Morphology and Effects of an S-PEDOT Film on Neutral Beam Etched Silicon Nanopillar Structures for Hybrid Solar Cells

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Introduction: Poly(3,4-ethylenedioxythiophene):poly(4-styrenesulfonate) (PEDOT:PSS) has been one of the most successful conductive polymers of the last two decades. Consequently, hybrid solar cell architectures which use *n*-type Si as the absorber and PEDOT:PSS as the carrier-selective contact have been able to achieve device efficiencies exceeding 20%. However, on nanostructures which are necessary to improve photo-absorption and carrier separation, PEDOT:PSS films are unable to achieve good coverage or reach the bottom surface of the substrate. This reduces the overall area of contact and creates large voids which reduce the reliability if the final device. A highly conductive self-doped PEDOT (S-PEDOT) [1] can potentially eliminate these disadvantages in processability of PEDOT:PSS by completely enclosing even fine nanopillar structures created through a self-assembled ferritin mask and neutral beam etching [2]. Using this technique were able to increase the area of contact between S-PEDOT and the silicon substrate by a factor of 2.4. The purpose of this presentation is to demonstrate an Si:S-PEDOT heterojunction that will potentially improve both the optical and electric performance of future hybrid solar cells.

Experimental: Silicon nanopillars were created by using a chlorine neutral beam to etch over a Polyethylene glycol (PEG) decollated Ferritin bio-mask for 13 min and 25 min on 10 mm x 10 mm substrates. The resulting nanopillars were 50 nm and 80 nm in height respectively with a pitch of 40 nm. S-PEDOT (SELFTRON® H provided by Tosoh Corporation) was spin coated at 2000 rpm for 60 sec. On a flat substrate, this creates a 60 nm thick coating. The samples were subsequently annealed at 180ºC for 15 min in an atmosphere of Argon and allowed to cool to room temperature. A scanning electron microscope (SEM) was used to observe the surface morphology.

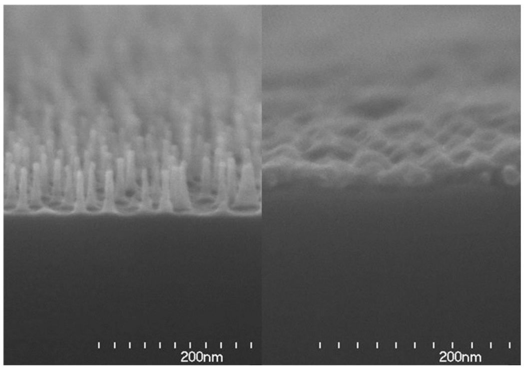

Fig. 1: SEM images of 50nm tall Si nanopillar surface before and after coating with S-PEDOT.

Results and Discussion: Previous attempts [3] at making hybrid solar cells with nanostructures have demonstrated its benefits to light absorption. However, the improvements to current density (J_{sc}) or voltage (V_{oc}) have not been as significant. This can be attributed to higher recombination rates due to poor interfacial contact between PEDOT and Si as compared to a planar interface. Additionally, the interstitial voids created can become potential sites for the growth of silicon oxides, which further deteriorate the performance of the device. This study shows that while PEDOT:PSS is not able penetrate more than 24% of the depth of Si nanopillars, thus having a ratio actual contact area to substrate area of 0.62. However, S-PEDOT was able to completely impregnate 50 nm nanopillars [Fig. 1] and penetrate at least 60% of 80 nm nanopillar translating to a contact ratio of 2.38 and 1.42 respectively. This increase in contact area should positively impact carrier separation and current concentration in future hybrid solar cells. More information will be shared in the presentation.

[1] H. Yano et al., *Sci. Adv.,* **5**, eaav9492 (2019).
[2] S. Samukawa, *Applied Surface Science,* **253**, 6681–6689 (2007).
[3] Z. Wang et al., *Nano Energy,* **41**, 519-526 (2017).