Stencil-nanopatterned back reflector increases efficiency of thin-film solar cells

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Nanopatterned back reflectors increase the performance of thin-film solar cells[1,2] compared to a planar morphology. Here we use stencil lithography (SL) as a parallel, clean and scalable technique for tuning the nanostructures' morphology of the back reflector. Cells with stencil-patterned back reflectors show an increase of the external quantum efficiency at 670 nm of up to 2.5 fold.

Millimeter-size SiN stencils with holes 220 nm in diameter were patterned by nanosphere lithography starting from wafer-spun close-packed bead monolayers[3] (Fig. 1a,b). Two stencils, A and C, with porous area fractions of 80±5% were used to pattern the solar cell back reflectors. On top of a 160 nm thick Ag layer on borosilicate glass substrates, arrays of 40 nm thick Ag nanodots were deposited by SL (Fig. 1c,d). The back reflector was completed by 70 nm thick ZnO layer RF sputtered on top of the nanodots. 250 nm n-i-p amorphous silicon solar cells were deposited by PECVD and ITO electrodes were DC sputtered.

Repeated fabrication of stenciled and reference solar cells showed uniform and reproducible results. Measurements were carried out using a dual lamp solar simulator. Results depend strongly on the scatterers' shape[4], with an efficiency of up to 8.7% for the cell with the taller and sharper nanodots prepared with stencil C (Fig. 2). The effect of the nanopatterns' morphology and stencil patterned area on the cells' performance will be presented and discussed. The cost-efficient nanofabrication of large-area membranes and their reusability makes SL a viable performance enhancer for photovoltaic applications.

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[1] K. Soderstrom *et al.*, Solar Energy Materials and Solar Cells **95**, 3585 (2011).
[2] V. E. Ferry *et al.*, Applied Physics Letters **95**, 3 (2009).
[3] M. J. K. Klein *et al.*, Journal of Vacuum Science & Technology B **29**, 5 (2011).
[4] U. W. Paetzold *et al.*, Opt. Express **19**, A1219 (2011).

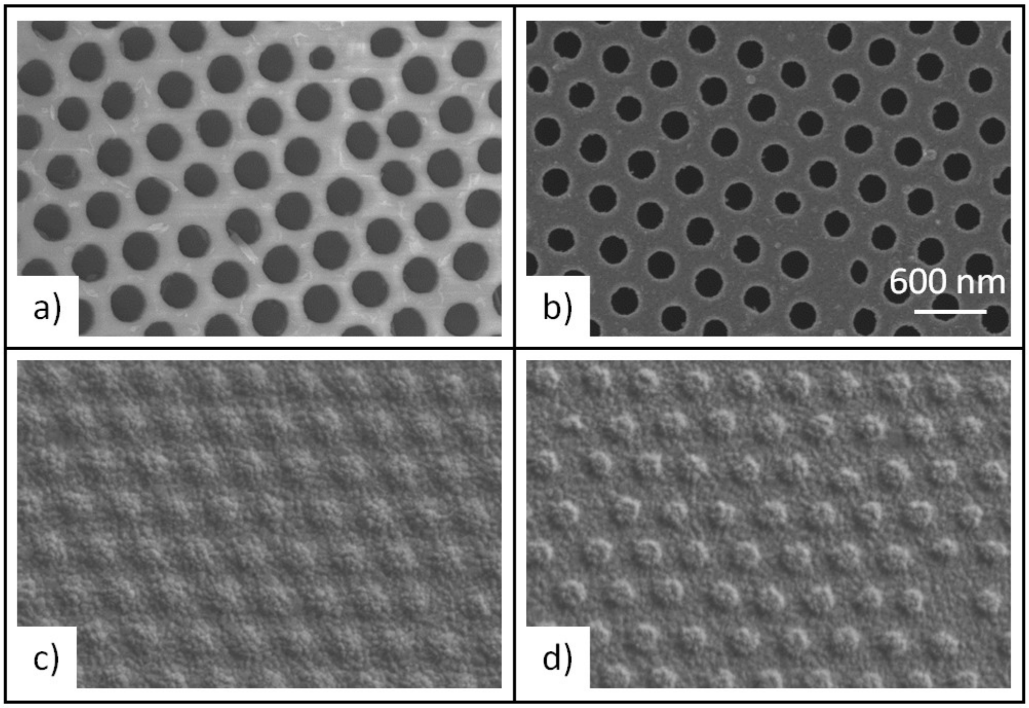

Figure 1: SEM images of holey stencil used for nanopatterning of the back reflector of a solar cell and the resulting nanodots: a) before and b) after 160 nm Ag deposition through it. SEM images of 40 nm tall Ag nanodots on Ag back reflector from stencils a) A and b) C; Stencil A consistently produced more blurred nanodots than stencil C, due to a larger substrate-stencil gap.

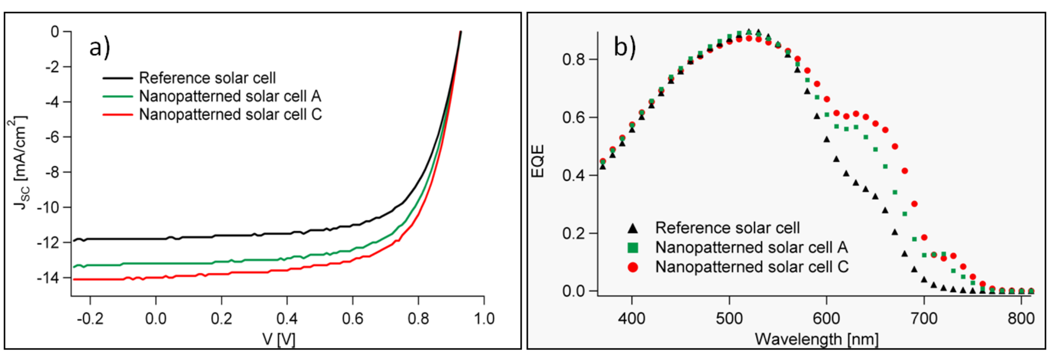

Figure 2: Graphs illustrating the net better performance of the nanostructured solar cells with stencils A and C than that of the flat reference cell: a) Short-circuit current vs. open-circuit voltage curve showing larger J_{sc} for nanopatterned cells, and b) external quantum efficiency as a function of wavelength, with an enhanced performance of the nanopatterned cells of up to 2.5 times at 670 nm.