Proposal Accepted:
Program:
Topic Number:
Title: The next generation of high efficiency hybrid solar cells for integration into the CAMMRAD (Juxtopia®) visor
Research & Technical Areas: Chemical/Bio Defense, Materials/Science

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Topic Author: M. Jamal Uddin, Phone: (410) 951-4118, Fax: (410) 951-4110, Email: juddin@coppin.edu
Jahangir Alam, Phone: (410) 951-3471, Fax: (410) 951-4110, Email: alamj2003@yahoo.com

Acquisition Program:

Objective: Simulation and design of hybrid solar cell nanotechnology processing and fabricate the product for recharging mimic power sources to be used in CAMMRAD (Juxtopia®) visor

Description: This proposal focuses on exploiting science and technology of nanomaterials for future generation. The alternative energy generation technologies, hybrid solar cells are considered to be clean energy production techniques and are potentially of high efficiency. Indium gallium nitride (InGaN), the semiconductor shows promise in converting solar energy more efficiently into electricity. The key to InGaN's solar potential, is the material's large energy band gap range, which extends from 0.7 to 3.4 electron volts(eV). By adjusting the compound's Ga/In ratio, the tandem solar cell configuration can be fine-tuned to develop a solar cell device capable of capturing light energy from the sun spanning ultraviolet to infrared(UV to IR) with minimal loss of energy. Thus an InGaN-based semiconductor solar cell structure can be engineered to cover almost 95 percent of the sun's wavelengths, potentially achieving a solar-to-electricity conversion efficiency of 40 to 50 percent.

Phase I. Simulation and Design the Solar Cell Device: GaN LED and photo-detector structures are taken as a starting point for design of GaN/ Polymer hybrid solar cells. These structures include standard GaN p-i-n diodes, GaN p-i-n with InGaN quantum-wells (QW) and GaN p-i-n with InGaN as the i-region. The structures are modified to optimize light absorption, instead of emission as in LEDs,. As a result, theoretically the material is supposed to absorb more than 95% of the incident light within the first 300 nm and more than 99% within the first 500 nm. Hence, the total thickness of the device may be limited to500 nm. The solar cells are designed to optimize light absorption in the field-bearing i-region for maximum collection. The basic principles for designing will be using the standard p-i-n diodes configuration and GaN as the primary material and InGaN as the i-region to test for photovoltaic properties. The device design will be optimized first using simulation software such SILVACO, ANSOFT, and COMSOL phase wise as needed and thus the structures will be modified to optimize different parameters such as light absorption, lifetime and diffusion lengths of charge carriers as needed to fabricate the final device. We also propose to use sapphire as a substrate for the growth of the material.

Phase II. Fabrication of Hybrid Solar Cell :
The requirement for achieving solar conversion efficiencies greater than 50% for a photovoltaic device is that the device must have a band gap of 2.4 eV or greater. $In_xGa_{1-x}N$ is one of the most promising alloyed material that have the potency to meet this requirement. With varied Indium compositions of 0 to 40%, this alloyed material can be grown with growth systems using Metal Organic Chemical Vapor Deposition(MOCVD) or Molecular Beam Epitaxy(MBE). The material thus grown can be used for experimental studies for best alloying material suitable to make photovoltaic devices suitable for high efficiency solar cells. Indium Gallium Nitride has the appropriate optical properties and has been tried by engineers and scientists and proved to be a very promising alloy for high efficiency energy conversion device fabrication. We propose to put our best efforts on using this material to simulate, design, and fabricate a device using the device type known as p-i-n diode configuration as the preliminary solar cell in the first phase. We also propose to characterize the material using X-ray Diffraction, Photoluminescence, Emission and absorption spectroscopy to check the materials quality as well.

Phase III. Solar Cell application in CAMMRAD (Juxtopia®) visor: Using quantum dots and nanowires of the GaN in micro tandem growth structure of the solar cells, the conversion efficiency may be increased to higher values along with further miniaturization of the solar cells. These micro solar cell structures using nano tubes or wires incorporated into the solar cells materials during fabrication process, can be used for continuous recharging of the batteries with a very high percentage of efficiencies in the CAMMRAD viewer which can be seen in the JUXTOPIA design template. Current tandem cell technology is very expensive because it requires three or four classes of semiconductors, which can necessitate multiple growths in different reactors. The advantage of nitride semiconductor technology is that you can grow the entire tandem cell in a single epitaxy in a single reactor. Although our focus is on the development of a miniaturized solar cell capable of powering the operation of the CAMMRAD, this proposed structure can also be used in other micro devices in the field of medical applications.

Keywords: Hybrid Solar Cell, Photovoltaic, CAMMRAD (Juxtopia®) visor, Nanowire GaN, Polymer, Semiconductor, Nanotechnology, Quantum dots