique beam at the edge; (c) stitching region with double interference intensity.