Using colloidal lithography to fabricate semitransparent metal anodes in organic solar cells

W. H. Lee, H. L. Chen, S. Y. Chuang, Y. H. Lin, C. H. Lin[1], and W. F. Su*

Department of Materials Science and Engineering, National Taiwan University, Taipei, Taiwan
[1]Institute of Electro-Optical Science and Engineering, National Cheng Kung University, Taiwan
*Tel: 886-2-33663240, Fax: 886-2-23634562, *E-mail: hsuenlichen@ntu.edu.tw*

Due to the advantage of low cost solar energy conversion, organic solar cells based on P3HT:PCBM thin films have attracted much attention recently [1]. For efficient electron injection into the organic layers, a low-work-function aluminium film is generally as a cathode. As an anode, ITO is the predominant material since it has high transmittance in the visible regime with electrical conductivity. However, the conductivity of ITO is far from optimal value for high-efficiency organic solar cells with large area. Therefore, we alter the anode by thin Au film with hole array as a transparent electrode [2]. The SPR induced by metallic hole array structure results in the strong optical field in the organic film and confined SPR waves on metal surface. The enhanced exciton generation near the interval between P3HT:PCBM and electrodes can elevate the organic solar cell performance.

Colloidal lithography is a low-cost and relatively high-throughput technique for patterning nanostructures. The advantage of colloidal lithography in nanofabrication is that large-area self-assembly of colloids having well-ordered structures can be performed without the need for expensive equipment. Fig. 1 displays a schematic illustrations of the colloidal lithography. A glass substrate was coated with close-packed polystyrene spheres (PS) using a spin coater. The size of spheres can be reduced by O_2 plasma etching. Following a thermal evaporator system was used to deposit a thin gold film, and then the PS spheres are dissolved in methyl benzene solvent with ultrasonic vibration. Fig. 2(a) and 2 (b) show the SEM images of PS spheres after 5 and 10 seconds plasma etching. Fig.2(c) displays the Au hole-array structure with 240 nm hole-diameter and period of 280nm. As shown in Figure 4, the average transmittance of 45 nm Au film is significantly increased from 5% to 55% after patterning the sub-wavelength hole-array structure. The simulated result indicating that 15nm Au film with hole-array structure has 77% transmittance. Because the excitons generated near the surface of electrodes in P3HT:PCBM are associated to the high efficiency of the solar cell, Fig. 3 shows the simulated electric field in the organic solar cell structure by the Finite Difference Time Domain, FDTD simulation. Figure 5 demonstrates that the light wave intensity at the interface of organic film and Au electrode are doubled with hole array structure. This technique can be used in organic solar cells for increasing their quantum efficiency. Detailed analysis and results will be reported in the conference.

1. C. Waldauf, P. Schilinsky, J. Hauch, C. J. Brabec, "Material and device concepts for organic photovoltaics: towards competitive efficiencies," Thin Solid Films 451–452, 503 (2004)
2. H. W. Gao, J. Henzie, T. W. Odom, "Direct evidence for surface plasmon-mediated enhanced light transmission through metallic nanohole arrays," Nano Lett. 6, 2104 (2006)

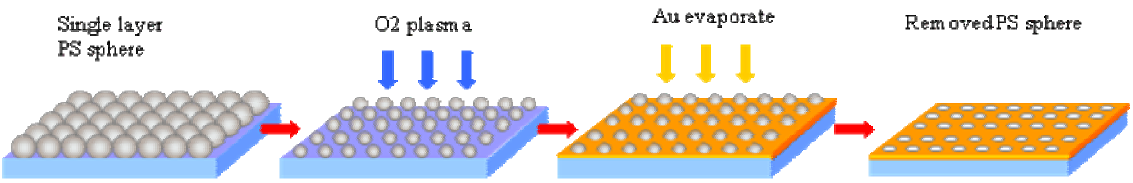
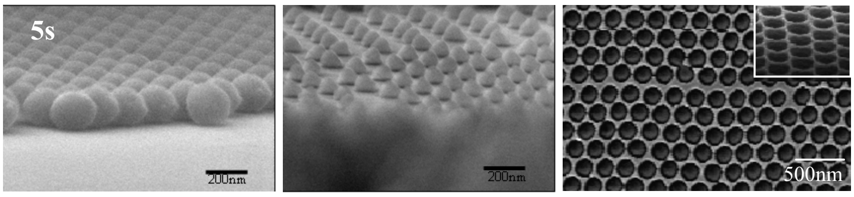


