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Performance Enhancement of Crystalline Silicon Solar Cells by Coating with Luminescent Silicon Nanostructures

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In this work we report a technique that is potentially capable of increasing the efficiency of crystalline silicon solar cells, which dominate the present-day market of photovoltaic devices. The simple and cost-effective method involves coating the surface of a commercially procured silicon solar cell with luminescent silicon nanocrystals. Core/shell silicon/silicon-oxide nanostructures are fabricated by an inexpensive and reproducible technique, where coarse silicon powders are repeatedly milled, oxidized, and etched until their sizes are reduced so as to exhibit room-temperature photoluminescence under ultraviolet excitation. A thin coating of these nanostructures on a standard solar cell, obtained by a simple dip-coating method, increases the open-circuit voltage and short-circuit current, which consequently increases the maximum power delivered by ~16.3% and efficiency by almost ~39%. We propose that the core/shell nanostructures act as luminescent convertors that convert higher-energy photons to lower-energy photons, thereby leading to less thermal relaxation loss of photoexcited carriers.

Key words: Core/shell silicon/silicon-oxide nanostructures, photoluminescence, luminescent convertors, solar cell

INTRODUCTION

Silicon (Si) is by far the most dominant material used in the photovoltaic (PV) industry.[1] More than 80% of solar cells produced are made from bulk crystalline Si and the remaining 20% mostly from amorphous Si. Consequently, almost all PV systems with >1 kW peak power rating (kW_p) are fitted with crystalline Si solar cells.[2] Despite considerable research on other semiconducting materials and polymers as potential candidates for solar cells, it has so far remained difficult to replace Si as the material of choice for PV devices. This is primarily because the development of Si PV is inextricably linked with the Si-based microelectronics industry.[3] However, standard Si PV technologies, which essentially focus either on wafer-based PV systems or on thin-film-based approaches, suffer from several drawbacks: the processes involved are energy consumptive, material wastage during processing is substantial, the cells are usually much thicker than desired, and most importantly there is a skewed trade-off between cost and efficiency.[4–6] In addition, another important limitation of bulk Si solar cells is their very low responsivity in the ultraviolet (UV) range.[7–9]

In response to the inherent shortcomings of standard Si PV technology, several new approaches which are often termed "third-generation" approaches aim to reduce the cost (per watt peak) of thin-film technologies by increasing the efficiency of PV devices with only a small increase in areal costs.[1,3,10] Besides effort to devise strategies to

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