FACILE FABRICATION OF ZNO IMPRINTED FABRIC FOR FLEXIBLE UV PHOTODETECTOR

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Abstract

In this work, we present an extremely low-cost and flexible photodetector using ZnO nanostructures thin film on substrate like Fabric. The film was deposited using a solution containing Zinc acetate ($(CH_3COO)_2Zn.2H_2O$) by spray pyrolysis technique on polyester fabric as substrate and electrodes were drawn by carbon conducting ink with the gap of 1, 2 and 3 mm between the electrodes. This ZnO thin film device shows a substantial increase in the photo-current under UV (λ = 253 nm) light of the intensities in the range from 8 to 100 µW/cm^2 with a higher I_p/I_d ratio of 583 observed at 30 V. This device shows higher responsivity of 3.4 A/W for the lowest incident intensity of UV light (8 µW/cm^2). Flexibility property of this device was tested at different bending angles and 25% degradation in the I_p/I_d ratio was observed and is suitable for its using flexible photodetection applications.

Keywords: ZnO, fabric based, flexible photodetector, high responsively

I. INTRODUCTION

The development of ultraviolet (UV) photodetectors has gained significant interest due to their diverse applications in various fields, including environmental monitoring, medical diagnostics, and space communication [1]. These devices rely on the interaction of light and matter, and their performance is influenced by various factors such as material properties, device design, and fabrication techniques [2].

Zinc oxide (ZnO), with its non-toxic nature, suitable band gap (~3.37 eV), and diverse nanostructures, has emerged as a promising material for UV photodetector fabrication [3,4]. However, achieving ideal photodetector characteristics including strong photo-responsivity, fast switching, and low noise, at an affordable cost remains a challenge [2,3].

This research explores the potential of spray pyrolysis as a simple and cost-effective method for depositing ZnO thin films on fabric substrates for UV photodetector applications. This approach leverages the advantages of flexible electronics, offering the potential to develop low-cost, wearable UV photodetectors with potential applications in biomedical sensors and smart wearable electronics [5,6]. This paper investigates the UV photodetection capability of ZnO thin films deposited on fabric substrates using spray pyrolysis at a low temperature of 80°C. We present the findings on the material characterization and photodetector performance, highlighting the potential of this approach for developing practical and affordable flexible UV photo detectors.

II. EXPERIMENTAL

ZnO thin film was fabricated on Nylon fabric sample procured from local market at a very low temperature of 80 ^{o}C using the spray pyrolysis method. Zinc acetate ($(CH_3COO)_2Zn.2H_2O$), a source of zinc, is manually sprayed into a semi-non-aqueous solution (methanol in water) during the synthesis process [7]. After cooling the substrate to room temperature, a ZnO thin coating formed on the substrate.

The structural, morphological, and elemental analysis of the sample was performed using a Rigaku-made X-ray Diffractometer, a JEOL-made Scanning electron microscope coupled with energy dispersed X-ray spectrometer.

For photo-detection measurements, the ZnO thin film sample was later cut into a standard size of 0.5 cm x 1.0 cm and electrodes were patterned using carbon conducting ink. Photo-responsive measurements on ZnO thin film photodetector devices were performed using specially designed system consisting of a digital power source (Scientech 4078P) and electrometer (Keithley 6514). A standard 25 W UV (λ = 253 nm) lamp was used as a light source.

III. RESULTS AND DISCUSSION

The structural property of the synthesized ZnO thin film on the fabric substrate was characterized by XRD and shown in Figure 1(a). In the case of ZnO thin film on fabric (Figure 1(a)) the peaks observed at 31.9º, 34.5º, 36.3º, 47.4º, 56.7º,62.9º and 68.1º are assigned to (100), (002), (101), (102), (110), (103) and (112) crystalline planes of the hexagonal crystal structure of ZnO [8]. Along with this, the XRD pattern contains the peaks for the cellulose present in the fabric which a broad peaks at 22º and 26 º is due to the cellulose fibers of the fabric substrate [9]. The average crystallite size estimated using the Scherrer's equation is observed to be ~ 31 nm. This result shows that the formation of phase pure, polycrystalline, and nano-structured ZnO thin film on the Fabric.

