Creation of High Resolution Electron Diffraction Gratings using FIB and E-Beam Techniques

J. Pierce, C. Wright, T. Harvey, Benjamin McMorran
University of Oregon, 1371 E 13th Ave. Eugene OR
jpierce@uoregon.edu, cwright6@uoregon.edu

We have utilized FIB milling and EBL to create nanoscale phase gratings for producing predetermined electron wavefronts. Electron beams with specifically manufactured wavefronts are being studied for various potential applications. Many of these applications utilize only the first order diffracted beams and try to reduce the background noise produced by the zeroth order beam, which is usually much more intense than the diffracted beams. We are particularly interested in creating electron vortex beams to study the interaction of the OAM beam with matter.

Electron vortex beams have applications in high resolution dichroism[1] for magnetic domain imaging. For this and for most applications, the use of electron vortex beams requires diffractive optics (holograms) with high efficiency in the first diffraction order, since the zeroth order beam is usually either unnecessary or adds unwanted background noise. Using nanoscale diffraction gratings, laguerre-gaussian beams carrying up to 100ħ of orbital angular momentum have been created[2]. We have demonstrated phase grating with efficiency up to 150%.

We have created electron diffraction gratings for use in TEM experiments using both FIB milling and E-beam lithography to create sub 100 nm pitch gratings for making shaped STEM probes. We use Si3N4 membranes between 15 nm and 75 nm thick to hold the diffraction gratings, depending on the size and application of the grating. Our main concerns are diffraction efficiency and spatial coherence, followed by pitch and minimizing defects. The nature of the diffraction process dictates that the pitch of the gratings should be as small as possible. Using EBL with HafSOx inorganic resist we have achieved pitch width of 30 nm. We have also utilized E-beam platinum deposition on a Helios DualBeam to create sub 80 nm lines. Figure 1 shows a test pattern with slightly larger pitch that demonstrates the feature size achievable on the FIB.

Future direction is to use reactive ion etch in conjunction with EBL to improve diffraction efficiency while preserving resolution. We have also been exploring new ways of controlling and patterning with the FIB. Our hope with all of these improvements is to be able to use diffraction gratings in experiments in a TEM for the purpose of imaging novel techniques.

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[1] J. C. Idrobo and S. J Pennycook, Journal of Electron Microscopy 60(5): 295-300 (2011)

[2] B. J. McMorran et al., Science 331 (2011) 192.

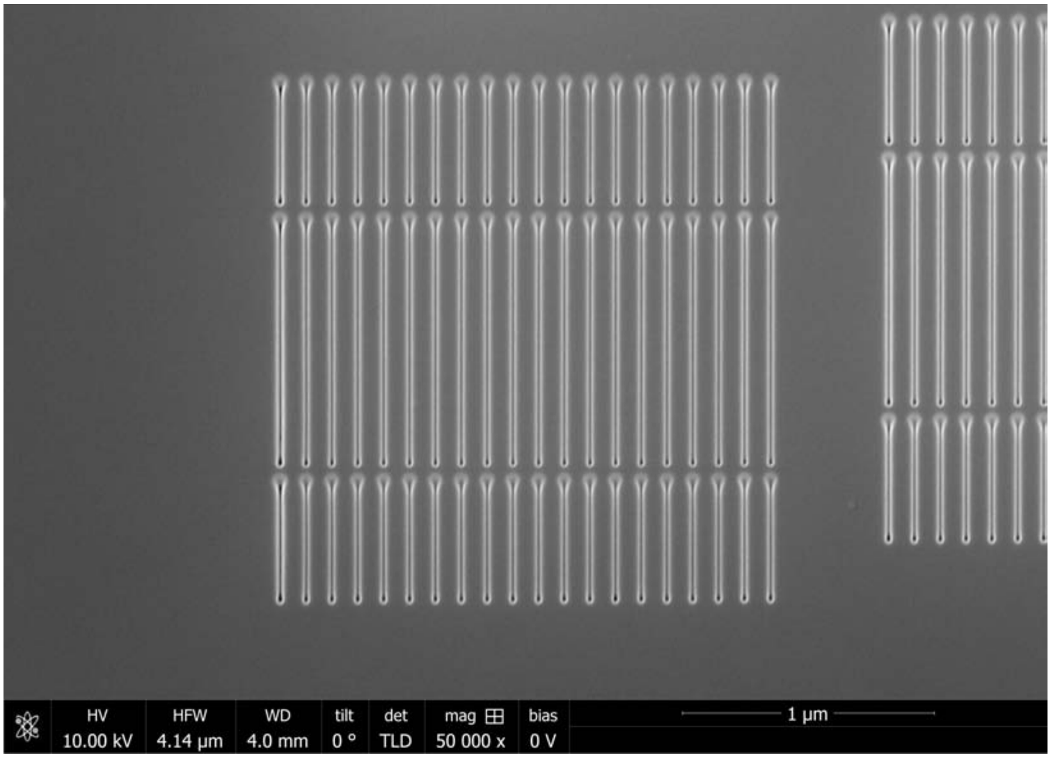

Figure 1: FIB milled grating with 100 nm pitch. This is a test grating to make sure the FIB is focused well. Feature size as been made at less that 70 nm on the FIB.