Small-Pitch Electron Diffraction Holograms
Patterned on Inorganic Resist with Electron Beam Lithography

Tyler Harvey and Ben McMorran
Department of Physics, University of Oregon, Eugene, OR 97403
trh@uoregon.edu

Gii Brougher and Kurt Langworthy
Center for Advanced Materials Characterization in Oregon, University of Oregon, Eugene, OR 97403

We have demonstrated electron diffraction through 20 nanometer pitch gratings. With the advent of electron vortex beams and the proposed application of vortex beams for a variety of new imaging techiques [4], the need has arisen for extremely small pitch, highly spatially coherent electron diffraction gratings to produce vortex beams [1,5]. Recently, we used focused ion beam (FIB) to mill diffraction gratings with a 60 nm pitch [5]. However, in order to produce well-separated beams for novel electron microscopy techniques, sub-50 nm pitch gratings will be necessary. In this work, we show that efficient electron diffraction grating structures may be produced by electron beam lithography (EBL) with negative inorganic resist on a silicon nitride membrane, even down to 20 nm pitch.

We have optimized diffraction efficiency by varying resist thickness and dose, producing inorganic structures with a 50% duty cycle and a height that induces a π-phase change in a 300 kV transmission electron microscope (TEM). These two parameters maximize the intensity of electrons with engineered wavefronts in the first diffraction order. We are particularly interested in "singular optic" holograms that produce electron vortex beams. We have tested a range of resist thicknesses and doses in order to maximize first-order diffraction and thus strengthen the detected signal in any vortex beam microscopy.

Examples of 50 nm and 20 nm gratings produced with EBL are shown in Figures 1 and 2. The corresponding electron diffraction patterns of these gratings were measured in a TEM (Figures 3-5). Using FIB, we have produced 60 nm pitch gratings that are spatially coherent over 50 μm. This nearly three order of magnitude difference between feature size and pattern size is necessary for the formation of isolated, intense, nanometer-sized scanned-beam electron microscopies (SEM and STEM). We expect that we will now be able to produce significantly larger patterns at a 20 nm pitch thanks to the much shorter patterning time and higher resolution of electron beam lithography.

[1] M. Uchida, and A. Tonomuram, Nature **464**, 737 (2010).
[2] J. Verbeeck, H. Tian, and P. Schattschneider, Nature **467**, 301 (2010).
[3] B. J. McMorran, A. Agrawal, I. M. Anderson, A. A. Herzing, H. J. Lezec, J. J. McClelland, and J. Unguris, Science **331**, 6014 (2011).
[4] P. Schattschneider, B. Schaffer, I. Ennen, and J. Verbeeck, Phys. Rev. B **85**, 134422 (2012).
[5] B. J. McMorran, T. R. Harvey, J. Perry-Houts, S. Cabrini, A. Agrawal and H. J. Lezec. P04-16. EIPBN 2012.

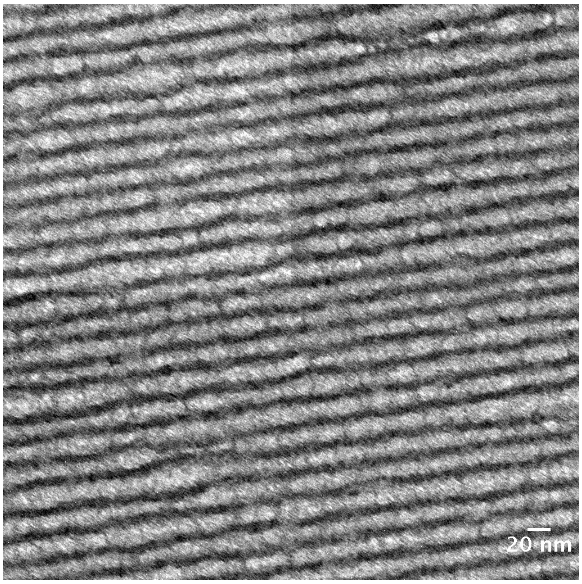

Figure 1: Transmission Electron Micrograph of 20 nm pitch electron diffraction grating.

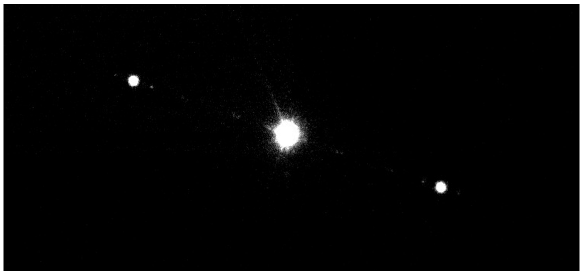

Figure 2: Low angle diffraction from the 20 nm pitch grating shown in Figure 1. Only the first diffraction orders are visible because the duty cycle of this grating is closer to 50%.

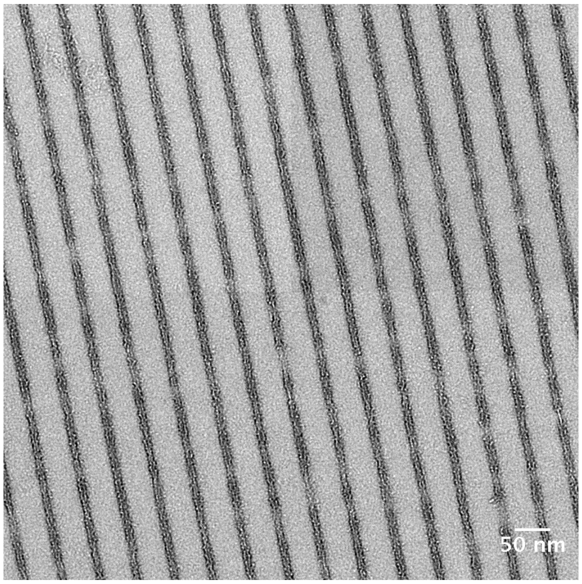

Figure 3: Micrograph of a 50 nm pitch electron diffraction grating.

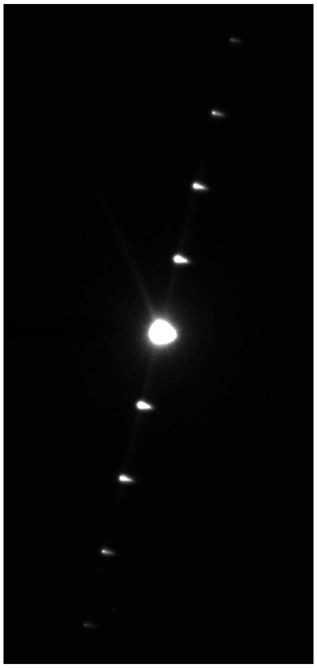

Figure 4: Diffraction from the 50 nm pitch grating shown in Figure 3. The first diffraction orders are more intense than in Figure 5 because the phase change through these inorganic resist structures was greater.

Figure 5: Diffraction from another 50 nm pitch grating which had a lower lithography exposure.