High density submicron features using a laser pattern generator and double patterning

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Line and space patterns with periods ranging from 1.0 μm to 1.5 μm have numerous applications such as optical gratings, nanofluidic channels, and interdigitated electrodes. However, laser diode-based optical pattern generators typically achieve a minimum isolated feature size of about 0.6 to 0.8 um; the proximity effect in high density line and space patterns decreases the spatial resolution further, making it practically impossible to write gratings with a pitches less than 1.5 um in a single exposure [1]. To define gratings in the 1.0 to 1.5 um range with direct–write optical techniques, both careful measurement of the energy profile and advanced lithography techniques are required.

In the present work, the spatial distribution of energy absorbed in photoresist of a 405 nm wavelength diode laser in a Heidelberg DWL66 pattern generator has been measured using the method described in Reference [2]. Fig. 1 shows the results of the measured energy distribution of a spot and a Gaussian fit to the data. The figure also shows the expected exposure distribution of various gratings based on the single line distribution. The solid horizontal line represents a threshold level of a photoresist; the smaller pitch gratings show diminishing contrast.

Test patterns were written using standard low reflection Cr mask plates coated with 500 nm thick AZ1500 series resist. Fig. 2 shows 3 line and space patterns developed in photoresist. The nominal line width in each is 1.0 μm. The measured line width increases as the density of the pattern increases until the lines completely overlap at 1.6 μm pitch. This response follows the trends shown in Fig. 1.

To achieve submicron line width for patterns with periods below 1.5 um, the double patterning technique, litho-etch, litho-etch was employed [3]. First, a layer with alignment marks and a grating with a period two times larger than that required was patterned in photoresist and dry etched into the wafer. Second, the wafer was recoated with photoresist, exposed and etched again with the new pattern offset to the first layer. The direct writing method also allows this approach to be extended for two arbitrary shaped patterns with submicron features.

An example of a grating fabricated with this technique is shown in Figure.3. Alignment accuracy in this case was better than 50 nm which allows us to print lines as narrow as 400 nm and a combined grating period of 1.4 μm.

1. G. Lullo, R. Leto, M.Olivia, C. Arnone, *Laser Beam Shaping VII*, **6290**, edited by Fred M. Dickey, David L. Shealy, Proc.of SPIE Vol. 6290, 62900A, (2006).
2. S. Babin, *Optical Microlithography IX*, edited by G. E. Fuller, Proc. of SPIE Vol. **2726**, 859-865 (1996).
3. J. Finders, et al., *Optical Microlithography XXI*, edited by Harry J. Levinson, Mircea V. Dusa, Proc. of SPIE Vol. **6924**, 692408, (2008).

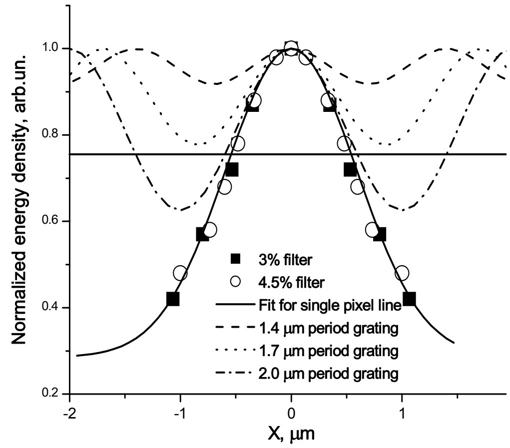

Fig.1 Absorbed energy density profiles: symbols represent experimental data, lines calculated profiles.

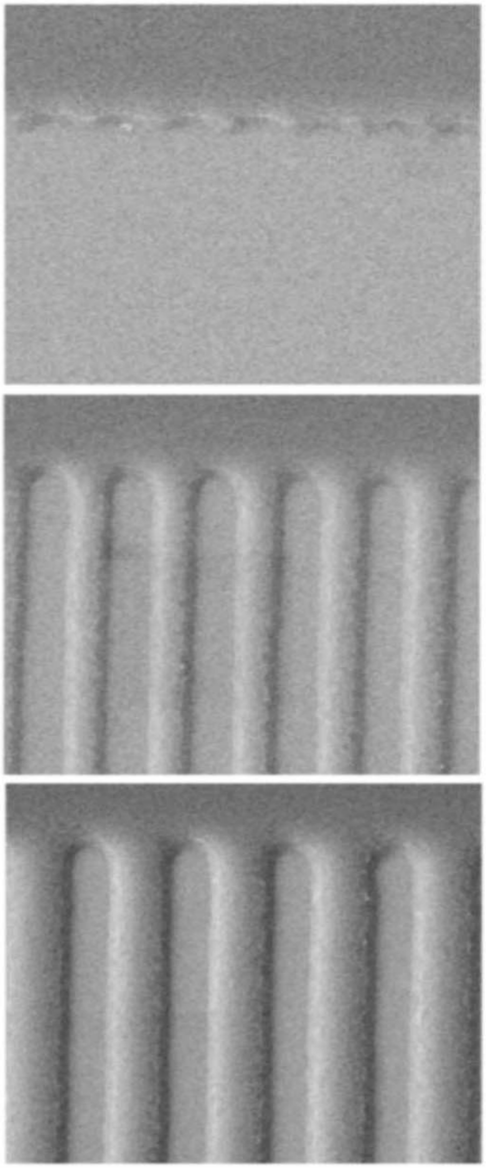

Fig.2. An SEM image of gratings with periods of 1.6, 2.0, and 2.4 µm from top to bottom. During the exposures the dose was set at the level marked on Fig.2 with solid line.

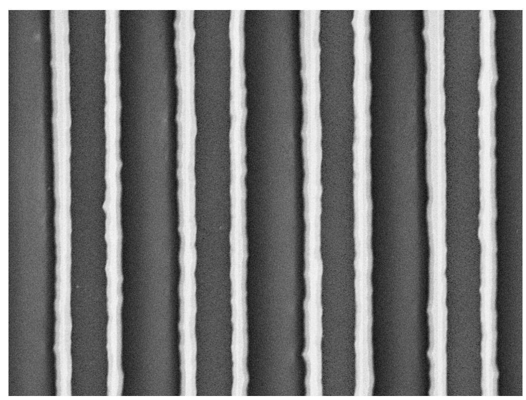

Fig.3 Two 2.8 µm period gratings superimposed using the litho-etch-litho-etch procedure. Lines were dry etched into a 110 nm thick Cr layer creating 0.4 µm Cr stripes (bright features) and a final 1.4 µm pitch.