Investigation of absorption enhancement in pseudo-disordered nanophotonic structures for thin-film crystalline silicon solar cells

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Thin film solar cells may exhibit high conversion efficiencies provided their active material exhibits a high quality (like crystalline silicon) and if the absorption in the active layer is properly controlled. As conventional light trapping scheme are still limited for thin cells, we propose to integrate advanced light trapping scheme based on controlled pseudo-disorder nanophotonic structure.

We firstly investigate theoretically the net absorption enhancement in a thin-silicon solar cell (Fig.1a) due to the pseudo-disordered photonic crystal structure and the associated spectral larger density of modes [1]. Thanks to an optimized photonic crystal, the absorption of the solar cell can be increased by more than 40% compared to unpatterned device. This value can be overpassed in the case of a properly chosen pseudo-disordered structure. The effect of the pseudo-disorder will be analyzed in the real space as well as in the Fourier space to evidence design rules (avoid cluster of holes, reducing the small spatial frequencies in dielectric function, …) allowing an increase of the absorption of the solar cell.

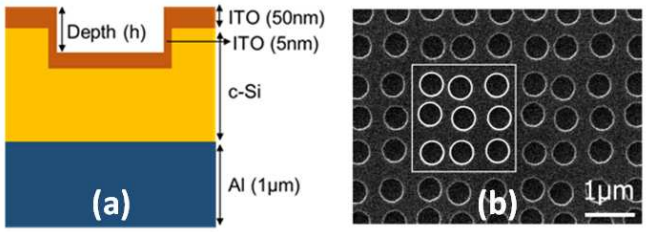

Fig. 1: (a) Side view of the numerically investigated thin solar cell. (b) SEM view of a fabricated pseudo-disordered structure.

Then fabricated structures are analyzed in light of this numerical investigation to evidence the impact of such pseudo-disordered structures as well as the influence of the measurement method and technological fluctuations. The integrated absorption in a 1µm thick crystalline silicon layer increases from 37.7% in the case of the flat structure to 70.7% in the case of a properly designed pseudo-disordered structure. The effect of the pseudo-disorder (Fig. 1b) on the optimized periodic photonic crystal structure corresponds to an increase of 2% as predicted by simulations while both structures are fabricated using exactly the same process flow.

[1] R. Peretti et al, Phys. Rev. A, 88, 053835, 2013