Ultrathin Epitaxial Silicon Solar Cells with Inverted Nanopyramid Arrays for Efficient Light-Trapping

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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 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 plasma enhanced chemical vapor deposition 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 (T<200°C) and bonded on a glass host substrate using anodic bonding (T<200°C).[2] 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 modeling, we show that diffraction in the Si epilayer by the nanopyramids grating is the main cause of the short circuit current increase. We infer an optical path enhancement of 10 in the long wavelength range. A propagation model reveals that the low photon escape probability of 25% is the key factor in the light trapping mechanism. The main limitations of our current technology and the potential efficiencies achievable with contact optimization are discussed.[3]

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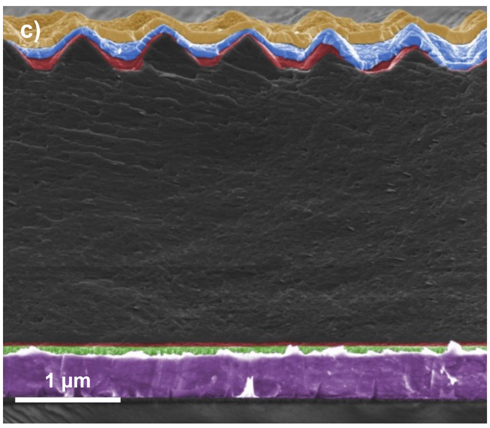

Fig. 1. SEM cross-section of nanostructured c-Si solar cell transferred on a silver mirror on glass.

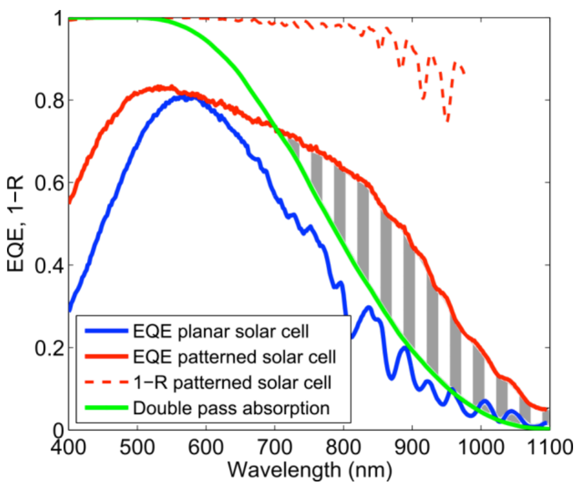

Fig. 2. Comparison of the EQE measurements on planar and patterned solar cells. Also displayed are the reflectivity and the double pass absorption in a silicon slab of same thickness. The hatched grey area represents the J_{sc} gain due to diffraction.