Fig1. Schematic illustrations of the colloidal lithography for patterning hole array in Au film



(a) (b) (c)

Fig. 2 SEM image of (a) single layer of PS spheres after 5s O_2 plasma etching; (b) after 10s O_2 plasma etching; (c) hole array in gold film with 280nm period.

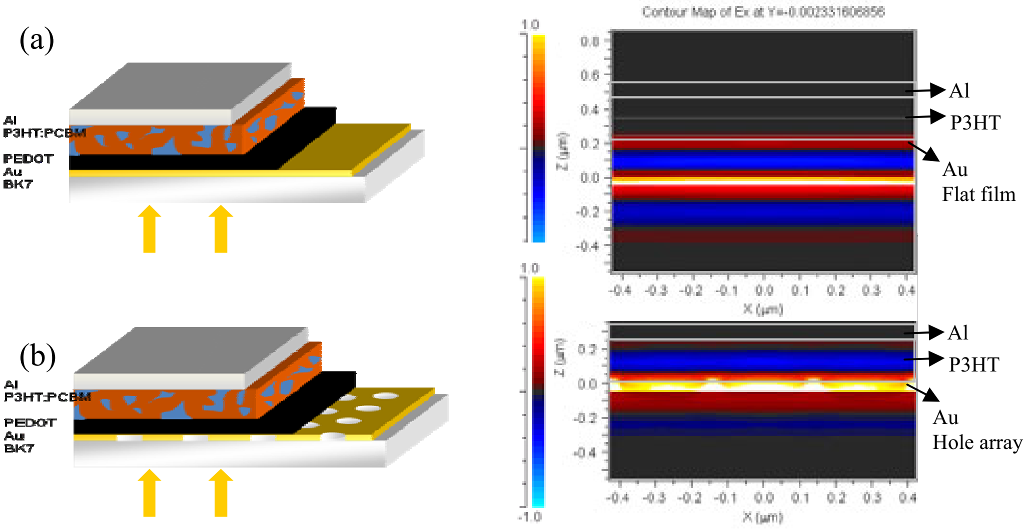


Fig. 3 FDTD simulation of light distribution in organic solar cell structure

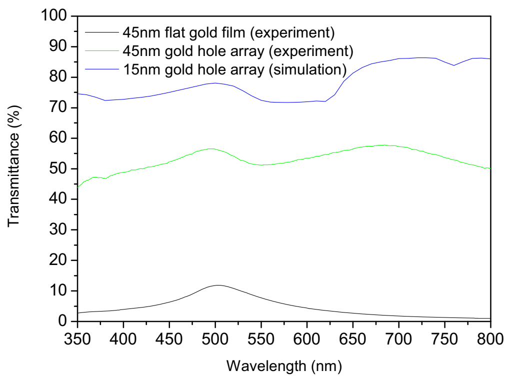


Fig.4 Experimental and rigorous coupled-wave analysis (RCWA) simulation transmittance of flat Au film and hole array in Au film.

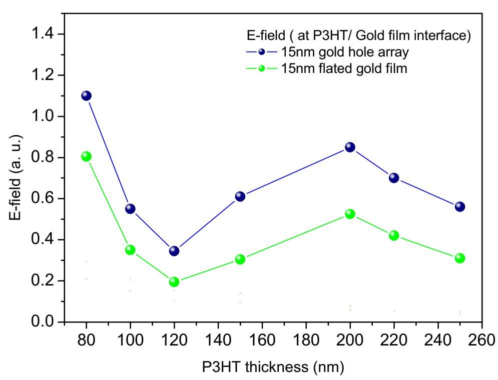


Fig.5 Electric field in P3HT:PCBM at the anode / P3HT:PCBM interface with varied active layer thickness.