Renewable and Sustainable Energy Reviews 65 (2016) 537–552

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Progress in plasmonic solar cell efficiency improvement: A status review

P. Mandal*, S. Sharma

Department of Physics, University of Petroleum and Energy Studies, Bidholi-248007, Dehradun, India

ARTICLE INFO

Article history:
Received 29 June 2015
Received in revised form
28 June 2016
Accepted 7 July 2016

Keywords:
Review
Plasmonic solar cells
Surface patterning
Surface plasmon
Dye-sensitized solar cells

ABSTRACT

Solar cell efficiency improvement has been one of the major concerns to realize ultimately the cost effective efficient solar cells. Among various ways to improve solar cell efficiency, plasmonic light trapping mechanism has been found to be of immense interests recently. The mechanism of strong scattering into the active materials and guiding of light at the excitation of plasmons at the metal-semiconductor interface play significant role for better photon harvesting. The present review concentrates on the recent advances on the application of plasmonics in inorganic semiconductor solar cell efficiency improvements. Various research groups active in this field have employed various metal nanostructures on to the surface of solar cells to achieve higher efficiency. This review partially also concentrates on surface nanopatterning of solar cells with nonmetallic dielectrics. Finally, a brief account on the dye-sensitized solar cell is presented to show the potential of plasmonics in solar cell research.

Contents

1. Introduction

Solar cell, a source of cleaned electrical energy has been the most important alternative renewable energy source for many years. The device basically converts sunlight or solar radiation into electrical energy and therefore, it can reasonably be considered as a source of endless energy as long as sunshine persists. This has led to the primary interests in solar cell research by several research groups worldwide. The most important and technologically developed solar cell module is based on 'silicon' till date. However, a wide variety of solar cell structures also available based on various active materials, such as, thin film CIS ($CuInS_2$ (/Se_2)), Cu(In, Ga)S_2 (/Se_2) solar cell, single-/multi-junction III−V solar cells etc.

Dye-sensitized/quantum-dot−sensitized solar cells and polymer solar cells also seem to be very interesting and promising since the price of these types of solar cells is expected to be much cheaper. However, in general, many factors such as device efficiency, materials capital and the mature device processing

* Corresponding author.
E-mail address: pmandal@ddn.upes.ac.in (P. Mandal).

http://dx.doi.org/10.1016/j.rser.2016.07.031
1364-0321/

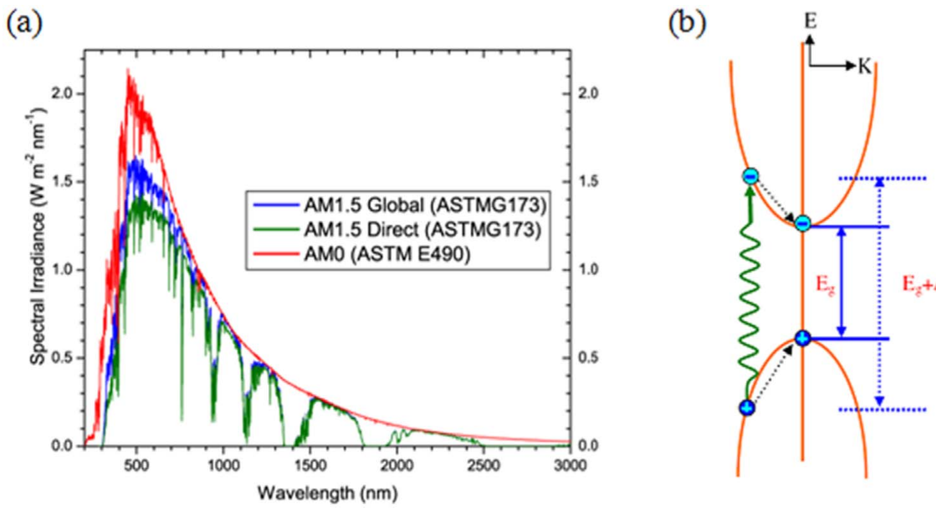

Fig. 1. (a) Represents standard solar spectra and (b) schematic for the electron-hole (e-h) pair generation by the absorption of photon energy by an arbitrary semiconductor having band gap (direct) energy E_g. Photons energy above the band gap (i.e excess energy ΔE) will be lost due to thermal heating (indicated by black dotted arrows). (a) is adapted from the reference [1].

