Ordered GaN nanowire array as acceptor material for bulk heterojunction organic solar cells

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In this work we report on application of self-assembled vertically oriented GaN nanowires (NWs) grown on silicon substrate by plasma-assisted molecular beam epitaxy as an ordered inorganic acceptor in bulk heterojunction solar cells with active layer fabricated with poly(3-hexylthiophene-2,5-diyl) (P3HT) and phenyl-C61-butyric acid methyl ester (PCBM) blend. Prepared organic mixture was spin-coated on top of GaN NW layer and annealed in Ar atmosphere at 150°C for 15 minutes. Then metal contacts were deposited.

In order to investigate processes occurring on the interfaces between organic active layer, GaN nanowires and silicon substrate, comparison of photovoltaic devices with pure silicon acceptor layers without NWs was made. J-V characteristics were measured in dark and under AM1.5 light conditions. Short circuit current vs. incident light wavelength measurements were performed in the range from 300 to 1400 nm using a tungsten lamp combined with a monochromator as a light source. We also conducted calculations of external quantum efficiency (EQE) from photocurrent spectroscopy data.

Results indicate that incorporation of ordered GaN NW acceptor increases power conversion efficiency of a device compared to reference solar cells with planar Si acceptors. The unoptimized solar cell demonstrated short circuit current density J_{sc}=2.4 mA/cm^2, open circuit voltage V_{oc}=0.46 V and power conversion efficiency PCE=0.25%. Comparison of external quantum efficiencies calculated from photocurrent shows, that efficiency of carrier collection by GaN NW is the highest between all measured samples. EQE values show increase at wavelengths of incident light corresponding to GaN absorption edge, reaching maximum value of EQE=0.32. We assume existence of Schottky junction on P3HT:PCBM/Si interface which explains low rate of charge carrier transfer between organic active layer and silicon substrate. These findings demonstrate the high potential of crystalline nanowire acceptor material to enhance the efficiency of charge carrier separation and collection processes. Basing on experimental observations presented in this work, we propose a qualitative model explaining operation mechanism of hybrid solar cell.

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