IMPROVED HYBRID SOLAR CELLS VIA IN SITU UV-POLYMERIZATION

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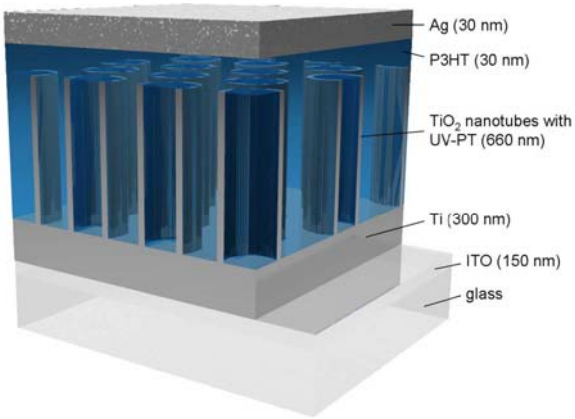
INTRODUCTION

Hybrid solar cells have been developed in the past decade as a promising alternative for traditional silicon-based solar cells. One approach for making inexpensive inorganic-organic hybrid photovoltaic (PV) cells is to fill nanostructured titania films with solid organic hole conductors such as conjugated polymers1. These compounds can function as light-absorbing species and inject electrons into the conduction band of the n-type semiconductor, while at the same time they conduct the holes to the cathode. For creating high quality conjugated polymers for PV devices, it is critical to minimize defects such as fragmented monomer structure, mis-linking of monomer units (α-β and β-β coupling), conformational disorder, and cross-linking of polymer chains. It was shown previously that surface initiated in situ polymerization achieved better interface contact, larger surface coverage, and more complete filling compared with a nanoporous structure infiltrated by polymer synthesized outside the network; however, this methodology created regiorandom polythiophene[2].

In contrast, by using in situ UV polymerization one can grow regioregular polythiophene: in our simple and efficient photochemical approach, nanotubular TiO2 substrate is immersed overnight in a 2,5-diiodothiophene (monomer precursor) solution and then irradiated with UV light in an argon environment. The selective UV photodissociation of the C–I bond (λ = 250-300 nm) in the precursor molecule produces monomer radicals with intact π-ring structure. Since the C–I bonds are present at the ends of the reaction coupling products, further photodissociation can take place forming oligomeric and polymer species that can couple to and self-assemble on the surface of TiO2 nanotubes[3].



METHOD

In order to grow vertically oriented TiO2 nanotube arrays on conductive transparent electrode, first step is to sputter deposit a Ti film on an ITO-coated glass substrate. Nanotube arrays of TiO2 are then formed by potentiostatic anodization of Ti. The as-anodized samples were crystallized by annealing in an oxygen atmosphere at 450 °C for 4 h.

The resulting length of the nanotubes (thickness of TiO2 layer) was 660 nm. Crystalline TiO2 tubes were infiltrated with polymer in two ways: directly with poly-3-hexyl-thiophene (P3HT) or with monomer followed by in situ UV polymerization. In order to prevent electrons in the TiO2 from reaching the top silver electrode, a 30 nm overlayer of P3HT was spin-coated on both types of devices. A 30 nm thick layer of Ag was sputter deposited as the top electrode. The photoelectrochemical behavior of the ITO/TiO2 (NT)/UV-PT/Ag device is presented in terms of photocurrent response. Upon illumination with visible light, we observe prompt generation of anodic current. A non-ideal backside-illuminated setup (with Ag top electrode optical transmittance of <10%) under illumination of 620 nm light surprisingly yields a photocurrent density as high as 5 μA/cm^2 (Figure 1). Compared with the reference device infiltrated with presynthesized P3HT, the UV-PT cell shows >10^3 increase in photocurrent. In addition, during light exposure, flat photocurrent values show that charge recombination during hole transport through the polymer is greatly minimized. When we compare action spectra and absorption spectra of the UV-polymerized device, we can conclude that the peak around 630 nm is the primary
photoactive one and is responsible for the hole transfer process through the polymer.

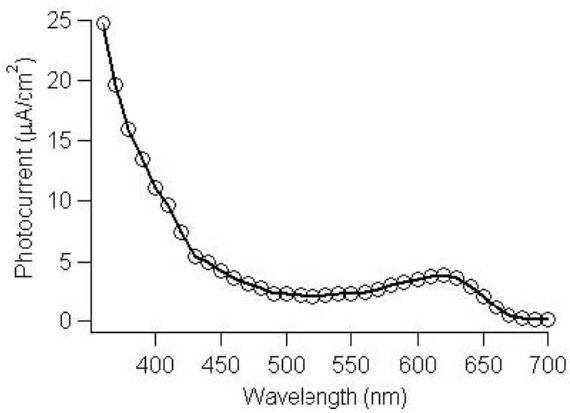


Figure 1. Photocurrent action spectra of UV-polymerized PT (UV PT) recorded in terms of incident photon to generated photocurrent.

When the cell is illuminated from the backside, through the Ag top electrode, there is a possibility for Ag plasmon-enhanced solar energy conversion. When light is absorbed in the photoactive layer, dipole-allowed photogeneration of excitons scale with the electric field squared. It has been shown that by enhancing the local electromagnetic field with the inclusion of surfaceplasmon active materials, it is possible to enhance the photogeneration of excitons in polymer[4]. Enhancements to the photogeneration of excitons would lead to higher photocurrents from wavelengths near the plasmonm resonance and into the red.

REFERENCES

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