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A Prototype Commercial System for Massively-Parallel Maskless Zone-Plate-Array Lithography (ZPAL)

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Abstract

Exploding mask-set costs and scanner-prices have ensured that maskless lithography, even at moderate throughputs, will be essential to address the requirements of research, prototyping and low-volume manufacturing. Most of the development of maskless lithography tools has centered on scanning-electron-beam lithography, with single or multiple beams [1,2]. Throughput with a single electron beam is too low for many applications due to the serial writing. Multiple-beam systems, which are under development, are intended to solve this shortcoming [1,2]. In addition to the issue of throughput, electrons are sensitive to extraneous electromagnetic fields, and electrostatic fields due to charge buildup on substrates and system components. Although focused electron beams can pattern fine features, nanometer-level placement accuracy has been achieved only by employing spatial-phase locking [3], which is not presently available commercially, and is probably not feasible in multiple-beam systems.

Our approach to maskless lithography employs an array of 1000 or more focused optical beamlets [4]. This approach, which we call Zone-Plate-Array Lithography (ZPAL), uses an array of high-numerical-aperture zone plates to form the focused spots (see Fig. 1). An upstream micromechanical spatial-light modulator (SLM) controls the intensity within each beamlet. Substrates are scanned in the focal plane of the zone-plate array in synchrony with the data on the SLM, enabling patterns of complex geometry to be patterned in a dot-matrix fashion. Based on the ZPAL concept, a commercial system, the ZP-150™, has been designed with emphasis on combining flexibility with high-resolution and high-throughput in a low-cost optical maskless lithography tool for low-volume manufacturing and R&D.

In this presentation, we provide an overview of the ZP-150™ system design and present initial performance results. Using 405nm light, 0.85NA zone-plates, and with a sustained data rate over 320MB/sec, the ZP-150™ is capable of patterning dense features of 150nm half-pitch at a writing speed of over 1.7mm^2/s (equivalent to a 100mm-diameter wafer in 1 hour[1]). Higher throughput may be achieved at larger feature sizes, and via faster modulators. Design considerations related to achieving 15nm pattern-placement and overlay accuracy in a multi-beam system will be addressed. We also describe the design trade-offs in the motion-control, optics, and data-path, along with the prospects for future performance enhancements. Novel pattern-processing software, including optical-proximity-effect correction tailored to ZPAL's incoherent imaging, is shown to improve lithographic performance. Lithography results will showcase the ZP-150™ unique capabilities.

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[1] Assumes 80% coverage of wafer area.

References:

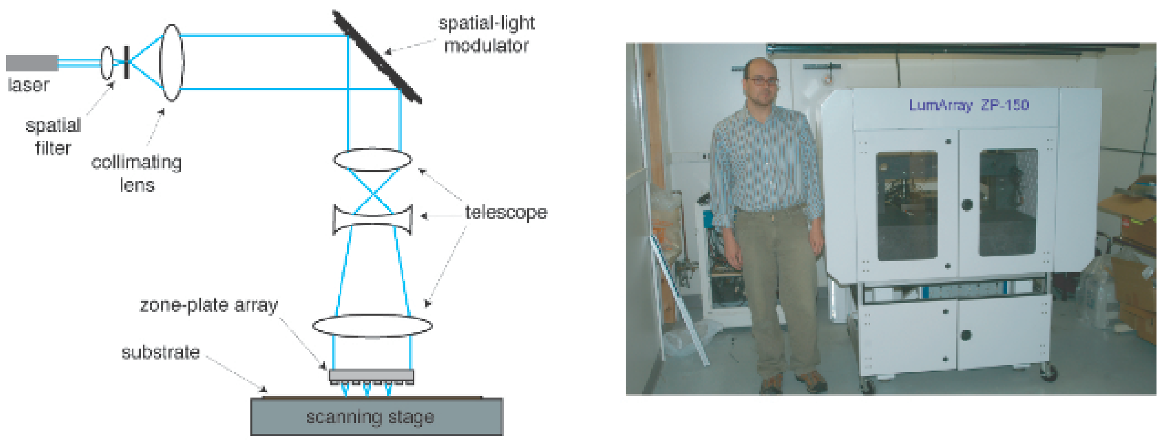
[1] http://www.mapperlithography.com/index.html

[2] < http://www.arradiance.com>

[3] J. T. Hastings, F. Zhang and H. I. Smith, "Nanometer-Level Stitching in Raster-Scanning E-Beam Lithography Using Spatial-Phase Locking," J. Vac. Sci. Technol. B **21**, 2650-2656 (2003); J. T. Hastings, To be published, J. Vac. Sci. Technol. B, Nov/Dec 2007.

[4] H. I. Smith, R. Menon, A. Patel, D. Chao, M. Walsh, and G. Barbastathis, "Zone-plate-array lithography: A low-cost complement or competitor to scanning-electron-beam lithography," Microelectronic Engineering, **vol. 83**, pp. 956-961 (2006).

Figures:



(a) (b)

Figure 1: *(a) Schematic of Zone-Plate-Array Lithography. (b) Photograph of the ZP-150™.*