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Study of bilayer porous structure for efficient light absorption

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In this paper, we present a novel bio-inspired photochemical light absorption method based on porous silicon. Samples with different pore morphologies were obtained by anodic etching on highly-doped n-type silicon substrate via electrolytes consisting of HF, ethanol and H_2O_2. TiO_2 nanoparticles were synthesized by the sol-gel hydrolyzing method. Light absorption effects were characterized by the reflective spectrum.

Many research efforts have been carried out to develop artificial photosynthetic system in order to find a solution for energy crisis. T. Fan et al. [1] fabricated artificial inorganic leaves composed of Pt/N-doped TiO_2 for efficient water splitting by using natural leaves as biotemplates. In our earlier work [2], we demonstrated the ability to fabricate varieties of multilayer structures with different pore morphologies on one silicon substrate by varying the applied current density. Such multilayer structures, combining advantages of different types of pore microstructures, are expected to offer many attractive features. For instance, the macro-microporous bilayer structure shown in Fig. 1 may have great advantages in light trapping and absorption due to its morphology similar to that of natural leaves (inset upper-right).

Herein we use HF-containing electrolytes modulated with strong oxidizer, H_2O_2, to fabricate porous silicon samples with different pore sizes on highly doped n-type silicon by varying the current densities. By immersing the porous silicon sample in the precursor for sol-gel coating and calcinations thereafter, TiO_2 nanoparticles can be synthesized in the porous structure. Finally, we investigated the reflectance spectrums of all the porous samples before and after TiO_2 synthesization to characterize the effect for light absorption.

In our experiments, highly doped n-type samples (0.01-0.02 Ω·cm, 300 μm-thick, CZ-grown, (100)-oriented and polished) were used. The anodizing solution was composed of 10 ml 48 wt.% HF, 10 ml 30 wt.% H_2O_2 and 10 ml 99.7 vol.% ethanol. Galvanostatic conditions were applied for both macro- and microporous silicon etching. The current density and etching time are 300 mA/cm^2, 30 s and 10 mA/cm^2, 5 min, respectively.

The as-prepared samples were then immersed in the precursor for sol-gel coating composed of 13.3 ml 99.7 vol.% ethanol, 10 μl acetylacetone and 200 μl tetrabutyl titanate. Acetylacetone was used to control the hydrolysis of the precursor. The samples were placed in N_2 atmosphere and existence of $CaCl_2$ for 6 h, rinsed with ethanol and then left in air for hydrolysis by moisture for 2 h. Afterwards, the samples were desiccated in an aerated oven at 40 □, 60 □,80 □ and 105 □ successively, with each temperature for 2 h. Finally, the samples were calcined in air at 280 □ for 2 h and then 500 □ for 2 h, with a ramping rate of 1 □/min. Fig. 2 (a) and (b) show the macro- and microporous sample after TiO_2 nanoparticles synthesized, respectively.

The reflective spectrums of macro- and microporous samples before and after TiO_2 nanoparticles synthesized are shown in Fig. 2 (c). The tested wavelengths are located from 200 nm to 800 nm in the visible light range. It can be easily found that the reflectance of macroporous sample is much lower than microporous sample in all testing spectrum and the synthesis of TiO_2 nanoparticles effectively reduces the reflectance for both macro- and microporous samples.

References

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[2] D.H. Ge, M.C. Wang, P.L. Yang, J.W. Jiao, “Formation of macro-meso-microporous multilayer structures”, Electrochimica Acta, accepted.

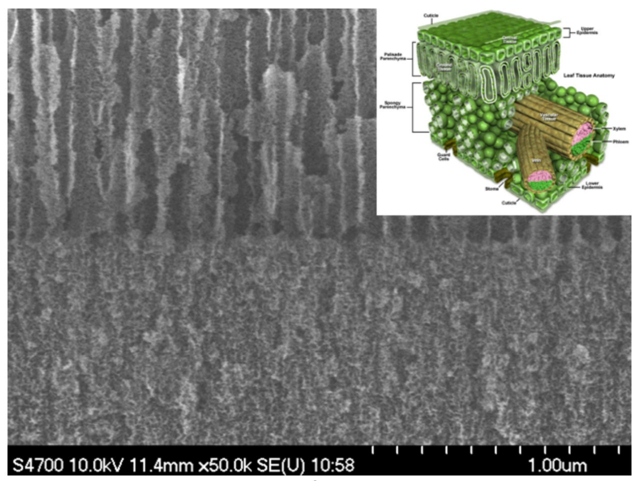

Fig.1 The SEM picture of macro-microporous bilayer structure and the diagram of natural photosynthetic system.

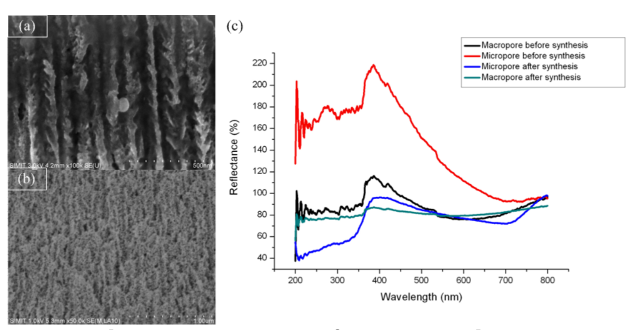

Fig. 2 The SEM pictures of macro- and microporous layers with synthesized TiO_2 nanoparticles (a, b) and the reflectance spectrums of macro- and microporous samples before and after TiO_2 synthesized (c).