Diffractive Optical Element Fabrication by Electron Beam Lithography

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Optical diffractive elements typically require sub-micron to nano-scale accuracy in fabrication. For surface structures with more complex three-dimensional geometries, such as gray-scale Damman gratings, electron beam lithography offers the necessary flexibility, control, and accuracy in fabrication. However, a challenge with electron beam lithography has been the difficulty in patterning large (~1mm by 1mm) areas with accurate field stitching and with minimal distortion.

In this work, we demonstrate techniques for defining convex or concave blazed surface diffraction gratings[1,2] with large areas. We explore both gray-scale lithography and digitally chirped graded index elements that require sub-micron to nanometer accuracy. Both of these geometries require careful depth control to optimize spectral performance and diffraction efficiency. We are using up to 5 micrometer thick poly-methylmethacrylate (PMMA) resist to form the gray-scale lithography defined diffractive optical elements. The patterned PMMA layer then serves as a substrate for a reflective layer. Gray-scale electron beam lithography is followed by the deposition of a reflective coating to form the optical structure. In this presentation, we will review the effects of dose and development conditions on the grating quality. Moreover, we show the opportunity to replication-mold diffractive optical devices from electron beam lithography-defined replication molds. Figure 1 shows the depth of exposure as a function of electron beam dose at 100 keV for 950K PMMA, whereas Figure 2 shows a 4x4 micro-lens array defined by electron beam lithography and subsequent replication molding.

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1. P. Mouroulis, F. T. Hartley, D. W. Wilson, V. E. White, A. Shori, S. Nguyen, M. Zhang, and M. Feldman, *Optics Express* **11** (3): 270-281 (2003).
2. P. Mouroulis, D. W. Wilson, P. D. Maker, and R. E. Muller, *Appl. Opt.* **37**, 7200-7208 (1998).

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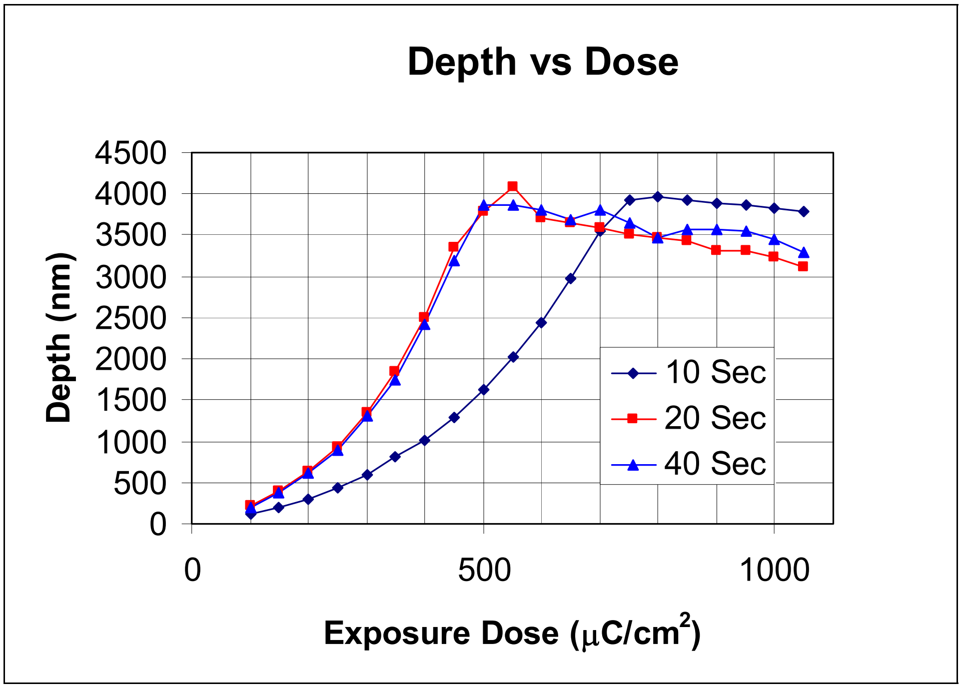

Figure 1. Depth profile of dose in gray-scale exposure for 5 μm thick PMMA on silicon for three different development times. The resist was developed in acetone at 20 °C, then dried with N_2. Depth profiles were made with a stylus profilometer.

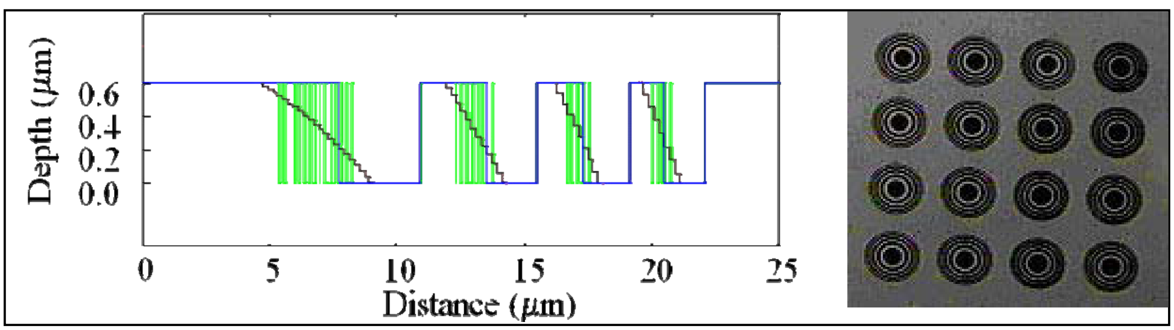

Figure 2. Replication-molded 4x4 lens array defined in polydimethyl siloxane (PDMS) by replication of an electron beam written lens master mold.