Stitch-Error Free Electron Beam Lithography of Periodic Structures

Jason E. Sanabia and Kevin Burcham
Raith USA, Inc., 2805 Veterans Highway, Suite 23, Ronkonkoma, NY 11779
js@raithusa.com

Michael Kahl and Ralf Jede
Raith GmbH, Konrad-Adenauer-Allee 8, Dortmund, 44263, Germany

Periodic structures are important for photonics and can be found in distributed feedback lasers (DFB), fiber Bragg gratings, optically variable devices (OVD), holograms, UV / x-ray optics, photonic crystals, and charge modulation in quantum cascade lasers. And, in the emerging field of plasmonics, there are examples of periodic structures in magnetoplasmonic crystals and sensors that employ extraordinary optical transmission. Vector scanning electron/ion beam lithography (EBL/IBL) can offer higher resolution and more flexibility for writing periodic structures over large areas, as compared to direct write laser lithography and optical interference lithography. The drawbacks of periodic patterning with conventional vector scanning EBL have been the stitching errors and overall throughput. Several groups have addressed the stitching error problem in vector scanning EBL by overlapping writing fields (also known as shot-shift or voting) and thereby smearing out the stitching errors.

Here we report a relatively straight-forward method for eliminating the stitching errors and increasing the throughput in the EBL of periodic micro and nano structures. The method is called modulated beam moving stage (MBMS) and is unique among commercially available EBL/IBL systems. In MBMS, the beam is periodically deflected in a 1-dimensional (1D) or 2-dimensional (2D) manner, while the laser interferometer stage moves the sample continuously over long distances. In conventional vector scanning lithography, the field distortions in a 2D writing field causes stitching errors. In MBMS, a 1D field can be used, making it easier to correct for field distortions in the 1D direction and eliminating field distortions in the orthogonal direction. Thus, MBMS can fabricate periodic structures with virtually no stitching errors in the direction of the stage motion. Furthermore, MBMS can enhance the throughput by making higher beam currents and larger writing fields accessible, and by eliminating the times associated with stage acceleration, stage deceleration, and settling times in conventional vector scanning lithography.

We show that MBMS produces the following stitch-error free structures: a 2 μm pitch grating written with high throughput over a 9 mm length (Figure 1), a demonstration by moiré effects of perfect sub-1 nm pitch control in 250 nm pitch gratings over a 1 mm length (Figure 2), an array 300 nm diameter circles over a 1 mm^2 area (Figure 3), a $\Lambda/4$ phase-shifted grating over a 1.5 mm length, and a linearly chirped grating where the period is varied at 0.1 nm resolution.

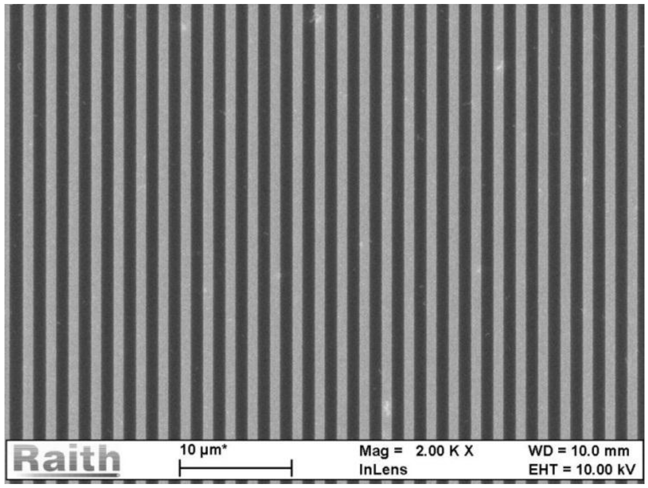

Figure 1 Scanning electron microscope image of a 2 μm pitch grating written at high throughput over a 9 mm length**.**

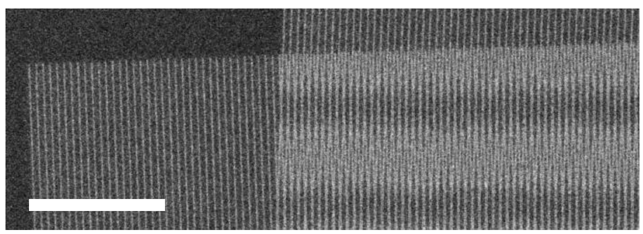

Figure 2 Scanning electron microscope image showing the moiré effect, which occurs when two gratings intersect. The scale bar is 5 μm.

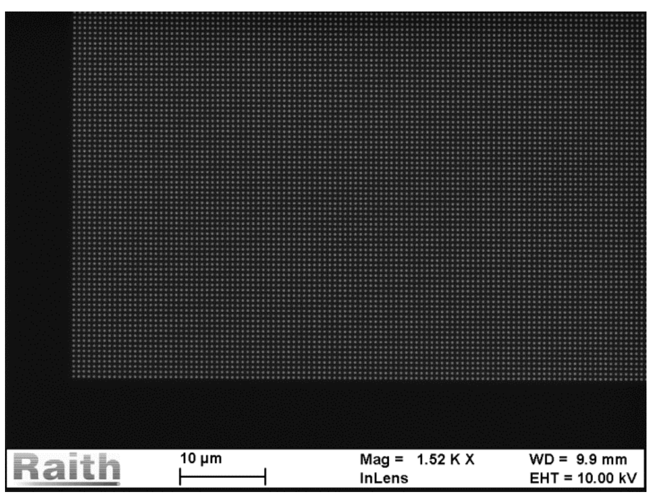

Figure 3 Scanning electron microscope image of an array of 300 nm diameter circles written over a 1 mm^2 area.