technology have always been the important issues for making these devices efficient and cheap with large scale productivity. Among the issues, the first and foremost importance is given to the improvement in the solar power conversion efficiency. Effective absorption in the wide solar spectral range covering 350–1250 nm (standard solar spectrum [1] is shown in Fig. 1(a)) has been an important aspect of solar cell research. The primary interest of increasing the cell efficiency is to study the efficient light trapping mechanism which can result in enhancement in the optical absorption [2–21]. However, efficient absorption does not guarantee for efficient generation of electron-hole pairs and hence photo-voltage. Photon energy around the band gap of the semiconductor used as the active material will only effectively create charge pairs. The excess photon energy (above the band gap) will be dissipated as heat. A schematic representation (Fig. 1(b)) will help in understanding the process. Therefore, suitable choice of active materials will enable in obtaining better photon absorption and generation of charge pairs. However, no single active semiconductor will be best for the efficient absorption; therefore multi-junction solar cells (or tandem solar cells) have also been

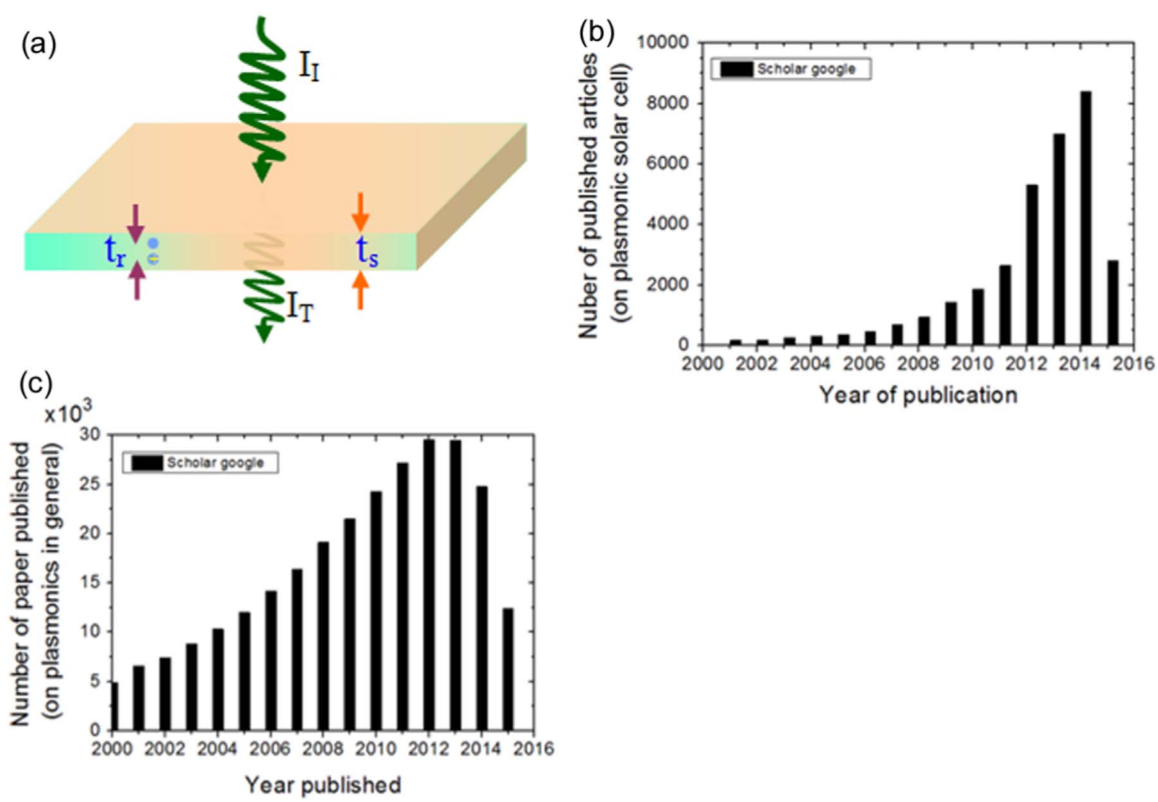

Fig. 2. (a) Represents photon absorption scheme by a semiconductor of thickness t_s. Carrier diffusion length is represented by t_r. I_I and I_T represent incoming and outgoing photon fluxes, respectively. (b) represents the research strength over the years in terms of published papers (to the author's knowledge using search engine 'scholar google') showing interest in plasmonic solar cells. The above search engine has also been used for the general search on plasmon associated with all possible fields of research (corresponding bar graph plot is shown in (c)).