Moth-eye antireflection nano-structure on glass for CubeSats

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A CubeSat is a type of miniaturized and modular satellite designed for space research or technology demonstration. By filling the unused capacity of major launch vehicles, CubeSats significantly lower the cost of entry to the space. It has been reported that just nine years after the first launch in 2003, more than one hundred CubeSat-class satellites have flown, fielded by nearly 80 organizations from 24 countries on 29 rockets [1]. However, not all the missions were successful; and power subsystem failures (e.g. insufficient power generation) accounts for 14% of mission failures [1]. To address this issue, here we designed and fabricated a moth-eye antireflection (MEAR) surface on quartz solar cell cover glass to enhance the performance of solar cells on CubeSats.

It has been demonstrated that biomimetic moth-eye structures increase light transmission at the air/Si and air/SiO_2 interfaces [2-4]. Featuring a gradient refractive index (GRIN), the moth-eye structure achieves superior broadband and omni-directional antireflection over traditional thin-film antireflection coating (ARC) [5-6]. Low reflection over a broad range of wavelengths increases the power production of body-mounted solar cell, which is commonly used in CubeSats. Furthermore, cells on CubeSats are also expected to experience very high angles of incidence to the sunlight during scientific operation. Both of these advantages make the application of moth-eye antireflection technology an attractive method to increase the overall power generation [7].

Herein, we report a simple lithography approach to create large-area moth-eye antireflection structure on the quartz cover-glass used to protect solar cell from radiation damage. Since the etching of SiO_2 for high aspect ratio features is not straightforward, we first deposited 1.2 um of polysilicon on the glass substrate by LPCVD as the patterning layer. With 25 nm Al deposited on the poly-Si layer by sputtering, a self-assembled monolayer of 200 nm diameter polystyrene (PS) nano-spheres was prepared on top of metal layer using dip-coating (Langmuir-Blodgett) method. Compared to spin coating, where the duration, rotation speed and acceleration rate have to be perfectly controlled [8], the dip-coating method can produce large area self-assembled monolayer by using a simple configuration, and it also has great tolerance to the surface flatness of the sample. The Al layer was used as a hard mask that can offer a higher etching selectivity to poly-Si than the PS sphere. The reduction of sphere size was achieved by oxygen plasma RIE for 40 secs. During the plasma etching, spheres were etched both horizontally and vertically, resulting in a degradation in the roundness. A soft baking step, above glass transition temperature of PS at 130 degrees, was introduced to improve sphere roundness. Figure 1 shows the nano-sphere coated on Al before shrinking (Figure 1a) and after baking (Figure 1b). In the next step, the Al layer was patterned by RIE using BCl_3 chemistries, and the pattern was further transferred into poly-Si using SF_5/C_4F_8 gas. Figure 2 shows the moth-eye structure in Si. In the last step, dry oxidation was performed to convert Si into SiO_2. Reflectivity/transmission measurement and simulation result are under way and will be presented.

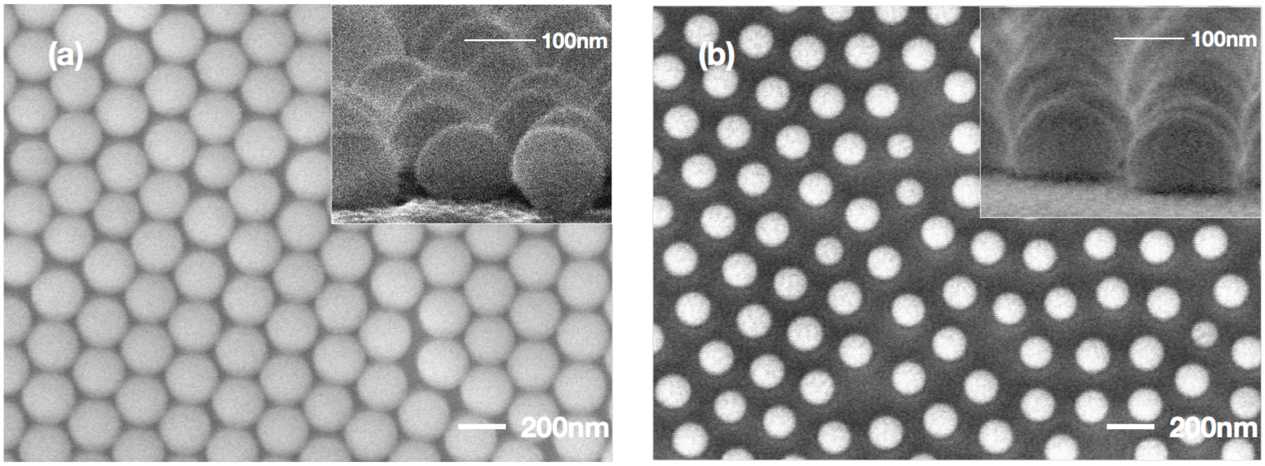

Figure 1. Top view scanning electron microscope of (a) PS sphere on Al before oxygen plasma treatment and (b) PS sphere after soft baking. The insets in (a) and (b) are the corresponding magnified 80-degree images of sphere.

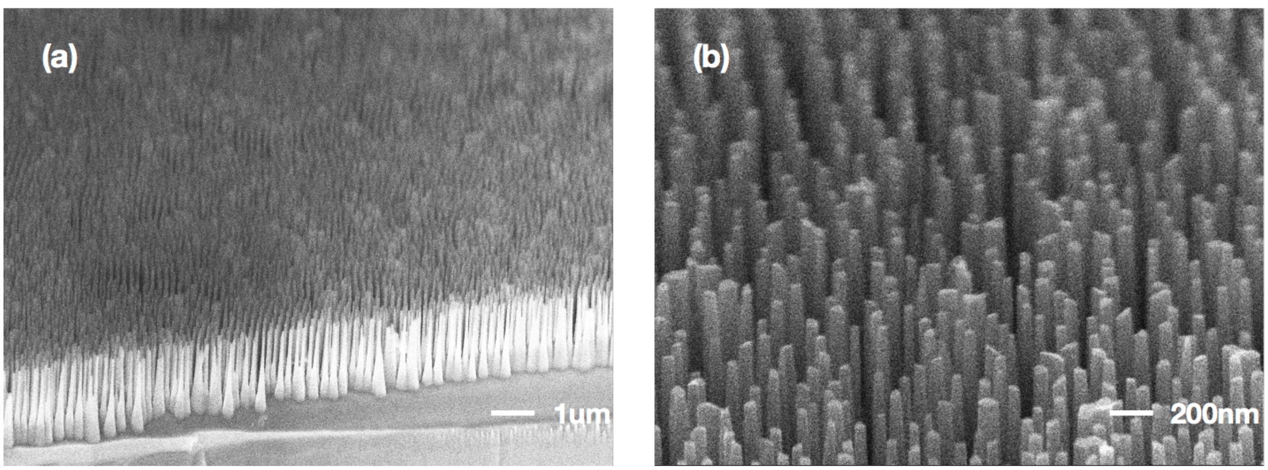

Figure 2. 70 degree angle cross-sectional SEM image of close-packed Si moth-eye nanostructures

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