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A Phase Shifting Technique for Ultrahigh Resolution Deep-UV Lithography

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Abstract

Optical lithography at 193 nm using phase shifting masks is a promising technique for the fabrication of high density integrated circuits, in particular the new generation of 256 Mbit and 1 Gbit DRAM's. In recent years, several phase shifting methods have been proposed to extend the resolution limit and contrast of image patterns. However, fabrication of phase shifting masks is more difficult as the wavelength decreases: (a) it is hard to find appropriate phase shifting materials which do not absorb strongly at 193 nm, (b) the required tolerances for the appropriate phase shifting materials become tighter as the wavelength is decreased, and (c) masks become even more difficult to evaluate and repair.

To address these issues a novel technique based on an interferometric phase shifting technique was developed and combined with off-axis illumination. A single layer chrome mask (with line-space patterns) deposited on a fused silica substrate was illuminated symmetrically from both sides. Experiments show that for the correct phase and intensity conditions between the front and back illumination, the contrast of the image can be improved as compared to simple off-axis illumination. The depth of field (DOF) of the image is also significantly improved. This approach is a convenient test bed for designing phase shifting masks that can be used at 193 nm.

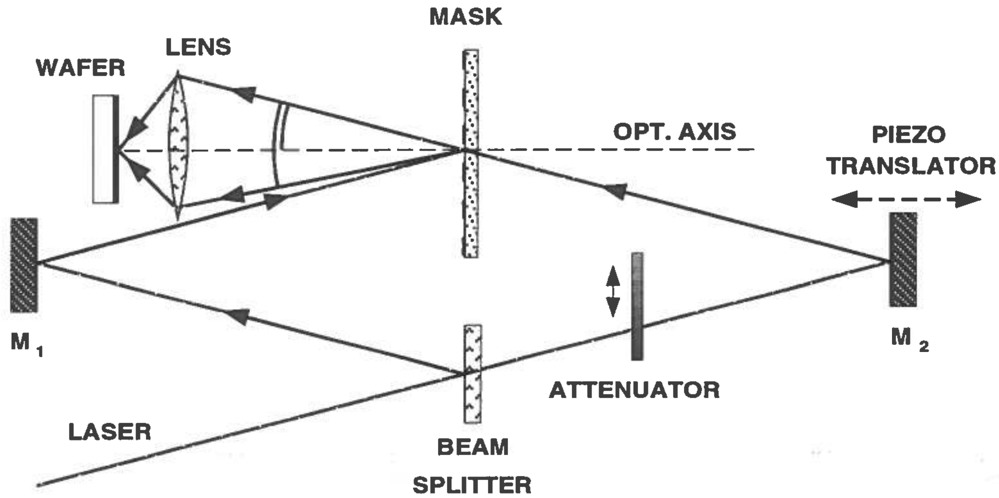

Figure 1. Scheme for off-axis illumination combined with interferometric phase shifting. The mask is illuminated symmetrically from both sides with a beam splitter and two (M1, M2) mirrors. The phase difference between the two beams and amplitude of the beam coming from the back can be adjusted by a piezo-controlled linear translator and a variable attenuator, respectively. The lens collects only the zero and first order diffracted beams, and produces an image of the mask on the wafer.

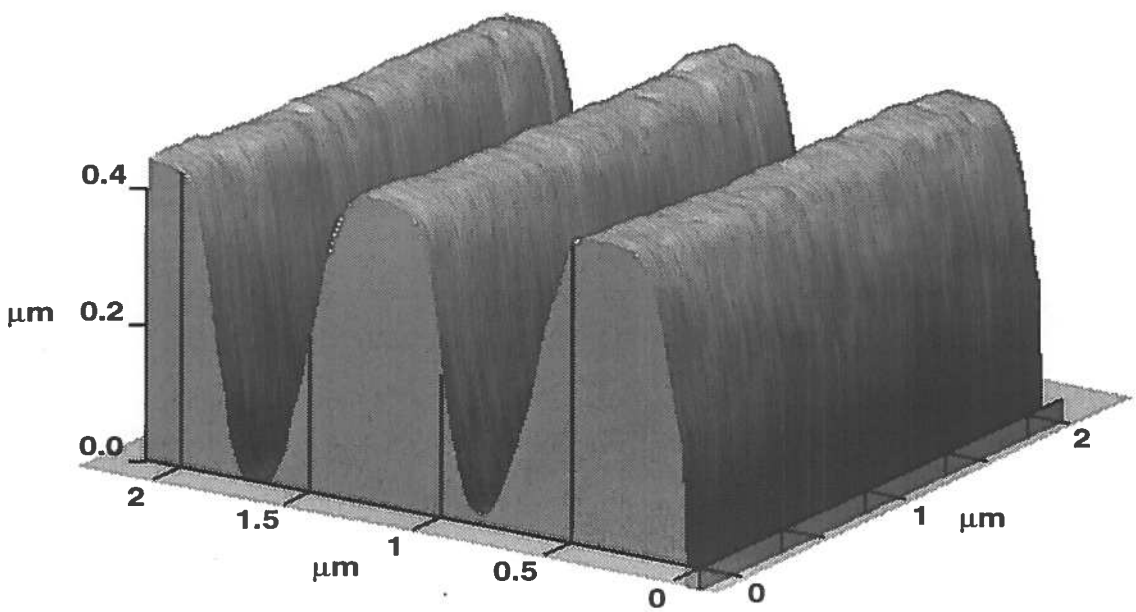

Figure 2. AFM photograph of line-space patterns produced on the photoresist. (photoresist: Shipley 94314, light source: 457.9 nm laser illumination)

