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Roll-to-roll fabrication of flexible thin film solar cells on low cost three-dimensional nano-textured substrates

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Thin film solar cell is an attractive alternative other than conventional crystalline silicon based solar cell. They have advantages of low cost and potentially flexible as thin materials are used. Typically, thin film solar cells, such as amorphous silicon (a-Si), Cadmium telluride (CdTe), etc., have relatively lower power conversion efficiency as compared with the conventional crystalline silicon solar cells. Introducing the bottom texture is one of the typical methods to improve the performance of the thin film PV devices by enhanced optical absorption. Previously we have reported self-organized nanospike (NSP) and nanowell (NWL) which can significantly enhance the photon absorption of PV material [1, 2, 3]. Recently, we have developed a novel type of three-dimensional (3-D) nano-textured substrate base on aluminum, using low cost electrochemical processes which can significantly improve the efficiency of a-Si thin film solar cells. Particularly, the textured aluminum is used as the supporting substrate and back contact which makes the device/module becoming flexible at low cost. It is worth noting that the key of forming 3-D nano-texture with controllable pitch and roughness is the specially designed nanoscale pattern imprint. By engineering the pitch and the roughness of the nano-texture, optical absorption of the PV device can be maximized. Therefore, thinner a-Si film is needed to absorb same amount of light as compared to planar counterpart. Other than the fact that less material will be consumed, thinner film of a-Si can greatly facilitate the minority carrier collection without sacrificing the photon absorption. In addition, this is favorable for a-Si solar cell as the stability of the PV performance can be improved by decreasing the thin film thickness.

The PV device fabrication process can be elaborated as follows. A clean aluminum foil will be imprinted with silicon stamp to create initial nanoscale pattern on the foil. The foil will be then anodized with our previously developed high voltage anodization. During anodization, three-dimensional (3-D) nano-textured aluminum will be obtained under the anodic aluminum membrane (AAM). After acid treatment to remove AAM, the resulting nano-textured aluminum is ready for a-Si thin film deposition by plasma enhanced chemical vapor deposition (PECVD). After that, 200nm of ITO is deposited serving as top electrode contact.

Due to the engineered photon trapping mechanism, our preliminary results have shown that the power conversion efficiency of a-Si based devices can be improved by more than 20% as compared to the planar control devices. Moreover, we have developed a roll-to-roll process to scale up the nano-textured substrate which enables large scale production and commercialization. Considering light weight, flexibility and low cost nature of Al foil used in this technology, a-Si thin film solar cells developed on this platform will have attractive cost-effectiveness and can be used for variety of applications including utility power generation and portable electronics.

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