Superlattices and Microstructures 83 (2015) 61–70

Contents lists available at ScienceDirect

Superlattices and Microstructures

journal homepage: www.elsevier.com/locate/superlattices

A novel thermo-photovoltaic cell with quantum-well for high open circuit voltage

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ARTICLE INFO

Article history:
Received 27 December 2014
Received in revised form 6 March 2015
Accepted 10 March 2015
Available online 17 March 2015

Keywords:
Thermo photovoltaic cell
Tandem cells
Solar cells with quantum-wells

ABSTRACT

We design a thermo-photovoltaic Tandem cell which produces high open circuit voltage (V_{oc}) that causes to increase efficiency (η). The currently used materials (AlAsSb–InGaSb/InAsSb) have thermo-photovoltaic (TPV) property which can be a *p*–*n* junction of a solar cell, but they have low bandgap energy which is the reason for lower open circuit voltage. In this paper, in the bottom cell of the Tandem, there is 30 quantum wells which increase absorption coefficients and quantum efficiency (QE) that causes to increase current. By increasing the current of the bottom cell, the top cell thickness must be increased because the top cell and the bottom cell should have the same current. In the top cell, by increasing the thickness, absorption coefficients and quantum efficiency increase that causes to increase the current. Current increment is also the second factor that causes to increase overall efficiency.

1. Introduction

In the quest for renewable energy sources, mankind has placed great interest and re-sources toward the progression of photovoltaic. As this interest has grown, various types of solar cells have

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http://dx.doi.org/10.1016/j.spmi.2015.03.018

been produced: organic, thin films II–IV, single crystalline silicon, single-junction III–V, Tandem and multi-junction (MJ) III–V cells [1].

Using Tandem solar cells is one of the methods to achieve high efficiency in transforming solar energy into electricity. These solar cells made of III–V semiconductors can be arranged in a cascade architecture which increases their efficiency. A tunnel diode structure is thus normally used. The optical and electrical losses of these diodes must be as low as possible in order not to affect the increased efficiency of the cells. A small thickness of cascaded layers and large rates of I_p/V_p can lower the optical and electrical losses, respectively. On the other hand, in the process of tunnel diode production, high density of dopants will result in crystal defects and light absorption. Also unwanted diffusion of impurity atoms may occur when subsequent layers are grown [2].

In multi-junction solar cells such as Tandem, each cell converts a portion of the solar spectrum into electrical energy that causes the optimized use of the spectrum [3].

Tandem is made when the junctions are stacked on top of one another in series, the cells can be modeled as an equivalent series circuit such that the output current would be limited by the junction to produce the least amount of current. So, to increase the least amount of the current, a technology such as QWs can be used. On the other hand, the voltages of each junction must add to each other [1].

The trade-off between incorporation of a sufficient number of quantum wells ensures high photon absorption efficiency and increased short-circuit current. That is, extending of absorption spectrum leads to longer wavelengths [4].

The rate of radiative emission from the QWs can be calculated from the knowledge of the absorption coefficient and applying the principle of detailed balance [5].

Thermo-photovoltaic (TPV) systems are subsequently converted into electron-hole pairs via a low-bandgap photovoltaic (PV) medium; these electron-hole pairs are then conducted to the leads to produce a density current [6]. The obvious difference between solar photovoltaics and thermo photovoltaics is that a TPV system generates its own light. As a result, high efficiency is possible by tailoring the emission spectrum to match the spectral response (or quantum efficiency) of the TPV cells [7].

III–V group semiconductors are suitable for TPV cells since their narrow direct band-gaps in a range from 0.3 eV to 0.7 eV closely match to the peak wavelength of the thermal source [8].

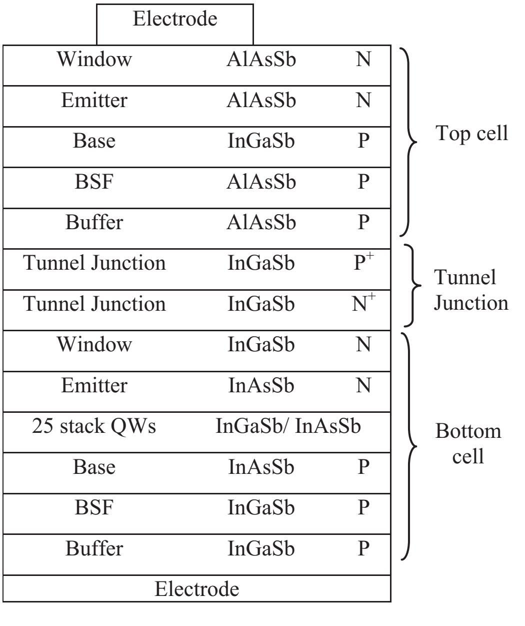

Fig. 1. A double junction AlAsSb–InGaSb/InAsSb Tandem solar cell.