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Organic photodetector with coumarin-adjustable photocurrent

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ABSTRACT

Drop casting technique was used to fabricate Al/p-Si/coumarin doped fullerite/Al diodes. The effects of coumarin doping on the photoresponse properties of the diodes were investigated. The forward bias current of the diodes increases exponentially with voltage confirming rectification behavior. The reverse current of the diodes increases with increasing illumination intensities. The photocurrent of the diodes is higher than the dark current. The obtained *m* value indicates that the photocurrent exhibited a linear photoconducting behavior. The coumarin doped fullerite diodes indicate a non-ideal behavior with obtained ideality factors. The obtained barrier height value of the Al/p-Si/coumarin doped fullerite/Al diode is comparable to that of the conventional Al/p-Si (ϕ_b = 0.58 eV) Schottky diode. The measured values of the capacitance decrease with the increasing frequency. The decrease in capacitance was explained on the basis of interface states. It was concluded that the obtained barrier height and interface state density values of the diode are modified doping fullerite with coumarin. The obtained results suggest that the fabricated diodes could be used as an optical sensor in various optoelectronic applications.

1. Introduction

Photodiodes based on organic materials offer great potential in the prospects of harnessing clean solar energy [1,2]. It has heighten interest among researchers due to its lightweight, mechanical flexibility and low-cost technology [3,4]. Furthermore, organic solar cells are fast approaching its cost-effectiveness with progressive reports of increasing efficiencies and low cost manufacturing techniques [3]. It is expected that the discovery of new smart materials in the form of organic photodiodes for the fabrication of solar cell device could potentially lead to inexpensive clean solar energy converters [5]. Even though conventional silicon-based photovoltaic devices have achieved higher power conversion efficiencies, several researchers are focusing on the development of organic molecules and allied photovoltaic devices [6,7], because of the above mentioned advantages.

Of particular interest is the use of C_{60} (fullerene) with other derivatives which has led to the improvement in the performance of organic solar cells and photodiodes [8–12]. Fullerene (C_{60}) is a special spherical π-electron carbon cluster and it is an organic semiconductor. C_{60} is also a well-known electron acceptor and has been used in various molecular systems for photoelectrochemical energy conversion [13]. Another important feature of fullerene worth mentioning is its relatively low internal reorganization energy [13,14].

Itoh et al. [15] investigated the surface potential built across the electrode/fullerene (C_{60}) or copper phthalocyanine (CuPc) interface and C_{60}/CuPc interface as a function of the thickness of the semiconductor film in the dark condition and under illumination. They reported on improvement of the performance of photovoltaic device using low work function metals such as Mg as electrode, which was due to the very high electric field formed at C_{60}/Mg contact. Other reports in literature have shown the potential of fullerene as a possible photovoltaic device because of its band gap energy being in the range 1.6–1.7 eV [16].

On the other hand, coumarins are considered among the most promising classes of organic heterocyclic molecules with

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adaptable application in nanotechnology [17]. Coumarins belong to the group of heterocyclic compounds known as benzopyrones. They are known to be good electron donors characterized with high π-conjugation and relatively low oxidation potentials. Coumarins (organic compound) occur naturally in a number of plants, and its derivatives are biologically very active and have particular importance for biological and medical fluorescence labeling studies [18]. Coumarins and its derivatives have attracted widespread research interest in organic semiconducting materials applications such as, solar energy collectors [19] and potential organic light-emitting diodes (OLEDs) [20], because of the possibility to easily adjust photoelectric properties by chemical modification. Seo et al. [21] investigated the photovoltaic properties of a series of coumarin dyes containing a low-band-gap chromophore of ethylenedioxythiophene (EDOT), and reported a fill factor of 0.70, an overall conversion efficiency η of 6.07% under the standard AM 1.5 irradiation. Showing their suitability as good electron donors in semiconductor photocell and phototransistor applications [22,23].

Herein, this work investigates the photovoltaic properties of organic coumarin doped fullerite to fabricate a photodiode (Al/p-Si/coumarin doped fullerite/Al diode) using sol-gel technique. The potential of fabricating photovoltaic device having low cost and facile technologies is an extremely important consideration for applications in solar energy converters. The effects of the doping on the optical properties of the devices were studied. The functional properties of photodiodes were investigated in detail.

