Visible subwavelength dielectric grating reflector fabricated using focused ion beam

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Polarized thin film mirror with high reflectivity and broadband characteristics for optoelectronic devices can be realized using subwavelength grating (SWG).[1] For nanoscale SWG, most of the out-of plane emission devices utilized electron beam lithography, however this technique is challenging for SWG fabrication on the facets of in-plane emission devices. Direct SWG patterning at facet of in-plane devices using focused ion beam (FIB) technique has been reported for antireflector in quantum cascade laser (QCL)[2] and plasmonic collimator for QCL[3], besides the subwavelength slit grating[4] for typical out-of plane emission case. However, these FIB patterned SWG are only demonstrated for III-V compounds and metallic based devices at infra-red spectrum. Here we propose SWG reflector fabrication using FIB technique on dielectric multilayers (Si_3N_4/SiO_2) using GaN-sapphire substrate at visible wavelength. We spin-coated electron dissipation polymer (ESPACER 300Z) on the sample surface to reduce the charging effect of the dielectrics, GaN and sapphire during milling.

Figure 1(a) and (b) show the top-view and cross-section SEM images for the fabricated dielectric SWG, respectively. The gratings formed are highly uniform with a sharp contrast indicating no charging effect during FIB milling. Based on the measured grating dimensions and angle sidewalls, we performed numerical simulation using rigorous coupled wave analysis (RCWA) method to investigate the reflectivity spectrum and electrical profile of the fabricated SWG reflector. Figure 2(a) shows the computed reflectivity spectrum for the fabricated SWG. It shows high reflectivity >99% at 425 nm for the TE-polarization while the TM-polarization is being suppressed below 40% reflectivity, indicating polarization selectivity. Figure 2 (b) exhibits the electrical profile of the grating per period. Although the fabricated SWG is not perfectly a vertical sidewall grating, high intensity localization between the grating and air interface indicate that the incident light is mostly reflected by the grating.

Our results show that a highly reflective and broadband dielectric based SWG reflector at visible wavelength can be fabricated using the FIB technique. This could provide an opening for direct SWG reflector integration for both in- and out of-plane optical devices at visible wavelength in the near future.

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[1] C. J. Chang-Hasnain and W. Yang, Adv. Opt. Photonics **4**, 379 (2012).
[2] A. O. Dirisu, G. Silva, L. Zhijun, C. F. Gmachl, F. J. Towner, J. Bruno, and D. L. Sivco, IEEE Photon. Technol. Lett. **19**, 221 (2007).
[3] N. Yu, R. Blanchard, J. Fan, Q. J. Wang, C. Pflugl, L. Diehl, T. Edamura, S. Furuta, M. Yamanishi, H. Can, and F. Capasso, Nanotechnology, IEEE T. Nanotechnol. **9**, 11 (2010).
[4] M. V. Gorkunov, V. V. Artemov, S. G. Yudin, and S. P. Palto, Photonic Nanostruct. **12**, 122 (2014).

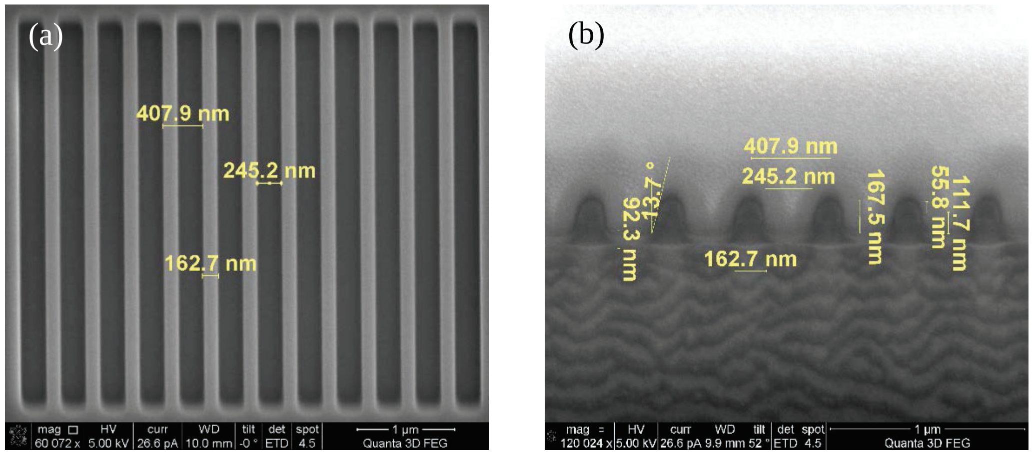

Figure 1: SEM microscopy for the FIB fabricated dielectric SWG reflector in (a) top-view, and (b) cross-section. Highly uniform, clean and good contrast of SWG dielectric grating obtained from the FIB milling with electron dissipation layer (ESPACER 300Z) spin-coated on the sample surface to eliminate charging effect from the dielectrics, GaN and sapphire layers. The SWG is then milled using FIB for cross-sectioning analysis. The grating dimensions (period, width, fill-factor, thickness) and angle sidewalls are measured for the RCWA computation.

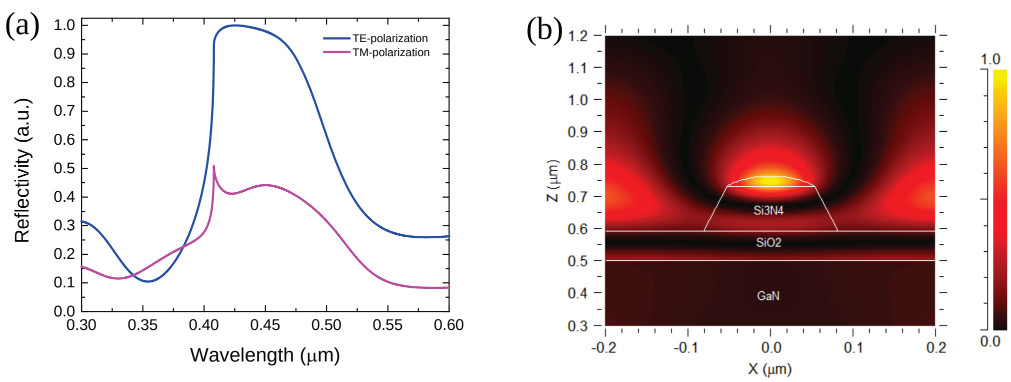

Figure 2: The RCWA computation for (a) reflectivity spectrum, and (b) electrical profile of the FIB fabricated dielectric SWG reflector. The reflectivity spectrum exhibits high reflectivity and broadband for TE-polarization compared to TM-polarization indicating the SWG is a polarization selective reflector. The electrical profile demonstrates high reflectivity of the fundamental mode at the grating-air interface although the grating sidewalls are not perfectly vertical.