Measuring Field-Stitch Boundary Error of Electron Beam Lithography With X-ray Diffraction

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In many electron beam lithography (EBL) applications, including photonic waveguides and nanoscale gratings, a major limiting factor is field-stitch boundary error. This error occurs when design layouts are larger than a single writing field (often 500um-1mm) and thus, during exposure, multiple fields are stitched together with a stage movement between each field resulting in imperfect alignment between features in one field to the next.

With laser-interferometrically controlled stages and careful calibration of deflector and field distortions, this error can be minimized, but not compensated for completely. Additionally, advanced exposure strategies such as field overlapping or layout schemes can be used to further minimize the field-stitch error. We have developed a new metrology procedure to help characterize the field-stitch boundary error of an EBL tool as well as the effectiveness of the various error-minimization strategies using synchrotron-based x-ray diffraction. X-ray diffraction measures the average structure in the illuminated X-ray spot. This makes this method a potentially quick and quantitative way to characterize the average field stitch with nanometer precision over a large area in one measurement, as opposed to taking multiple single-point measurements and averaging them together.

In the first part of the experiment, we have created a set of gratings with specified errors that simulate the field-stitch errors. Specifically, a series of 100 nm-pitch gratings of 1mmx1mm area are fabricated by electron beam lithography with a manufactured field stitch boundary error of varying size from 0 nm (no error) to 50 nm (maximum error) (figure 1). The gratings are then measured by x-ray diffraction at the X13B beamline at the National Synchrotron Light Source. Shown in figure 2, a beam of x rays of energy 12.1keV is incident on the sample and a typical diffraction pattern from the gratings is shown on the area detector. The long streaks are characteristic of scattering from a surface; the separation between the streaks is a measure of the 100nm spacing. With further analysis we correlate the magnitude of a specified stitching error with diffraction pattern intensities, giving some insight on the limitations and advantages of this method. We will present the results of the calibration and the measurement of the error for an EBL tool with and without various error-minimization schemes.

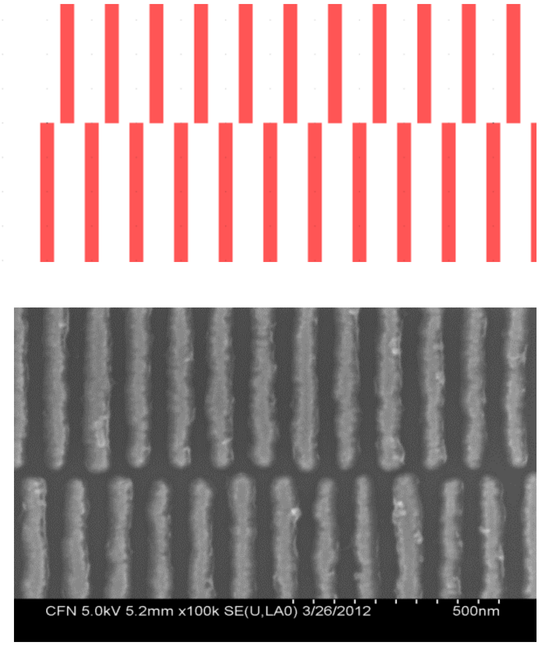

Figure 1. Designed grating with manufactured field stitch error (top). The actual 100nm-pitch grating fabricated with electron beam lithography and titanium lift-off. The grating is 1mm in area, written in a single field with 250um designed boundary errors.

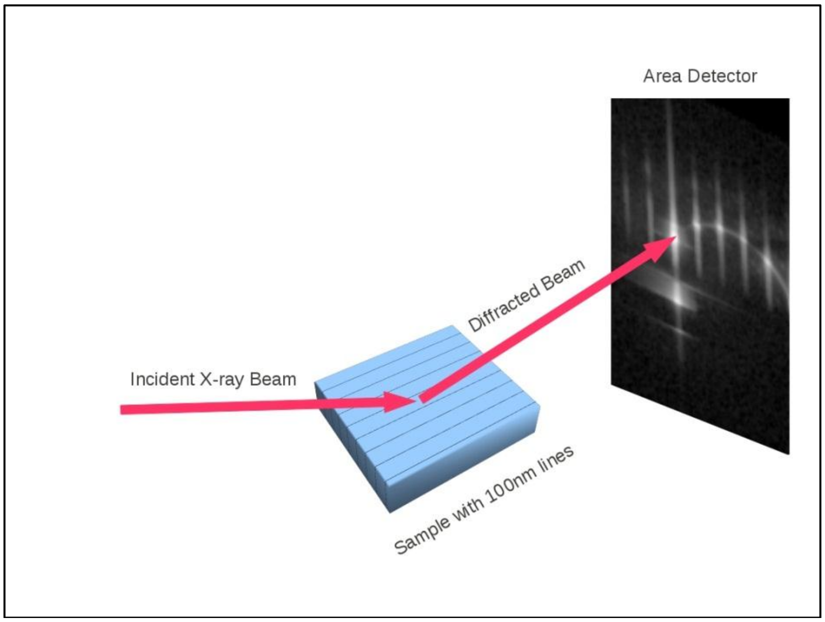

Figure 2. Schematic of the experiment. A beam of x rays of energy 12.1keV is incident on the sample and a typical diffraction pattern from the gratings is shown on the area detector. The long streaks are characteristic of scattering from a surface; the separation between the streaks is a measure of the 100nm spacing.