Ultrathin c-Si solar cells with efficient light trapping

A. Gaucher[1], A. Cattoni[1], I. Massiot[1], C. Dupuis[1], W. Chen[2], R. Cariou[2], M. Foldyna[2], P. Roca i Cabarrocas[2], L. Lalouat[3], E. Drouard[3], C. Seassal[3], S. Collin[1*]

[1]*Laboratoire de Photonique et de Nanostructures (LPN), Route de Nozay, 91460 Marcoussis*
[2]*Laboratoire de Physique des Interfaces et Couches Minces (LPICM), Ecole Polytechnique, Route de Saclay, 91128 Palaiseau Cedex*
[3]*Institut des Nanotechnologies de Lyon (INL), 36 avenue Guy de Collongue 69134 Ecully Cedex*
[*]*e-mail : andrea.cattoni@lpn.cnrs.fr*

Thin film (<10 µm) crystalline silicon based solar cells have gained great attention in the past few years. The main objective of this approach is to drastically reduce the absorber thickness to benefit from important material cost reduction. However, light trapping strategies must be implemented in the cell architecture to achieve acceptable short circuit current. It has been shown that the implementation of nanostructures on both the top and the bottom cell surfaces can greatly enhance the short circuit current[1] and compensate the loss from the thickness shrinkage. We present the development of ultrathin (2-5µm) nanostructured c-Si solar cells fabricated by industrially relevant techniques based on low-temperature PECVD and nanoimprint lithography.

We report on the fabrication and characterization of both flat and nanopatterned solar cells transferred on glass. Epitaxial silicon is first grown by PECVD at low temperature[2] (T<200°C) and bonded on a host substrate using anodic bonding (T<200°C). A porous layer between the substrate and the epitaxial silicon layer is used to mechanically remove the silicon substrate. A ZnO/Ag back mirror is added to the structure before the transfer process to improve the absorbance. Inverted nanopyramids with a pitch of 800nm are fabricated by nanoimprint lithography and wet etching in alkaline solution to further improve the absorption.

With 3µm-thick c-Si layers, the performances achieved with planar solar cells are Jsc=18.3mA/cm² and η=6.1%. We demonstrate more efficient light trapping with an additional nanopyramid array on the front side of the cell. Improved external quantum efficiency is measured on a large spectral range. A short-circuit current of 25.3mA/cm² is obtained on patterned solar cells. Thanks to FDTD simulations and simple modeling, we show that diffraction in the Si epilayer by the nanopyramids grating is the main cause of the short circuit current increase. A light path enhancement factor of 10 is found. At long wavelengths, most photons are trapped for five round trips in the epilayer.

This work was partly supported by the ANR project NATHISOL and by the RENATECH network.

[1] X. Meng, E. Drouard, G. Gomard, R. Peretti, A. Fave and C. Seassal, *Opt. Express*, 20 (S5), A560-A571 (2012)
[2] R. Cariou, I. Massiot, R. Ruggeri, N. Ramay, J. Tang, A. Cattoni, S. Collin, J. Nassar and P. Roca i Cabarrocas, *Proc. 28Th European Photovoltaic Solar Energy Conference*, 2225-2227 (2013)

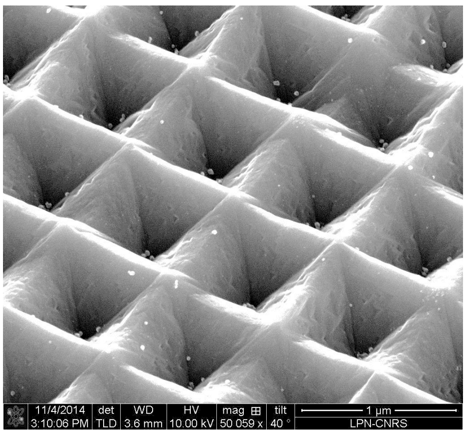

Fig. 1. SEM image of the inverted nanopyramids array.

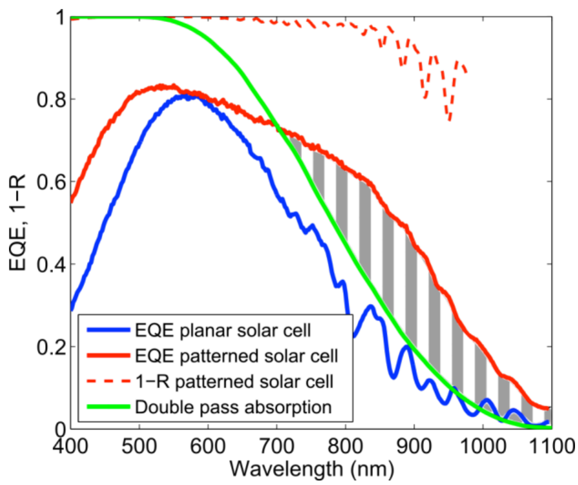

Fig. 2. Comparison of the EQE measurements on planar and patterned solar cells. Also displayed are the reflectivity and the double pass absorption in a silicon slab of same thickness. The hatched grey area represents the J_{sc} gain due to diffraction.