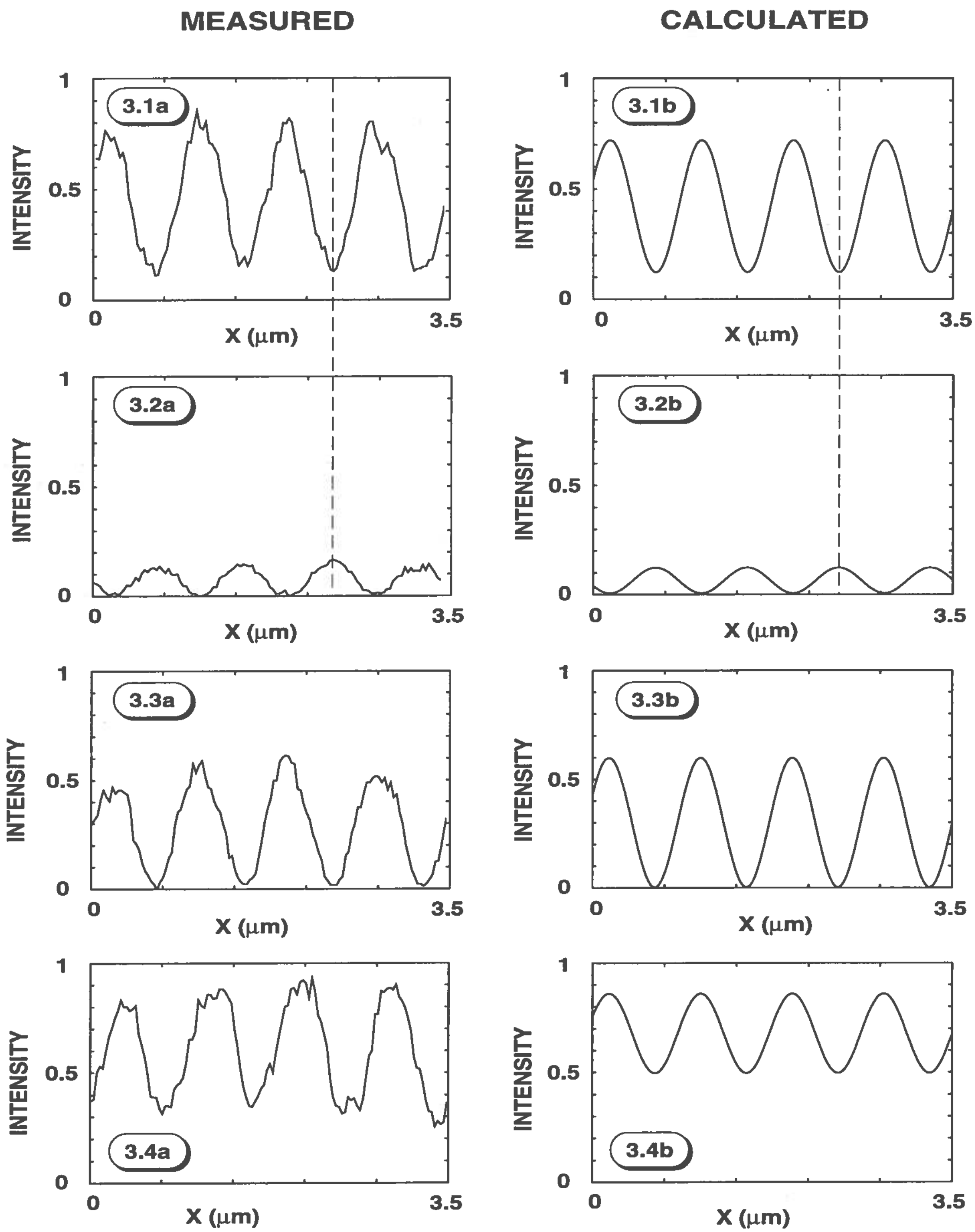

Figure 3. Intensity patterns on the photoresist. The (a) figures show the measured and the (b) figures show the calculated curves. 3.1: blocking the back illumination, 3.2: blocking the front illumination, 3.3: using both beams with 180° phase difference, 3.4: using both beams with 0° phase difference on the surface of the mask.

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Brief Biography

M. Erdelyi graduated from JATE University, Szeged, Hungary as a physicist in 1994. He joined the laser science group at Rice University upon graduation as a visiting research scientist. He is participating in the photolithography project that started in 1994 and involves faculty collaborators from Rice University, Texas Instrument and faculty from JATE University. Mr. Erdelyi is investigating new optical wavefront engineering concepts applicable to subquarter micron technology.