Plasma-etch Fabrication of High Aspect Ratio Freestanding Silicon Nanogratings as Deep UV Filters

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Space plasma composition measurements require a filter that allows particles to pass through while blocking energetic UV photons that can degrade the performance of downstream sensors. One effective filter type is high aspect ratio, freestanding gratings composed of deeply etched Si beams. Our simulation of freestanding nano-gratings as ultraviolet filters demonstrated that while pure silicon gratings preferentially reject transverse magnetic (TM) waves over transverse electric (TE) in the deep UV (specifically, for Sun's Lyman alpha line, λ=121.6nm), the addition of thin layers of dielectric and metal can equalize the transmission of TM and TE modes (Fig 1). Both SiO_2 and Al_2O_3 dielectric layers were simulated as well as Pt. The metal alone was not useful, but a thin layer of metal layered atop the SiO_2 provided a significant advantage. The deposition of a thin and uniform metal and oxide layers in high aspect-ratio trenches can be accomplished by using the atomic layer deposition (ALD) technique; and in the case of platinum with adhesion characteristics significantly better than evaporation or sputtering techniques. These coatings enable the potential of gratings with unprecedented UV rejection in the Ly-alpha and similar spectral bands.

For efficient UV blocking, a grating must meet three criteria. It must have high aspect ratio, be freestanding, and cover a large geometric open area. In the past, such gratings have been fabricated by a variety of wet or dry-plus-wet etch techniques, but in this work we discuss a solely plasma-based approach to the problem. The first major challenge in making such a structure is to achieve deeply etched Si trenches with very smooth sidewalls. A modified Bosch process deep reactive ion etch (DRIE) using 80% oxygen content results in high aspect ratio (15:1), sub- 100nm grating trenches with minimal scalloping[1,2] (Fig 2). The second challenge is the double-sided processing required to attain a freestanding grating. Using a silicon-on-insulator (SOI) wafer, both the grating (front side) and diaphragm release (back side) etches have the buried oxide layer as a built-in etch stop. The challenge is to protect the delicate high aspect-ratio nanograting structures from possible damage during the release process. We devised an innovative carrier wafer design with built-in channels for air evacuation to prevent the possible breaking of the membrane structure during the through-wafer plasma etching. The complete device integration will be discussed.

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[1] Mukherjee et al., *J. Vac. Sci. Technol. B*, **25**(6), 2645-2648, 2007
[2] Kawata et al., *Jap. J. Appl. Phys.*, **45**(6B), 5597-5601, 2006

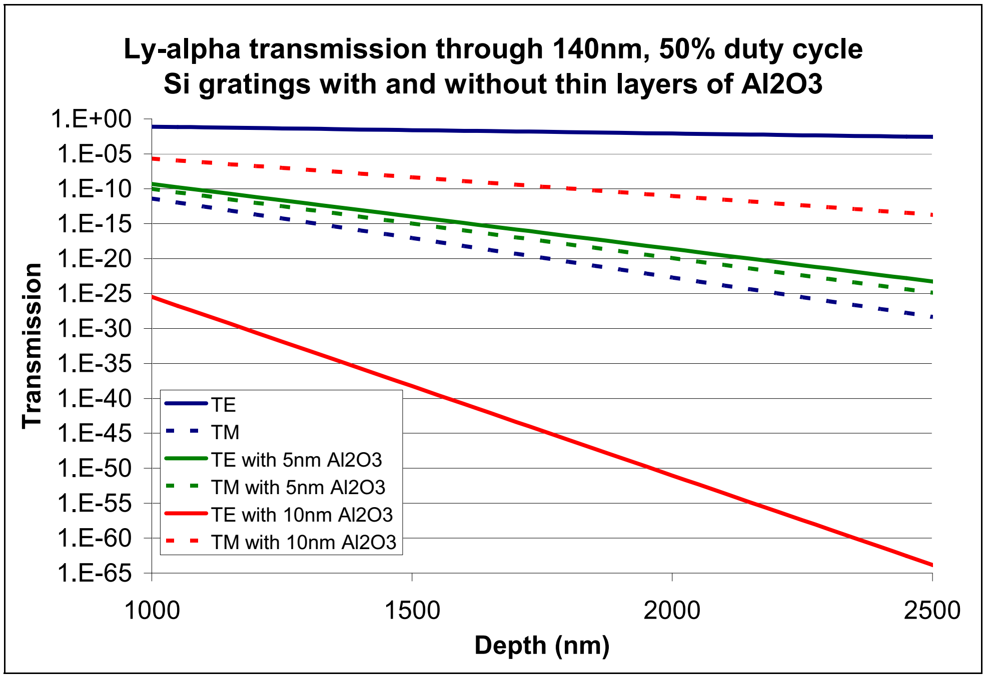

Figure 1: A thin conformal dielectric layer on a grating structure provides better overall performance than thicker coatings or none at all. The effect of a thin dielectric (5nm, green lines) is to raise the transmission of transverse electric modes while suppressing transverse electric. Thicker layers (10nm, in red) can even reverse the normal behavior of a bare silicon grating (blue).

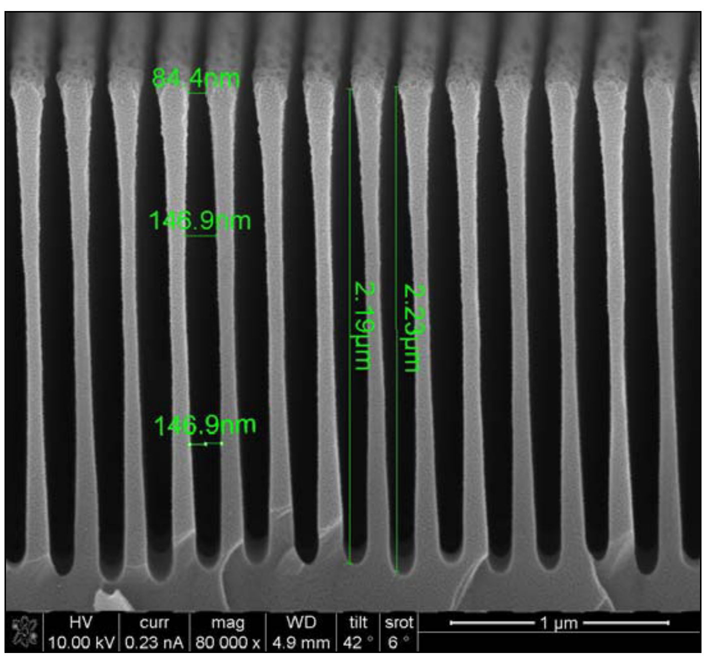

Figure 2: The modified Bosch process results in minimal scalloping and high aspect ratio even for 220nm period gratings.