2. Experimental

Coumarin (COU) doped fullerite (FULL) diodes were fabricated using drop casting technique. The required chemicals were of analytical grade and used without further purification. For the doped samples, calculated amounts of coumarin were added to the mixture to obtain weight ratios of COU:FULL = 0, 5, 10 and 20. The prepared mixture was stirred using a magnetic stirrer at 60 °C for 10 min. Before drop coating, the silicon substrate (*p*-type, 600 um thickness, 5–10 ohm cm resistivity, and <111> orientation) was etched with HF to remove the native oxide layer. Subsequently, the substrates were ultrasonically cleaned in a bath of deionized water for 10–15 min, followed by chemical cleaning in successive baths of methanol and acetone. Aluminum (Al) Ohmic contacts were deposited at the rear side of the silicon substrate by thermal deposition. After the coating procedure, the substrates were annealed at 570 °C for 5 min in nitrogen atmosphere Before films coating process, Al/p-Si wafers were again chemically cleaned and then, the films were deposited on the right side of the silicon wafer by drop casting and were dried at 50 °C for 5 times. An aluminum (Al) circular top contact was evaporated on the samples using

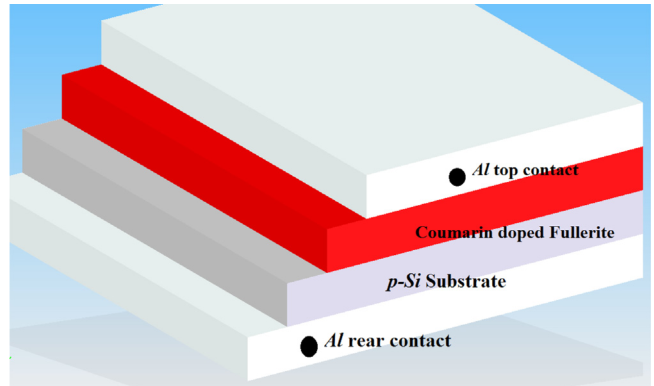

Fig. 1. Schematic diagram of the fabricated device.

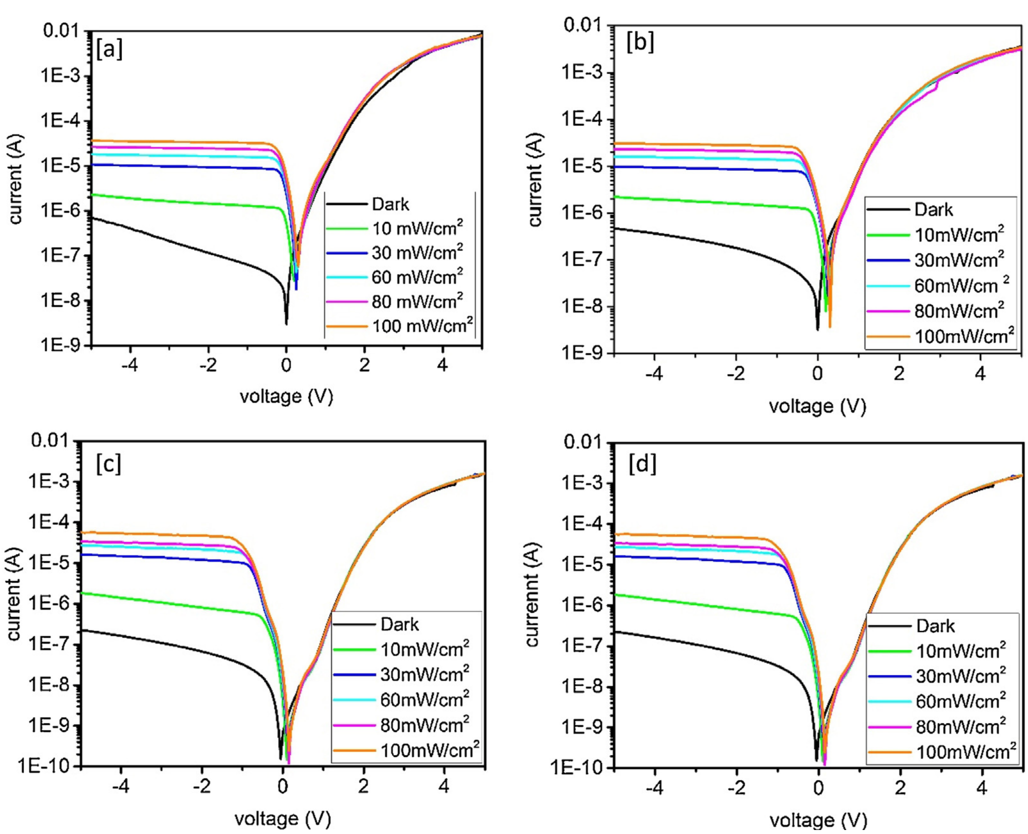

Fig. 2. *I–V* characteristics of the photodiodes under dark and various illumination intensities (a) undoped (b) 5 wt% (c) 10 wt% (d) 20 wt%.