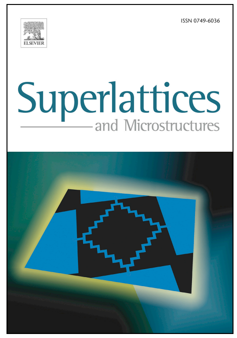
Accepted Manuscript



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PII: S0749-6036(18)31041-3

DOI: 10.1016/j.spmi.2018.08.016

Reference: YSPMI 5861

To appear in: *Superlattices and Microstructures*

Received Date: 18 May 2018

Revised Date: 7 August 2018

Accepted Date: 17 August 2018

Rear Contact Silicon Solar Cells with a-SiC$_X$:H Based Front Surface Passivation for Near-Ultraviolet Radiation Stability

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Abstract

Surface recombination (due to dangling bonds) and lower absorption (due to the low absorption coefficient of silicon (Si)) are the major hindrances in silicon-based photovoltaic (PV) devices. To overcome this, numerous complex texturing schemes are projected to enhance the light trapping. However nanostructured cells are not efficient due to the large surface to volume ratio which enhances surface recombination. Thus, the nanostructured cells require additional passivation scheme to mitigate the recombination losses. Here, we have designed a nontextured, 15% efficient, amorphous silicon carbide hydrogenated (a-SiC$_X$:H) passivated, 10-micron thick rear contact Si solar cell device. Considerable reduction in photo reflectance is obtained in the near ultraviolet (UV)/visible spectral region together with near UV stability at higher surface recombination velocity (SRV). External quantum efficiency (EQE) >90% is achieved by the a-SiC$_X$:H based device (within the wavelength spectrum of 480-620 nm). Improvement in spectrum response give rise to 28.1 mA.cm^{-2} short circuit current density (J_{SC}). Further, the performance of a-SiC$_X$:H passivated device is compared with a conventional dielectric anti-reflective coating (ARC) and high-low junction-based surface passivation techniques. Results indicate that the presence of a-SiC$_X$:H reduces the hole concentration near the front surface which eventually decreases the surface recombination. Highly efficient and reliable solar cells can be achieved by the design schemes reported in this paper, which balance both the photonic and electronic effects together.

Keywords — Absorption, Interface, efficiency, recombination, surface passivation, solar cell

I. INTRODUCTION

Photovoltaic (PV) market is dominated by silicon (Si) wafer technology [1], which is a reliable material present in abundance. It is employed as PV material due to its established fabrication process. However, Si-based PV devices face absorption related issues due to the low absorption coefficient of Si and hence requires thick (>100 µm) Si wafer, in order to utilize the spectrum efficiently [2]. Therefore, the necessity of thick wafers and high-quality Si considerably raises the cost of the module, whereas cost-effective modules are required to make PV system feasible at a commercial level, with module price to be <$0.5/watt [3]. Cheaper and energy efficient solar cells with high efficiency can be realized by a reduction in the thickness of the active layer [4, 5]. Nevertheless, electrical characteristics should be optimized along with optical absorption of these thin devices to enhance the performance of solar cell [6, 7]. In previous years, significant effort has been made to increase the light absorption by nanoscale light trapping using nanocones [8, 9], nanowires [10, 11], nanodomes [12] and nanoholes [13]. Despite the success in light trapping the power conversion efficiencies (PCEs) of the thin devices remains below 11%, excluding 15.7% and 13.7% as reported by Branham et al. [14] and Jeong et al. [3] respectively (the aforesaid research works used complex texturing schemes). Large surface to volume ratio enhances surface recombination which eventually decreases the overall performance of these devices [3]. In the 1980s the advancement in the passivation of both surfaces leads to the PCEs above 20%. Today's trend is to minimize the thickness of active materials keeping the efficiencies high. Thus, passivation of both front and back surfaces is essential for Si solar cells. This is due to higher surface to volume ratio of thin devices compared to thick devices. In crystalline Si, recombination losses occur