Performance analysis of Plasmonic based ZnO/Silicon Thin-Film Heterojunction Solar cell

Syed Sadique Anwer Askari, Manoj Kumar, Muzaffar Imam, Tauseef Ahmed and Mukul Kumar Das
Department of Electronics Engineering, Indian Institute of Technology (ISM) Dhanbad, India
E-mail: anwer.ism@gmail.com

1. Introduction

Silicon based heterojunction solar cells have gained popularity in the market recently because such structure with c-Si as absorber layer can have the power conversion efficiency me than 25% [1]. Several efforts has been made to reduce the cost by curtailing process steps e.g., by using ZnO as both emitter and anti-reflector layers. But the experimentally reported efficiency of ZnO/p-Si solar cells is somewhat below the theoretically predicted values. Therefore this requires sophisticated light management technique to enhance the efficiency. Scattering centers can be created by introducing metal nanoparticles (MNPs) which can trap the incident light into the absorber layer by increasing the optical path length of solar cell. Therefore by introducing MNPs, the performance of the ZnO/Si solar cell can be improved [2-4].

This work is focused on investigating ZnO/Silicon heterojunction solar cell to reduce the cost and to improve the efficiency of Si based heterojunction solar cells. In this paper, we have presented a two-dimensional (2D) TCAD simulation study of plasmonic effects of gold MNPs on ZnO/Si heterojunction solar cell considering finite difference time domain (FDTD) method and complete carrier transport.

2. Device structure and Simulation Results

The schematic structure of the ZnO/Si heterojunction solar cell of TCAD simulation is shown in Figure 1. Thin layer of ZnO on p-Si thin-film is considered as emitter layer. Carrier lifetime and doping density in p-Si are considered to be ~10^{15} /cm^3 and 10μs respectively. Gold MNPs with 20nm diameter are taken to analyze the plasmonic effects of sub-wavelength sized MNPs. FDTD simulation with complete carrier transport simulation is performed by SILVACO TCAD simulator [5] to study the effects of plasmonic effects of gold MNPs on ZnO/Si heterojunction solar cell.

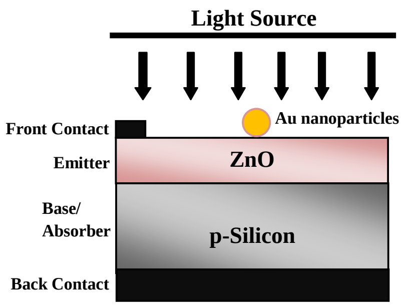

Figure 1: Schematic diagram of ZnO/p-Si solar cell with gold MNPs on top of ZnO layer.

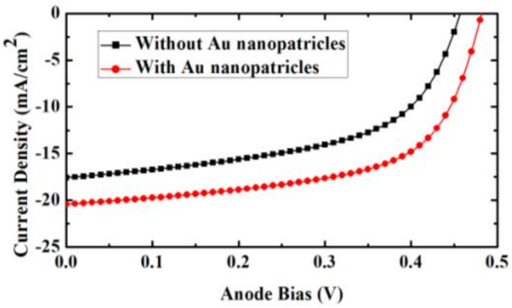

Figure 2: Light J-V characteristics calculated with the ZnO(80nm)/p-Si(1μm) heterojunction solar cell with and without gold (Au) MNPs.

Figure 2 shows illuminated JV characteristics of ZnO/Si solar cell. For ZnO/Si solar cell, short-circuit current density (J_{SC}) and open circuit voltage (V_{OC}) are observed as 17.58 mA/cm^2 and 0.457Vrespectively. J_{SC} is improved to 24.51mA/cm^2 by incorporation Au MNPs on the top surface of ZnO. An increase in J_{SC} is mainly due to scattering of incident light by Au MNPs. Increment in V_{OC} has been observed, that is because of reduction in electrical resistance due to incorporation of Au MNPs. Power conversion efficiency (PCE) increased from 4.46% to 7.24%.

3. Conclusions

Performance of ZnO/Si heterojunction thin-film solar cell has been investigated by considering the effect of gold (Au) MNPs on J_{SC}, V_{OC} and PCE. By incorporating the plasmonic effects, J_{SC} has been enhanced. Further, proper selection of diameter and material of MNPs can improve the light trapping in the absorber layer, hence enhances the PCE of ZnO/Si heterojunction solar cell. Achieved PCE is low mainly due to the recombination loss at ZnO/Si interface which may be reduced by proper choice of buffer layer between ZnO and Silicon.

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