Fabrication and Measurement of Solar-blind Aluminum Nano-Grid UV Filters by Nanoimprint Lithography and Edge Patterning

Wen-Di Li and Stephen Y. Chou
NanoStructure Laboratory, Princeton University, Princeton, NJ 08544

Detection of UV light with good rejection of visible light with longer wavelength has demonstrated high demand in a number of important applications such as flame detection, covert space-to-space communication and astronomical imaging [1]. In this paper we demonstrate a large area nanostructured metal grid filters (MGFs) of 20 nm wide Al sidewall and 190 nm pitch that pushes the cut-off wavelength of MGFs from infrared and visible range [2, 3] to sub-350 nm (UV) range for the first time, therefore it can be cascaded with low-cost Si detectors to block the visible light and offer the "solar-blind" detection at low-cost.

To avoid the difficulty of patterning metals at high aspect ratio, we first fabricated the SiO2 square grid of 190nm in period and 250 nm deep on fused silica substrate to act as the core, and then deposit aluminum on the sidewall to complete the metal grids. The SiO2 grid fabrication includes patterning by nanoimprint lithography (NIL) with 190 nm pitch two-dimensional hole mold, Cr etching mask deposition, lift-off and fluorine-based reactive ion etching (RIE). The wall thickness of the SiO2 grid was well controlled to be as thin as possible through tuning recipes for Cr mask deposition and RIE. Fig.1 (a) shows the 190 nm-pitch square SiO2 grid of 30 nm thick and 250 nm deep. Aluminum was then deposited on the sidewall of the SiO2 grid at an oblique angle by e-beam evaporation. The deposition angle was adjusted so that the deposited aluminum can cover about 200 nm deep on the sidewall without blocking the bottom. The deposition of Al repeated 4 times by 90° rotation to have 20 nm Al on each sidewall. The SEM micrographs of the complete metal grid filter are shown in Fig.1 (b).

The transmission of the fabricated Al MGFs was experimentally characterized from 200nm to 700nm using a UV/visible spectrometer (Fig.2 (a)). At normal incidence, a peak transmission efficiency of 27% is observed at 290nm. The transmission drops to a half of the peak at 350nm. For wavelengths longer than 480nm, the rejection ratio is higher than 20dB. Fig.2 (b) is a rigorous coupled wave analysis (RCWA) numerical simulation of the MGFs using the dimensions the same as the fabricated structures. Experimental measurements agree well with the numerical simulation.

In summary, we demonstrated a wafer-scale aluminum grid filter fabricated on fused silica substrate using nanoimprint lithography and oblique metal deposition. With the low-cost, large-area and high-throughput offered by NIL [4], this filter can be cascaded with conventional Si detectors to achieve solar-blind UV detection with low cost and large area integration.

[1] J. T. Clarke et al, Appl. Opt. 38 (1999) 1803-1813
[2] K. Jefimovs et al, J. Mod. Opt. 51 (2004) 1651-1661
[3] K. Jefimovs et al, Microelectron. Eng. 83 (2006) 1339-1342
[4] S. Y. Chou et al, Science 272 (1996) 85-87

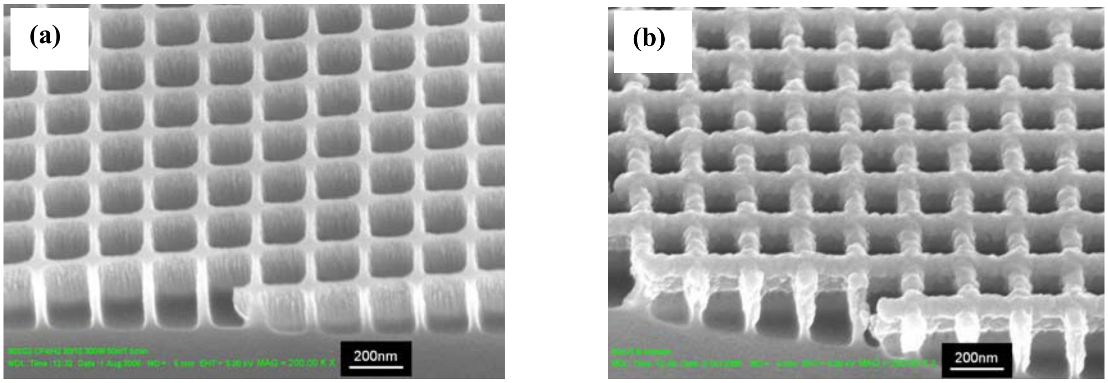

Fig.1. (a) SEM picture of SiO_2 grid fabricated on fused silica substrate by nanoimprint lithography. The 190nm-period SiO_2 grid is about 30nm thick and 250nm deep. (b) SEM picture after Al deposition by oblique e-beam evaporation. The aluminum deposited on SiO_2 sidewalls covers about 200nm deep and has an average thickness of about 20nm

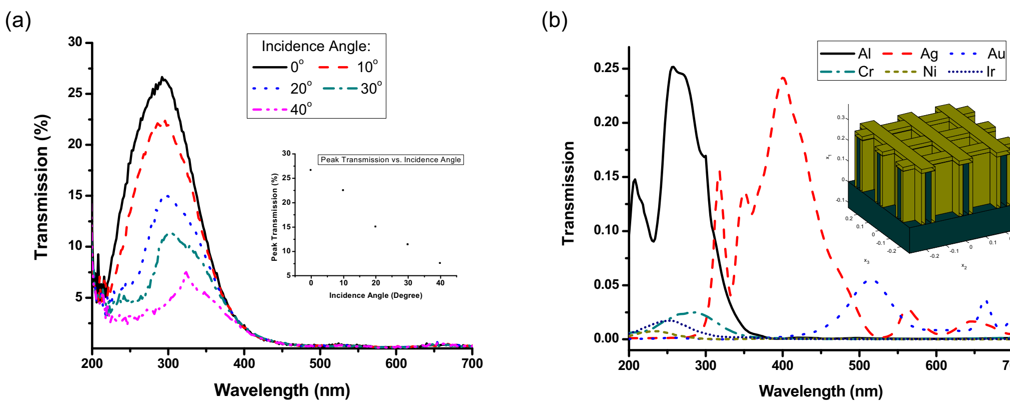

Fig.2. (a) Measured transmission from 200nm to 800nm at different incidence angles. The inset shows the filter has transmission efficiency larger than half of the peak transmission within ±25° incidence angle. (b) Numerical simulation on the performance of different metals on metal grid structure which has 190nm period, 250nm depth and 30nm thick SiO_2 core. The thickness of the deposited metal is 20nm.