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Letters

A graded diameter and oriented nanorod–thin film structure for solar cell application: a device proposal

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Abstract

This paper presents a device proposal based on a junction between an absorbing semiconductor nanorod structure and another window semiconductor layer for solar cell application. The possibility of band gap tuning by varying the diameter of the nanorods along the length, higher absorption coefficient at nanodimensions, the presence of a strong electrical field at the nanorod-window semiconductor nanojunctions and the carrier confinement in lateral direction are expected to result in enhanced absorption and collection efficiency in the proposed device. Process steps, feasibility, technological tasks needed for the realization of the proposed structure and the novelty of the present structure in comparison to the already reported nanostructured solar cells are also discussed.

Keywords: Nanorods; Nanojunctions; Graded diameter; Oriented structure; Nanoparticle

Thin film heterojunction solar cells are known to have several advantages over other solar cell configurations in terms of the availability of starting raw materials, low material and processing costs and a large number of possible techniques for fabricating large-area devices. A large number of semiconductor materials which exhibit only one conductivity-type but have properties useful for solar cell devices can be used for fabricating heterojunctions. A number of novel methodologies have

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been employed to increase the photon absorption and collection efficiency of thin film structures. These include use of heterojunction devices with a window semiconductor and variable gap multilayer structures.

Confining the growth of semiconductor materials to the nanolayer (2D), nanorod (1D) and nanoparticle (0D) forms, etc. allows tailoring the structural, optical and electrical properties of materials [1]. Band gap, absorption coefficient, nature of the band gap, conductivity type and density of states are some of the size-dependent properties which are important for solar cell applications [2–4]. *As will be described in the following paragraphs, variable diameter-nanorods are potentially more suited for use in solar cell devices in comparison to nanoparticles or fixed diameter nanorods.* Various solar cell semiconductor materials have been synthesized in the nanorod form using a variety of synthesis methods. These methods are low-cost, compatible with thin film processing methods and can easily be upgraded for large-area applications. By synthesizing a semiconductor material in the form of nanorods (i) the band gap can be modified by controlling the diameter (ii) the absorption coefficient can be enhanced at nanodimensions and (iii) the carrier flow can be restricted to the desired direction. The bandgap of a semiconductor material increases with reducing size due to the quantum confinement of the carriers in nanodimensions [2]. This behaviour can be explained by effective mass and tight-binding approximations [5,6]. The absorption coefficient of semiconductor nanomaterials is significantly enhanced due to the increase in the concentration of density of states at the band edges [2]. In a nanorod structure, carrier motion is confined in the lateral direction but unobstructed along the length [7].

A solar cell device proposal with the objective of utilizing the above-mentioned characteristics of nanostructured materials is shown in Fig. 1. The design is based on (i) a junction between an absorbing semiconductor material in nanorod form and a window semiconductor layer, (ii) orientation of nanorods along the incident light direction and (iii) tailoring the diameter of the nanorods along the length for efficient absorption. Size-selected metal nanoparticles can be used as seeds for controlling the starting diameter of the nanorods [8]. An optimized substrate coverage with the metal nanoparticles, i.e. uniform coverage with minimum overlap between the nanoparticles, is important for the maximal absorption of incident light energy by the resulting semiconductor nanorod structure. The extent of substrate coverage will

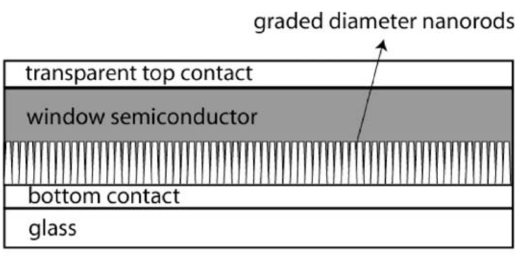

Fig. 1. Schematic of the graded diameter and oriented nanorod–thin film solar cell structure.