Spatial-Phase-Locked Electron-Beam Lithography

Personnel

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Sponsorship

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Spatial-Phase-Locked Electron-Beam Lithography (SPLEBL) promises to reduce pattern-placement errors in electron-beam-lithography systems to the nanometer level. Such high precision is essential for a variety of future lithographic applications. SPLEBL is currently the only approach capable of achieving such accuracy. In SPLEBL, a low-level, periodic signal, derived from the interaction of the scanning e-beam with a fiducial grid on the substrate, is used to continuously track the position of the e-beam while patterns are being written. Any deviation of the beam from its intended location on the substrate is sensed, and corrections are fed back to the beam-control electronics to cancel errors in the beam's position. In this manner, the locations of patterns are directly registered to the fiducial grid on the substrate.

We are pursuing a variety of modes of SPLEBL including the real-time global-fiducial-grid mode, depicted in Figure 6, a quasi-real-time mode, sparse sampling, and the segmented-grid mode. The real-time, quasi-real-time, and sparse sampling modes require a fiducial grid that is nonperturbative. Our first choice for such a grid is to make it from a scintillating polymer, and to pattern the scintillator by bleaching in interference lithography. Our research on improving the scintillator output, signal-to-noise, and robustness is reported in another section.

Base-line evaluation of pattern-placement errors in the Raith 150 were carried out to evaluate the non-SPLEBL performance of the system. The best overlay was 1-sigma ~ 14 nm with 10 kV acceleration voltage. The best field stitching was 1-sigma ~ 8 nm with 20 kV acceleration voltage. The long-term drift of the e-beam relative to the substrate was measured to be less than 6 nm/min for a 60-minute interval. The focal stability was less than 1 µm variation during the same interval. These results clearly demonstrate the need for implementing spatial-phase locking.

Two measurement methods showed that intrafield distortion was less than 15 nm for a 100 um sized field. The distortion was found to be maximum along two field boundaries. Nonlinearity of the deflection amplifiers is suspected to be the cause.

Custom-designed light-collecting optics and a photomultiplier were installed on the Raith 150 e-beam system for detecting the light emanating from the scintillating fiducial grid.

The segmented-grid mode of SPLEBL was implemented on the Raith 150. In this mode metallic outrigger gratings were used to provide strong signals for locking. These experiments showed the presence of a systematic intrafield patterning error caused by the Raith hardware. After compensating for this error, a placement precision of 1-sigma ~ 2 nm was achieved. This mode of SPLEBL is currently being used to pattern Mach-Zehnder integrated-optical channel-dropping filters.

Two approaches have been proposed for implementing quasi-real-time SPLEBL on the Raith 150. In one approach, the variable-sized aperture plate in the instrument will be used for dose modulation. For monitoring the grid at sub-exposure dose, a small aperture will be used. Once the beam is precisely locked to the grid, a large aperture will be selected for pattern exposure. Because we anticipate some shifting of the beam position in between these two aperture settings, we will likely build a software correction to compensate for the shift.

In the second quasi-real-time method, the beam will be scanned rapidly, i.e. a sub-exposure dose, across the sample for a single line, or set of lines. Once locked to the grid, the beam will be slowed to expose the desired pattern.

We are also investigating the use of voltage contrast for the fiducial grid. A thin film of Al would be evaporated over the e-beam resist, and on top of this a grid of a thin insulator such as S_iO_X would be formed by evaporation through a stencil mask. An electrical contact would be made to the Al film so that the energy of the secondary electrons emitted from the grid could be modulated. It is expected that this voltage contrast mode will provide high contrast using the in-lens detector of the Raith 150. Assuming the pattern of holes in the stencil mask is uniform, there should be negligible distortion. However, this issue remains to be investigated. If stencil distortion turns out to be a problem we will investigate the feasibility of direct ablation or deposition of an insulator in a standing wave of interference lithography.

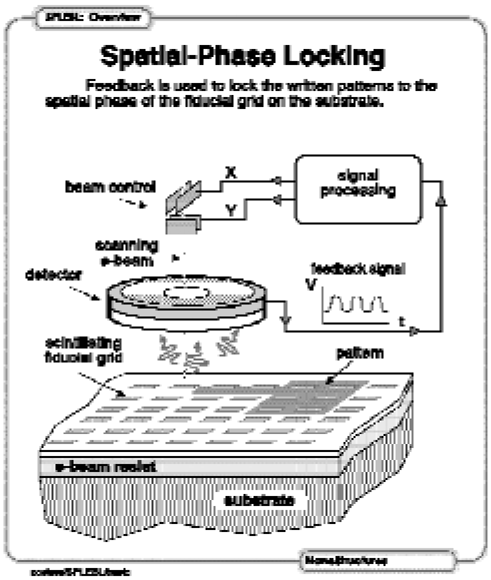

Fig. 6: Schematic of the global-fiducial-grid made of spatial-phase-locked electron-beam lithography. The periodic signal detected from the scintillating fiducial grid is used to measure placement error, and feed a correction signal back to the beam.