Hybrid Organic/GaN Nanowire Structures for Solar Cell Applications

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Organic semiconductors are the type of material which recently found application in consumer electronics. Conductive polymers with conjugated π-bonds in molecular chain are extensively studied as a p-type material for inexpensive solar cells. Good light-absorbing properties of π-conjugated polymers led to an idea to combine organic and inorganic semiconductors into one photovoltaic device [1]. In this work we present our results on fabrication and characterization of hybrid solar cell combining π-conjugated polymer with GaN nanowires grown on conductive nucleation layer. Such nucleation layer enables to grow self-assembled nanowires on virtually any substrate. Moreover, it serves as buried electrical contact to nanowires. Superior electrical properties of nanowires enhance conductivity of light-absorbing layer, which in case of organic photovoltaics is limited by low charge carrier mobility.

Hybrid structures of poly(3-hexylthiophene-2,5-diyl) (P3HT) [2] and GaN nanowires were fabricated and characterized for this study. Self-assembled GaN nanowires were grown on conductive nucleation layer deposited on top of non-conductive crystalline silicon substrate using Plasma-Assisted Molecular Beam Epitaxy technique. Bottom contact to GaN nanowires was provided through nucleation layer which is an amorphous material of metallic electrical conductivity deposited on silicon substrate. P3HT solution was put on the array of nanowires by spin-coating resulting in a layer of p-type polymer with embedded n-type nanowires. The layer was covered by PEDOT:PSS electron blocking layer. Top contacts to a solar device were made using transparent conductive Indium Tin Oxide (ITO) layer or by depositing thin metal pattern on the surface of the device.

Morphology studies show that the space orientation of nanowires remains close to perpendicular to the substrate surface independently from nucleation layer thickness, which is consisted with reported results for growth of self-assembled nanowires on different amorphous substrates [3]. Quantum yield spectroscopy measurements were made in closed circuit mode. The results (see fig. 1.) show that structure exhibits photogenerated current maxima at 1.9 eV and 3.4 eV energy light which correspond to bandgap edge of P3HT and GaN respectively. This means that light generates electron-hole pairs in both materials and that there is efficient transfer between the materials. The observed direction of photocurrent confirms that GaN works as n-type layer and P3HT is a p-type layer in this heterostructure.

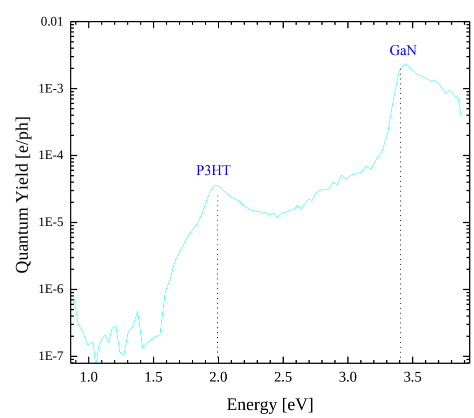

Fig. 1 Photocurrent spectrum

Electrical characteristics of nucleation layer-GaN interface were measured showing good ohmic contact between the components. Dependence of structures charge carrying properties on GaN doping is shown as well as electrical characteristics of polymer-GaN interface.

Finally, future possible improvements to the proposed design are discussed.

Ref:

1. Feng Qian et al., Chin. Phys. B Vol. 23, No. 2, 028802 (2014).
2. Ge, Weihao, Solid State Physics II, (2009).
3. M. Sobanska et al., J. Appl. Phys. 115, 043517 (2014).