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Solar Energy Materials & Solar Cells 85 (2005) 293–300
Solar Energy Materials & Solar Cells
www.elsevier.com/locate/solmat

Letter

Third generation multi-layer tandem solar cells for achieving high conversion efficiencies

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Received 19 July 2004

Abstract

Different ways of connecting solar cell structures to form multi-layer tandem solar cells have been considered by re-visiting relevant device designs. It is found that the present use of a series connection or tunnel junction approach is detrimental to charge-carrier collection in the tandem cells. Each tunnel junction introduced to the solar cell structure decelerates the charge carriers and allows them to recombine at the vicinity of the tunnel junction. The adoption of parallel connections has several advantages over series connections and there is high potential for achieving enhanced efficiencies in third generation tandem solar cells. In these devices, charge carriers are continuously accelerated across the whole device and collected in the external circuit. Multi charge-carrier production and impurity photo-voltaic mechanisms are also built into this system to enhance its performance by increasing the short-circuit current density.

Keywords: Third generation solar cells; Multi layers; Tandem solar cells; Tunnel junctions; Impurity photovoltaics

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0927-0248/$ - see front matter
doi:10.1016/j.solmat.2004.08.008

1. Introduction

The market penetration of PV solar technology is hindered by its high cost. Various new methods have been introduced to overcome this barrier. Multi-layer tandem solar cells, new low-cost materials and device structures and the mass production of PV-modules are some of them. In the case of tandem solar cells, the present trend is to move from one-junction devices to double-junction, triple-junction and multi-junction structures. The current popular method is to use a tunnel junction to combine different cells. This communication presents other methods of achieving this aim and outlines the disadvantages of the current practice of using a tunnel junction approach.

2. Tandem solar cells

The main aim of the tandem solar cell is to absorb a major part of the solar spectrum and hence to increase the efficiency of the device by increasing the electric current. The approach is to fabricate p–n, p–i–n or any other diode structure with different bandgap semiconductors and connect them to enhance the PV conversion. As shown in Fig. 1, cell-1 at the front is fabricated with a wide bandgap material to convert high-energy photons from the blue-end whilst cell-3 at the back is fabricated with a narrow bandgap material to convert low-energy photons from the infra-red end. With this approach, the next step is to connect the cells together to form one device. There are two possible ways of achieving such a tandem solar cell; by connecting them in series or in parallel configurations.

2.1. Connection in series

This type of connection is widely used today. Adjacent devices are connected using a tunnel junction. The schematic diagram of such a tandem solar cell is shown in Fig. 2 and the corresponding energy band diagram is shown in Fig. 3. In this series connection, the n-type material of one device is connected to the p-type material of the adjacent device (Fig. 2). In other words, the conduction band of one device is connected to the valence band of the adjacent device (Fig. 3). The idea is to convert photons with different energy ranges in 3 different devices and collect the charge carriers efficiently to generate high power in the external circuit.

2.2. Connection in parallel

The other approach to fabricating a tandem solar cell is by connecting a large number of solar cells in parallel. Figs. 4 and 5 show the schematic diagram and the energy band diagram of such a device. In this case the material changes its conduction type from n^+ to p^+ through a series of layers consisting of n^+, n, n^-, i, p^-, p and p^+. In this notation, n^+, n, n^- and i denotes heavily n-doped,