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ORIGINAL ARTICLE

Design guidelines of InGaN nanowire arrays for photovoltaic applications

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Abstract

III-Nitride NanoWire array Solar Cells (NWSCs) combine the inherent properties of III-N semiconductors with waveguiding and confinement properties of nanowire arrays. In the present paper, some design guidelines of NWSCs made from Indium-Gallium-Nitride InGaN alloys are presented. Firstly, a detailed balance analysis was performed to show the importance of using InGaN materials to effectively convert the light to electricity, followed by an optical modelling to point out the advantages of using periodic nanowire arrays in designing solar cells. From the detailed balance analysis, it is expected that single junction solar cells made from In0.63Ga0.37N alloy result in the highest light-to-electricity conversion efficiency of 31%, and the Rigorous Coupled Wave Analysis RCWA simulations show that nanowire arrays made from In_xGa1-_xN fractions (x values) ranging between 50 and 77% alloys may achieve efficiencies of more than 33%, with a maximum efficiency of 37.7% for In0.67Ga0.33N NW array. Substrate choice, array density and filling material impacts on device performance were also studied.

Keywords: *Detailed Balance Principle; InGaN Alloys; Nanowires; Optical Modelling; Solar Cell.*

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INTRODUCTION

Compound III-Nitride semiconductors (InN, GaN and AlN) and their alloys are widely used materials in optoelectronics fabrication of light-emitting diodes LEDs and laser diodes LDs emitting in visible and Ultra-Violet UV bands [1-3]. In photovoltaics, however, III-Nitrides are less used materials compared to other semiconductors (silicon, cadmium telluride, chalcopyrites,...) despite their potential to convert most of the solar spectrum to electricity [4] and their ability to withstand high-temperature and ionising radiation [5,6].

To build these devices, thin layers of III-nitrides are, usually, grown on foreign substrates (sapphire or silicon) with thicknesses limited by the high lattice mismatch which results in a high density of dislocations and strain induced polarisation.

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On the other hand, in the last two decades, III-Nitride nanowire based photonic devices attract big attention owing to the ability of nanowires to be grown on foreign substrates, by various methods, without having to worry about lattice mismatch [7-11]. Furthermore, NanoWire array Solar Cells NWSCs present a significantly large effective surface area compared to planar cells for the same volume of matter and, hence, can present an enhanced light absorption and free carrier generation.

According to several recent research, the best experimentally achieved efficiencies of nanowire solar cells nowadays are, 13.8% for indium-phosphide InP NWSC [11] and 15.3% for gallium-arsenide GaAs NWSC [13], however, the III-Nitride based ones are still at lower efficiencies (with the best record of 2.73% [14]) and they have a longer way to go to meet the expected ambitions.