Demonstration of Full 4-inch Patterning with Displacement Talbot Lithography

Christian Dais[1], Francis Clube[1], Harun Solak[1], Kimio Itoh[2], Yukio Taniguchi[2], Morihisa Hoga[2]

[1] Eulitha AG, 5232 Villigen PSI, SWITZERLAND
Phone: +41 56 310 4279 email: christian.dais@eulitha.com

[2] Dai Nippon Printing Co., Ltd. 250-1, Wakashiba, Kashiwa-shi, Chiba-ken
277-0871, JAPAN

A growing number of photonic applications require patterning of large areas with periodic structures. Examples are antireflection structures and 2D photonic crystals for enhancement of light extraction from light emitting diodes. Displacement Talbot Lithography (DTL) has recently been introduced as a new method for meeting these needs [1]. It is based on the Talbot effect in which a mask carrying a periodic pattern is illuminated with a collimated beam of monochromatic light. Self-images of the pattern are formed in the transmitted light-field behind the mask. The Talbot effect has been the subject of many studies but the limited depth of field (DOF) of the self-images severely limits its practical application in lithography.

The new aspect that is introduced in the DTL method is a movement of the substrate towards the mask during the exposure. Moving the substrate by one Talbot period prints an average image that is free of the DOF limitation. Experimental trials and electromagnetic simulations have shown the method generates high contrast images. Many applications that stand to benefit from the DTL method require uniform patterns over large areas. Here we demonstrate the successful patterning of 4" wafers in a single exposure step with DTL.

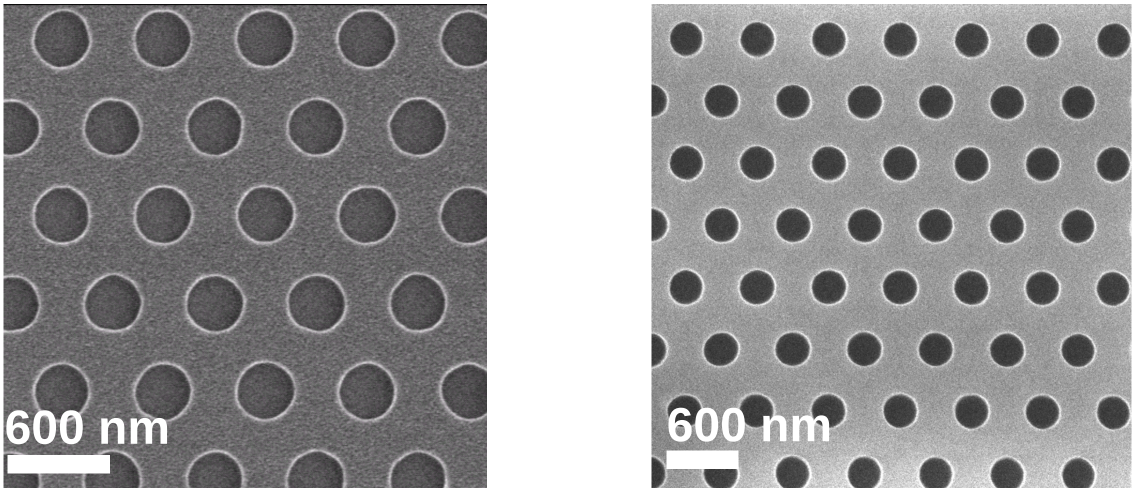
The masks used for the DTL exposure are of the conventional Cr-on-quartz type. For full-field patterning of a 4-inch wafer, the mask pattern also needs to be 4"-diameter. Therefore a method that has both high-resolution and high-speed is needed for the manufacturing of the mask. This was accomplished with laser writing. The mask pattern consisted of 320 nm diameter holes on a 600 nm period hexagonal grid (Fig 1a).

