

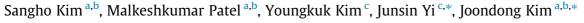
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# Multi-stacked transparent-electrode for transparent photovoltaics





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#### 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/cm²), 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.

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#### 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

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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/cm²) illumination. The transmittance was measured using a UV–visible diffuse reflectance spectrophotometer (UV-2600, Shimadzu).

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