Deep UV-Blocking Particle Filter Using High Aspect Ratio Si Nanogratings with Smooth Sidewalls

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Composition measurements of plasmas and neutral particle populations are part of many space missions designed for space weather forecasting, exploration of planetary environments, and analysis of space systems in the context of humans in space. The vast majority of these instruments rely on sensors that are highly vulnerable to energetic ultraviolet photons that can degrade their performance. In order to obtain accurate information about the particles, one must block the UV light while allowing the particles to pass and impact the sensor. A total UV suppression factor of 10^{-9}-10^{-10} is therefore often required.[1] To date, this suppression has been done through mechanical systems in front of the detectors.

Here, we propose a fundamentally new approach which relies on a UV-blocking silicon filter transparent to atoms.[2] The filter consists of a suspended nanoscale grating with deeply etched Si beams. Such high aspect ratio features are necessary to block the Lyman-alpha band of solar light at 121.6 nm, while offering the additional advantage of collimating the solar particles as they enter the filter. Simulations (Fig. 1) predict that a Si nanograting with a depth of 1.5-2.5 μm and line widths of 50-70 nm will provide sufficient attenuation of Lyman-alpha light, exceeding the requirement of current filters. Note that wider lines will require significantly greater depth to achieve the same level of rejection of the deep UV radiation.

The most challenging task in making such a structure is to achieve deeply etched Si trenches with very smooth sidewalls. While the high aspect ratio (~40-50) is achievable with deep reactive ion etching (DRIE) tools, the scalloping (well over 100nm) normally associated with such techniques needs to be minimized or eliminated in order to obtain dense and deep trenches with sub-100nm width.

We propose a process using nanoimprint lithography (NIL) for initial patterning of square-inch arrays due to its high resolution and high throughput, a modified Bosch process DRIE using high oxygen content[3] for the smooth etch, and a double-stage etch-oxidize-etch technique to narrow features and obtain the required high aspect ratio. Using an inductively coupled plasma (ICP) etcher with SF_6+O_2 etch chemistry and C_4F_8 passivation, we have achieved sidewall scalloping roughness below 10nm (Fig. 2). Details of this modified Bosch process and our strategies to fabricate the free-standing deep Si nanogratings will be presented at the conference.

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[1] Zurbuchen et al., *Opt. Eng.*, **34**(05), 1303-1315, 1995
[2] Van Beek, et al., *J. Vac. Sci. Tech.*, **B16**(6), 3911-3916, 1998
[3] Kawata et al., *Jap. J. Appl. Phys.*, **45**(6B), 5597-5601, 2006

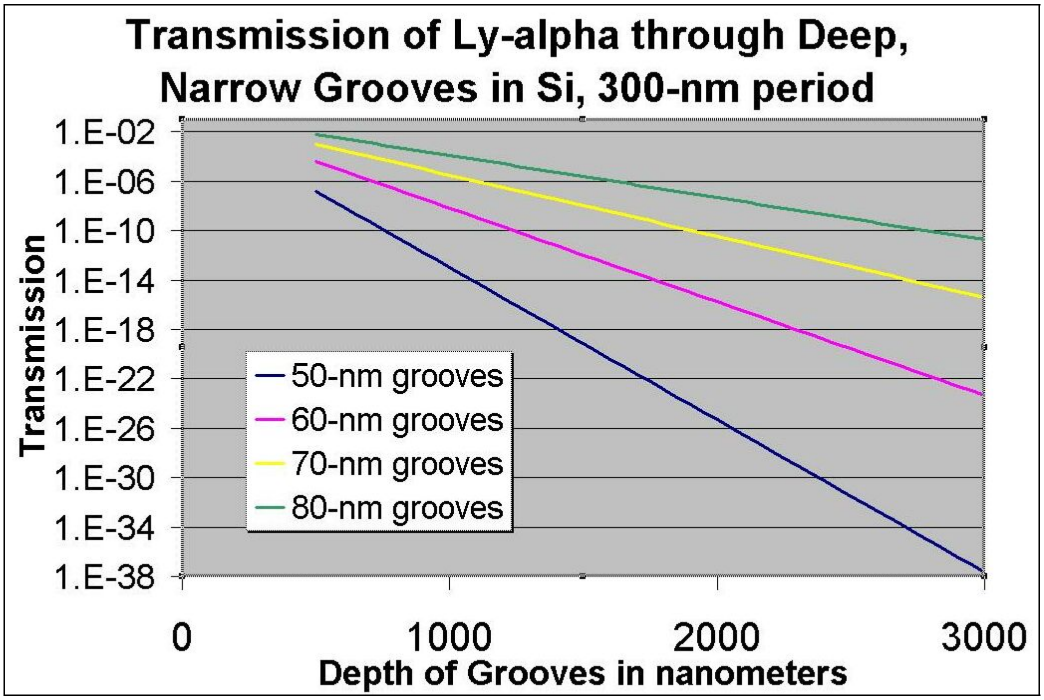
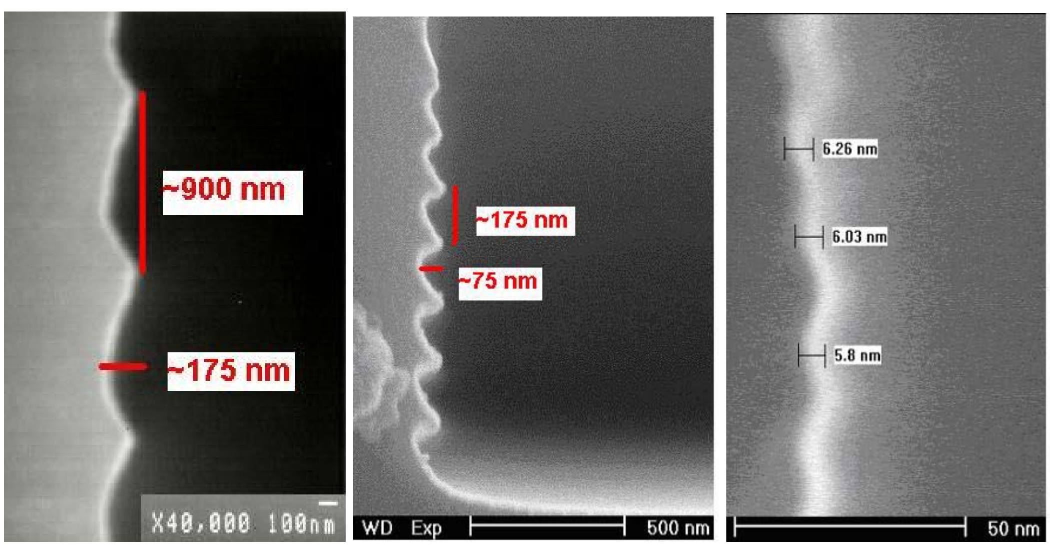


Figure 1: Simulated transmission characteristics of 121.6nm Lyman-alpha light through Si nanoscale gratings of different widths.



a b c

Figure 2: Scalloping of DRIE etches. (a) The standard Bosch process results in large, deep scallops. (b) Our initial tests with SF_6+O_2 etch chemistry reduced that significantly; (c) our current process results in sub-7nm scalloping separated by 15nm.