Nanopyramid-based absorber to boost the efficiency of InGaN solar cells

Walid El huni[1,], Yacine Halfaya[1] , Soufiane Karrakchou[1,2,*], Taha Ayari[1,2], Suresh Sundaram[1], Simon Gautier[3], Paul L. Voss[1,2], Jean Paul Salvestrini[1,2], Abdallah Ougazzaden[1,2].

[1]UMI 2958, G T - CNRS, 2 rue Marconi, 57070 Metz, France.

[2]School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0250, USA

[3]Institut Lafayette, 2 rue Marconi, 57070 Metz, France.

*Email : soufiane.karrakchou@gatech.edu

Abstract :

Today, due to its low cost, about 94% of the PV market is based on silicon solar cells whom highest efficiency is 26.3%, close to the theoretical maximum efficiency[1]. To further increase its efficiency, combination of III-V materials with silicon solar cells is an attractive solution. Despite the ideally positioned bandgap of the InGaN materials system, it has been so far difficult to achieve InGaN/Si tandem solar cells. One crucial challenge has been the growth of high quality epitaxial InGaN. A potential solution may lie in the use of nano-selective area growth to improve the materials as we have shown recently by achieving the growth of dislocation-free thick InGaN nanopyramid arrays with up to 33% of indium content[2]. In this work, we investigate the performance, through 3D optical/2D electrical coupled simulations, of $In_{0.30}Ga_{0.70}N$ nano-pyramid-based solar cells. When compared to planar InGaN absorber, such a nano-structured absorber, in addition to allow for the growth of thick and In-rich InGaN absorber (which is not the case of planar structure), is shown to drastically increase the efficiency of the solar cell especially in the case of low p-GaN doping and large residual doping of the InGaN absorber. These improvements are shown to originate from both the hetero- interface junction which lies on the semi-polar planes leading to much less required doping of the p-GaN layer to compensate for the polarization charge effect[3], and SiO_2 mask used for the selective area growth of the nanopyramids, which helps trapping the light into the nano-pyramids.

[1] K. Yoshikawa *et al.*, “Silicon heterojunction solar cell with interdigitated back contacts for a photoconversion efficiency over 26%,” *Nat. Energy*, vol. 2, no. 5, 2017.

[2] S. Sundaram *et al.*, “Nanoselective area growth and characterization of dislocation-free InGaN nanopyramids on AlN buffered Si(111) templates,” *Appl. Phys. Lett.*, vol. 107, no. 11, 2015.

[3] A. E. Romanov, T. J. Baker, S. Nakamura, and J. S. Speck, “Strain-induced polarization in wurtzite III-nitride semipolar layers,” *J. Appl. Phys.*, vol. 100, no. 2, 2006.