Silicon Thin Film Radial Junction Solar Cells

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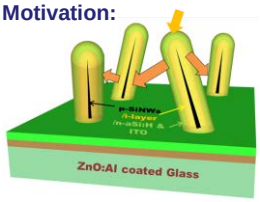
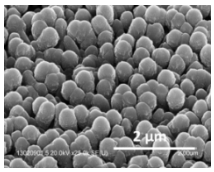
Abstract: Owing to their enhanced light trapping and anti-reflection effects, silicon nanowires (SiNWs) provide an active research platform for a new generation of cost-effective and efficient solar cells. By optimizing the density of nanowires and depositing amorphous silicon (a-Si:H) on top of them, stable radial junction PIN devices with efficiencies ~8% have already been realized and there is still room for improvement. For instance, by modifying the SiNW/a-Si:H interface, an open circuit voltage as high as 0.9 V has been achieved. Also, increasing the band gap of the window layer is found to be effective for blue-response enhancement. Modeling of equivalent structure with a-Si:H nanowires by rigorous coupled wave analysis method shows that short circuit current density can be improved up to 20 mA/cm² and changing the active material to a lower band gap material, e.g., µc-Si:H or a-SiGe:H allows to take the advantage of broader solar spectrum.

Motivation:

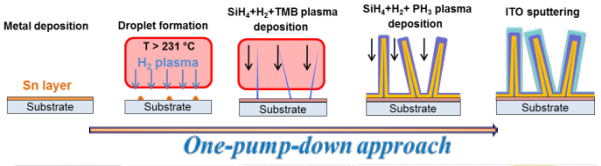


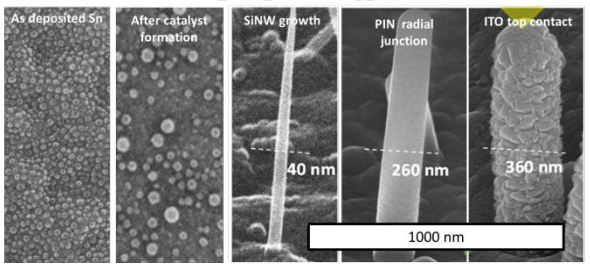
- Excellent light trapping and anti-reflection effect.
- Decouples light absorption and carrier collection direction.
- Lower material consumption, 100 nm is the typical thickness for a-Si:H radial junction cells compared to 250 nm used on the textured substrates.
- Improved stability against light soaking.
- Highest efficiency of 9.2% (J_{sc} calibrated with EQE).

Complete radial junction with ITO

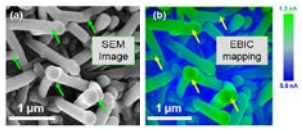


Fabrication procedure:





Feasibility of making a device on randomly tilted nanowire array:

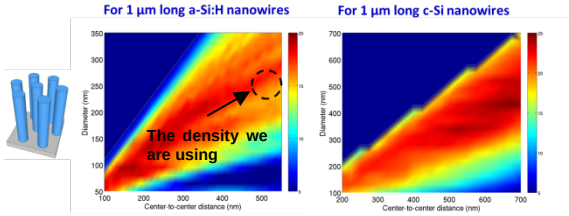


EBIC mapping shows that high quality and **robust junction** is feasible over random plasma-assisted VLS-grown SiNWs.

Modelling of radial junctions:

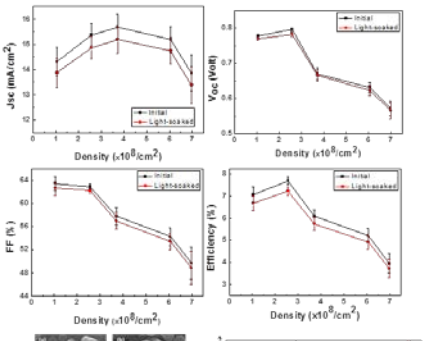
- Theoretical short circuit current density can be calculated by 3D rigorous coupled-wave analysis by using the formula: $J_{sc} = e\int_E A(E)N(E)dE$

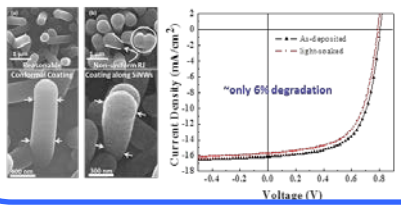
For 1 µm long a-Si:H nanowires | For 1 µm long c-Si nanowires



Results:

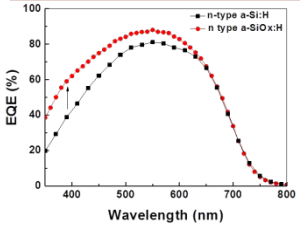
Impact of SiNW density on cell performance



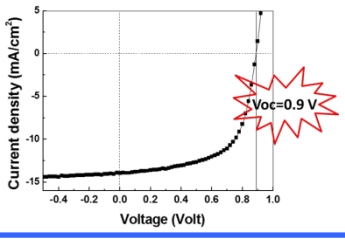


How to improve further

Good blue response with n-type aSiOx:H

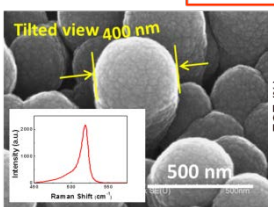


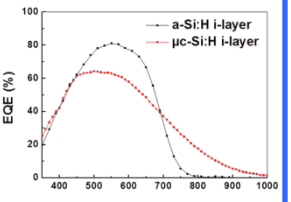
Very good Voc with p-type a-Si:H on the NWs



Attempts to change the absorber material

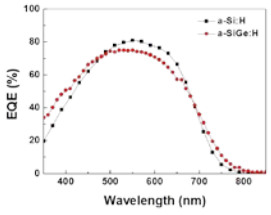
Comparison with µc-Si:H





Courtesy: Bastien Bruneau, Jean-Christophe Dornstetter

Comparison with a-SiGe:H



Future work: Improvement of the NIP cells, Improving the bottom cell, realization of tandem structure.

References: [1] S. Misra, L. Yu, M. Foldyna, P. Roca i Cabarrocas, SOLMAT, 118, 90-95 (2013), [2] S. Misra, L. Yu, W. Chen, P. Roca i Cabarrocas, The Journal of Physical Chemistry C, 117, 17786 (2013) [3] S. Misra, L. Yu, M. Foldyna, P. Roca i Cabarrocas, Journal of Physics D: Applied Physics , 47, 393001 (2014).

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