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Novel organic doped inorganic photosensors

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ABSTRACT

Coumarin doped CdSe/p-Si diodes were prepared to obtain new photodiodes for optoelectronic applications. The chemical composition of Cd and Se in CdSe and coumarin samples was confirmed by EDX spectrum. Using FE-SEM analysis, it was observed that the particle sizes of coumarin doped CdSe composites were changed with coumarin. The forward bias current of the diodes increase exponentially with voltage for all diodes studied exhibiting rectification behavior. The obtained m value indicates that the diodes exhibited a linear photocurrent behavior. The photosensitivity plot of Log (I_{PH}) vs. Log (P) yielded an average m of 1.24. The device with 0.03% coumarin doping level showed the best performance such as lowest ideality factor, highest current density. We have evaluated that the fabricated diodes could be used as an optical sensor in various optoelectronic applications.

1. Introduction

Solar energy is rapidly becoming the most promising option for green energy [1]. It is considered as the most abundant, cheapest and cleanest source of energy despite the dominance of fossil fuels for several decades [1,2]. The prospects of this abundant natural resource for clean energy have raised lots of interest among researchers for decades [2–4]. It is expected that the discovery of new smart materials in the fabrication of photo diodes and solar cells could potentially lead to inexpensive energy sources [5], alleviating the energy predicaments and its associated environmental issues.

Cadmium chalcogenide inorganic compounds, especially CdSe has been extensively investigated in recent years [6,7], because of its potential application in energy conversion system [8,9]. CdSe nanostructures have gained lots of attention because of its direct band-gap of 1.7 eV at room temperature [10]. Fundamentally, they form the basis for functional nano-devices having interesting optical and electronic properties in technological applications such as diodes, lasers, photovoltaic cells [11–14]. Unfortunately, the practical applications of CdSe nanostructures are limited its lack of control over its conductivity property. However, doping methods have proven to be efficient approach to alter this property, and has gained widespread industrial use [15]. CdSe thin films have been fabricated by several researchers using different techniques such as chemical bath deposition (CBD) [16], spray pyrolysis [17], vacuum evaporation [18], and electrodeposition [19]. Compared to the above deposition techniques, sol-gel method has many advantages such as low temperature processing, low cost, and facile technology [20].

Coumarins belong to the group of heterocyclic compounds known as benzopyrones. They are considered among the most promising classes of organic heterocyclic molecules with adaptable application in nanotechnology. Coumarin derivatives have attracted a lot of research interest in applications such as, solar energy collectors [21] and potential organic light-emitting diodes (OLEDs) [22]. 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 [23].

This present work reports on the fabrication of thin films of coumarin doped CdSe using sol-gel technique. The effects of the doping on the structural and optical properties were studied. The functional properties of doped samples on p-Si were investigated in detail.

2. Experimental details

Coumarin doped CdSe thin films were fabricated using spin coating technique. The required chemicals were of analytical grade and used

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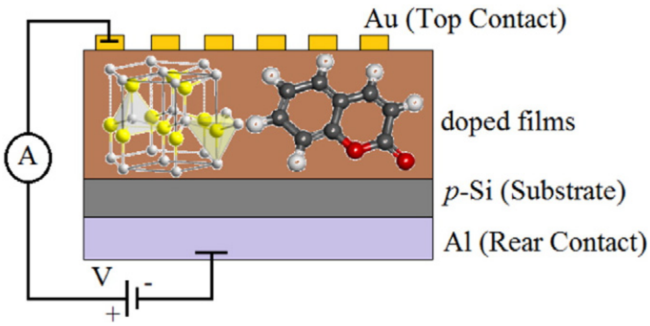

Fig. 1. Schematic diagram of the fabricated device.

without further purification. For the doped samples, calculated amounts of coumarin were added to the mixture to obtain weight percentages (wt%) of 0.00, 0.01, 0.1, 0.03 and 0.005. The prepared mixture was stirred using a magnetic stirrer at 60 °C for 2 h. Before spin coating, the silicon substrate (p-type, 600 μm thickness, 5–10 Ω 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. The films were deposited on the right side of the silicon wafer by spin coating with a rotating speed of 2000 rpm for 20 s. Successive layers of films were prepared in 10 min interval and dried at 150 °C for 5 times to obtain a solid film. A gold (Au) circular top contact (contact area = 7.85×10^{-3} cm^2) was evaporated on the samples using physical mask. The schematic diagram of the fabricated diode is shown in Fig. 1.

