Materials Letters 289 (2021) 129390

Contents lists available at ScienceDirect

Materials Letters

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

Multi-stacked transparent-electrode for transparent photovoltaics

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ARTICLE INFO

Article history:
Received 18 December 2020
Received in revised form 15 January 2021
Accepted 16 January 2021
Available online 26 January 2021

Keywords:
Transparent photovoltaics (TPVs)
Multi-stacked transparent-electrode
Invisible power generator

ABSTRACT

Transparent photovoltaics are the solar cells to generate electric-power from the light. Due to the high transparency, TPV has a high potential to be adopted in the transparent windows, as the invisible power generator. To improve the TPV performance, multi-stacked transparent-electrode (MTE) was designed having Ni film in two indium-tin-oxide layers. Ni-5 nm MTE shows prominently improvement to drive the high open-circuit voltage (V_{oc} = 0.507 V) and short-circuit current density (J_{sc} = 3.00 mA/cm^2), resulting in power-conversion-efficiency of 0.45% under AM 1.5G illumination. The functional transparent-electrode is a pivotal scheme to enhance TPV performance with less trade-off in transmittance. The TPV has the high potential to be applied in the transparent electronics and windows as the invisible power generator.

1. Introduction

Transparent photovoltaic (TPV) is the see-through solar cell device to transmit the visible range light while absorbing the ultraviolet (UV) light. This TPV is aimed for the transparent power generator [1]. And thus, the ultimate advantage of TPV is to be applied to the on-site windows for buildings, vehicles and displays [1], which removes the requirement of installation sites or space of the conventional and opaque solar cells. TPVs can be the invisible electric-power generator in residential and commercial buildings to pursue the goal of energy neutral.

Different types of transparent solar cells were investigated for the organic [2] and perovskite [3] materials, however, the instability of devices limit their application in the atmospheric condition besides the tiny scale of active area and electric-power production. In the aspect of long-term stability, metal-oxide based TPV may satisfy the requirement with advantages in the low-cost and common accessibility for semiconductor processes [4]. Recently, the functional light-absorbing materials have been investigated for the improvement of power production of TPVs [5,6].

In this work, a functional transparent electrode is designed to improve TPV performances. Multi-stacked transparent-electrode (MTE) was designed to enhance the electrical conductivity at a low degradation of transmittance of TPVs. The functional MTE (Ni-5 nm) use substantially improved the TPV efficiency of 0.45% from the 0.32% of the conventional TPV. The electrical and optical analyses were performed to find an optimum metal-thickness for the TPVs.

2. Experiment procedures

The fluorine-doped tin oxide-coated (FTO) glass was used as the substrate. The light-absorbing Si film was deposited by the plasma-enhanced chemical vapor deposition (PECVD) system. To form this Si TPV, electrically conductive and optically transparent electrode was applied on the Si. For the top electrodes, sole-ITO film (160 nm) and MTE (ITO/Ni/ITO) were prepared. MTE has the lower-ITO (80 nm), Ni-layer (1, 3, or 5 nm), and the upper-ITO (80 nm). The interface between the ITO layers and Ni-film was analyzed by a field-emission scanning electron microscope (FESEM, JEOL, JSM_7800F) a field-emission transmission electron microscope (FETEM, JEOL, JEM-2100F).

The current–voltage characteristics of TPV device were measured by using potentiostat/galvanostat (PGStat, ZIVE SP2, WonA Tech). A simulator system (McScience-K3000, Korea) was used to measure the solar cell performances, and a photovoltaic power meter (McScience-K101) was used to monitor the I-V characteristics under one-sun (100 mW/cm^2) illumination. The transmittance was measured using a UV–visible diffuse reflectance spectrophotometer (UV-2600, Shimadzu).

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https://doi.org/10.1016/j.matlet.2021.129390
0167-577X/