Photomask Image Enhancement using Grating Generated Surface Waves

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In recent years, the anomalous transmission of sub-wavelength apertures has become an emergent subject within the physical sciences[1]. While the gain mechanism of these structures is still uncertain, the effect has been observed in several different studies[2]. The same type of transmission enhancement may be realized for near wavelength sized photomask structures by including buried grooves in a dual-write mask design. Simulations of designs using such buried grooves, referred to as Evanescent Wave Assist Features, or EWAFs, have revealed both near and far field benefits, including increased intensity and contrast enhancement of the aerial image[3].

Initial investigations have concentrated on determining the magnitude of the enhancement, and determining which materials and conditions produce a maximum effect. Rigorous computer simulations of the near and far fields were used to determine optimum fabrication parameters. The use of gratings located at the interface between the mask substrate and the absorber with a pitch of λ/n and a duty ratio of 1:1 has resulted in the highest gain. The best absorber studied to date has been chromium oxide (Cr_2O_3). When used with a full wave grating depth, the chrome oxide absorber gives a near field intensity gain of 42% and a far field contrast enhancement of 27%[3].

In this paper, results are presented on the fabrication and testing of EWAF structures optimized so that surface waves enhance the final lithographic image. The features are fabricated in a fused silica substrate using a two layer e-beam writing strategy, combined with dry-etch pattern transfer into the substrate and the absorber. Testing of far field intensities from various features on the mask has been performed using a modified Woollam Variable Angle Spectroscopic Ellipsometer (VASE) in transmission mode, as well as lithographic evaluation in a commercial high NA scanner.

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1 For example H. J. Lezec and T. Thio, Optics express **12** (2004).

2 For example A. Nahata, R. A. Linke, T. Ishi, and K. Ohashi, Optics Letters **28**, 423 (2003).

3 N. V. Lafferty, J. Zhou, and B. W. Smith, in *Optical Microlithography XX*, edited by D. G. Flagello (SPIE, 2007).