The surface morphology was studied using field emission scanning electron microscopy (FE-SEM). Energy Dispersive Spectroscopy (EDX) was used to access the elemental composition. Electrical characterization of the anode was performed using 4200 Keithley semiconductor

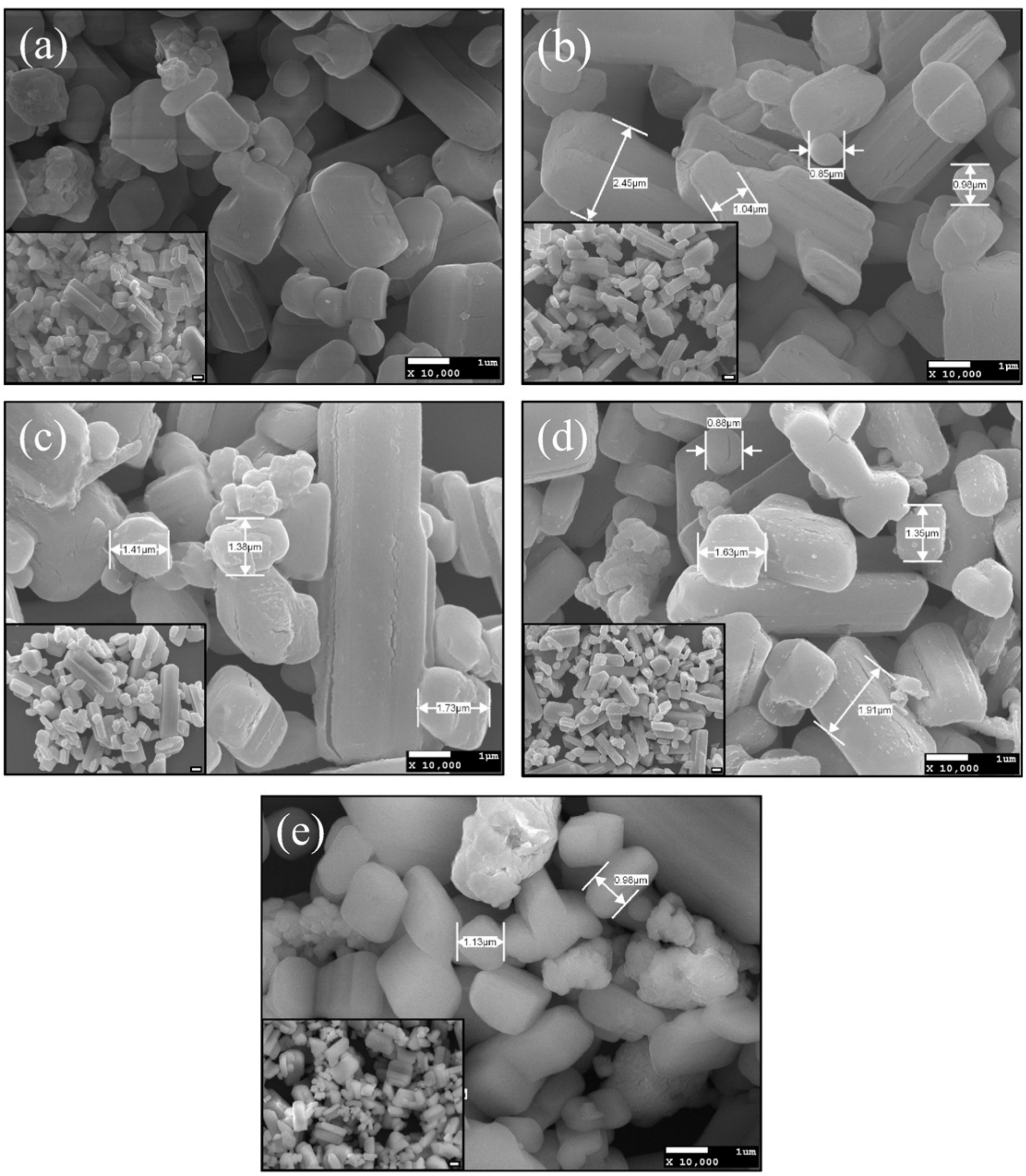

Fig. 2. a. SEM images of CdSe film b. SEM images of coumarin doped CdSe 0.005 wt% c. SEM images of coumarin doped CdSe 0.01 wt% d. SEM images of coumarin doped CdSe 0.03 wt% e. SEM images of coumarin doped CdSe 0.1 wt%.