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Dye-sensitized 1D anatase TiO_2 nanorods for tunable efficient photodetection in the visible range

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ABSTRACT

TiO_2 films with enhanced photosensitivity were deposited on alkali free glass substrates without intentional substrate heating by pulsed DC magnetron reactive sputtering with an average thickness of about 2 μm. Three dyes, commercial N719 and two new organic dyes were impregnated in order to control the optical spectral selectivity of such films. The type of dye used proved to dramatically influence the device's response to radiation pulses. The practical breakthrough is the use of different dyes according to the region of the electromagnetic spectrum one wants to detect. Devices with photocurrent 6 orders of magnitude higher than the dark current (from $\sim 2 \times 10^{-12}$ to 2×10^{-6} A for a 100 V bias) were fabricated with a spectral response within the visible range of the electromagnetic spectrum. In addition, this approach is likely to allow for the fabrication of hybrid photodetectors on cheap heat sensible flexible polymeric substrates.

1. Introduction

Titanium dioxide (TiO_2) is a wide band gap (~3.2 eV) n-type semiconductor that has been researched in many fields such as photocatalysis [1], dye sensitized solar cell [2], gas sensors [3–5] and UV detectors [6]. Recently, solution-processed semiconducting nanocrystals have been extensively studied in the photosensitive area due to their lower fabrication cost and large area scalability. However, UV detectors based on wet-chemical-synthesized semiconductors such as ZnO and TiO_2 usually show a slow photoresponse because of the high density of defects and/or the effect of gas adsorption on the crystal surface [7,8]. Photoconductivity is the enhancement of electrical conductivity of matter produced by the motion of carriers created by absorbed radiation. This phenomenon involves absorption, photogeneration, recombination and transport processes in an intimate relationship. Therefore, photoconductivity reflects the free carrier density and is straightforward to interpret in terms of competition between photogeneration, recombination and trapping without considerations of spatial variations or device geometry [9].

Organic materials have attracted considerable attention in organic photovoltaic research (OPVs) over the last three decades, however only recently the same attention has been deserved to organic photodetectors (OPDs) [10]. Hybrid devices, based on organic conjugated polymers and inorganic semiconductors as active materials, have been recently explored, due to the opportunity of combine the valuable properties of both materials groups, in particularly in terms of charge generation and transport [11]. The key parameters for photodetection are photocurrent and dark current intensities and another fundamental factor to be considered in photodetection is represented by the spectral selectivity. The opportunity to tune and properly, finely adjust the spectral response of photodetectors within visible range is one of their most attractive properties, which does not have counterpart in the silicon-based technology [6,12]. The distinctive UV absorption characteristics make TiO_2 very suitable for UV detection, where classic semiconductors (i.e., c-Si) show clear limitations: (1) difficulty of blocking out visible and IR photons and (2) degradation of the devices under UV irradiation [6].

Wavelength selectivity can be achieved using organic dyes with different absorption spectra. In this work, photodetectors based on dye-sensitized sputtered TiO_2 nanorods with a spectral response within the visible range were successfully prepared.

In these photodetectors light is absorbed by a sensitizer which is anchored, through a carboxylic group, to the surface of a wide band semiconductor oxide thin film (TiO_2, anatase). This nanocrystalline TiO_2 film with a high surface area acts as the dye molecule supporting layer and allows the conduction of electrons (electron injection

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