The mask was introduced in a PHABLE exposure system designed for the DTL technique. Patterns were printed into a standard UV photoresist coated on 4” silicon wafers. The wafers were positioned in proximity to the mask and the gap was changed by one Talbot period during the exposure. An SEM image of the pattern printed in the photoresist is shown in Fig 1b. In many cases the separation between the mask and wafer was measured to vary by many microns over the pattern area due to non-flatness of the used wafers. In spite of this uneven gap high-resolution patterns were printed very uniformly over the 4" wafer area, as illustrated by the photograph in Fig. 2. This demonstrates the very large DOF of DTL imaging.

This results show the practical achievement of high resolution patterning over 4” wafers without the requirement of precise alignment and gap setting in a proximity arrangement. We expect this new technology to be readily extendable to the patterning of even larger wafers, e.g. 6” or 8”. Laser writing is shown to be an effective method for producing the large-area masks required.

References:

1. H. H. Solak, C. Dais, F. Clube, MNC 2010, 23rd International Microprocesses and Nanotechnology Conference, November 9-12, 2010, Fukuoka, Japan.



Mask pattern (a) **Obtained pattern in photoresist** (b)

Figure 1 (a) SEM image of the mask pattern employed for the DTL exposure, which consists of 320 nm-diameter holes in a Cr film. (b) Result of the DTL exposure. SEM image of the pattern obtained in photoresist film after development.

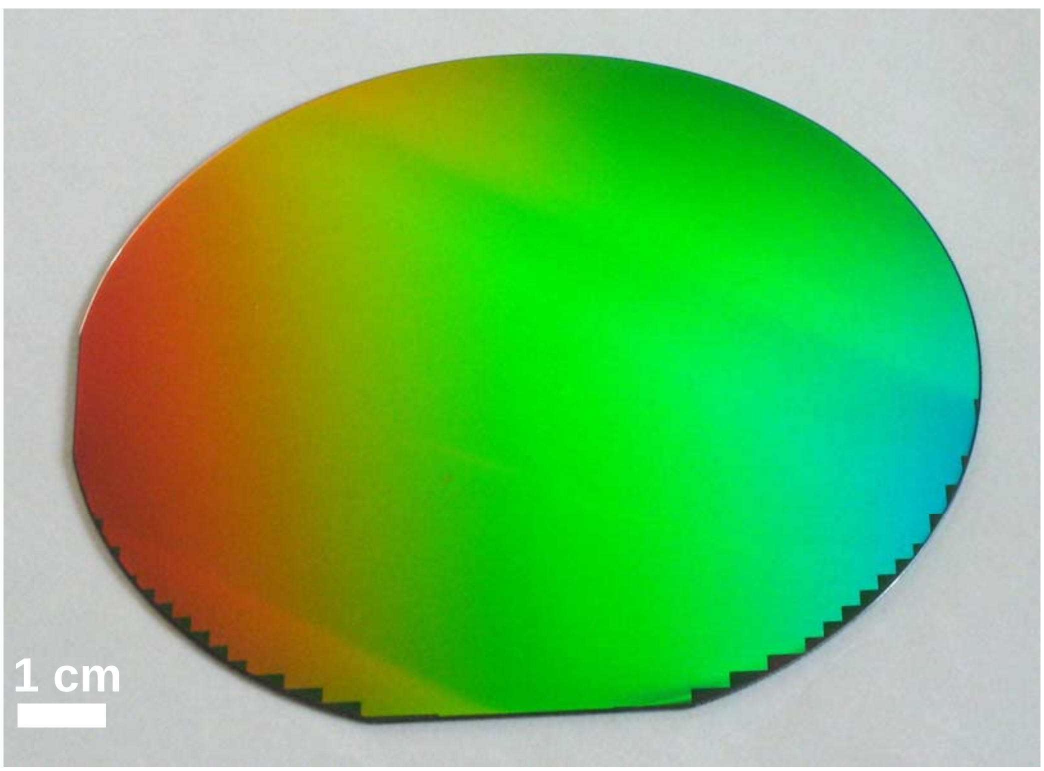


Figure 2 Photograph of a 4-inch wafer uniformly patterned with the DTL technique.