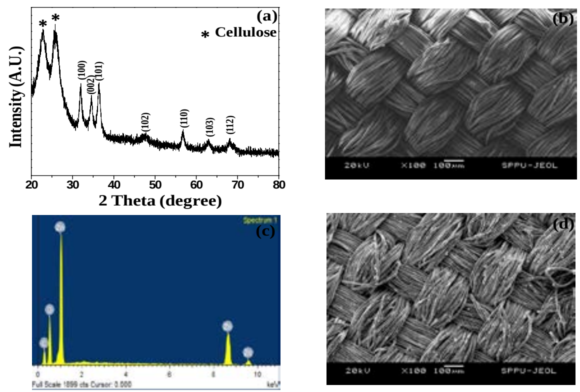

Figure 1: (a) XRD pattern of ZnO coated Nylon fabric, FESEM images of uncoated and ZnO coated Nylon fabric are shown in (b) and (d), respectively, (c) represents EDS spectra of ZnO coated fabric.

The FESEM images of the Nylon fabric and ZnO coated fabric are shows in Figure 1(b) and 1(d), respectively. Figure 1(b) shows a SEM image of the fabric with woven network orderly by many microfibers [5]. As seen in Figure 1(d), ZnO covers these microfibers uniformly and follows the network. The elemental analysis of the ZnO coated fabric shows the presence of the zinc and oxygen along with the carbon. This result confirms the formation of the ZnO on the fabric substrate.

Figure 2(a) shows the photoconductivity measurements on ZnO coated fabric device under UV light illumination. The current-voltage (I-V) characteristics were measured under dark and UV illumination (8 to 100 µW/cm^2). At a 30 V applied bias, this device shows an extremely low dark current value. As demonstrated in Figure 2(a), this device exhibits an overall increase in photo-current with increasing light intensity under UV illumination. It reaches a maximum of around 4 µA at 30 V under UV light of intensity of 100 µW/cm^2. When light intensity increases from 8 to 100 µW/cm^2, the photosensitivity (I_{light}-I_{dark}/I_{dark}) of this photo-detector rises from 150 to 408 with increasing UV light intensity.

Additionally, this device exhibits responsivity of 0.3 A/W at the lowest UV light intensity (8 µW/cm^2), whereas, it increases to 0.81 A/W at 100 µW/cm^2. The results shown in Figure 2(b), (c) and (d) were recorded under UV illumination (100 µW/cm^2) at an applied bias of 30 V. To test the device performance, the photo-response was observed under continuous light pulses lasting 60 seconds, as shown in Figure 2(b). When the light was turned on for 60 seconds, the photocurrent increased rapidly and then decreased dramatically after turning off the light. Photocurrent of this device remains almost constant for 2 hours. This device has exceptional stability as tested by its continuous operation for several hours. The device's static photo-response studied during an 1800-second optical pulse, indicates that the photocurrent rises rapidly, saturates in a few seconds, and then degrade by 35% until light is incident on it. The photocurrent rapidly decreased to the dark current value when the UV light was turn off, indicating the device's fast photo response. Additionally, as Figure 2(d) illustrates, the device's dynamic response time was also observed at an applied bias of 30 V. The device's expected rise (T_r) and decay time (T_d) were 2 and 26 ms, respectively.

Further we examined the flexibility of ZnO coated fabric device by bending measurement and the result shown in Figure 3. The device was tested at various bending angles ranging from θ = 0 to 70° with an applied bias of 30 V and pulses of UV light with an intensity of 100 μW/cm². After bending the device at a specific angle, the change(s) in the dark and photocurrent under consecutive light ON-OFF pulses of 60 s each.

Using a fabric, the advantage of being biocompatible and flexible, this increases the work's utility for wearable and flexible UV photodetector devices. Several devices made with ZnO thin films were tested, to show the device's reproducibility. It was discovered that these prototype ZnO thin film devices made in a lab were stable in natural environments.

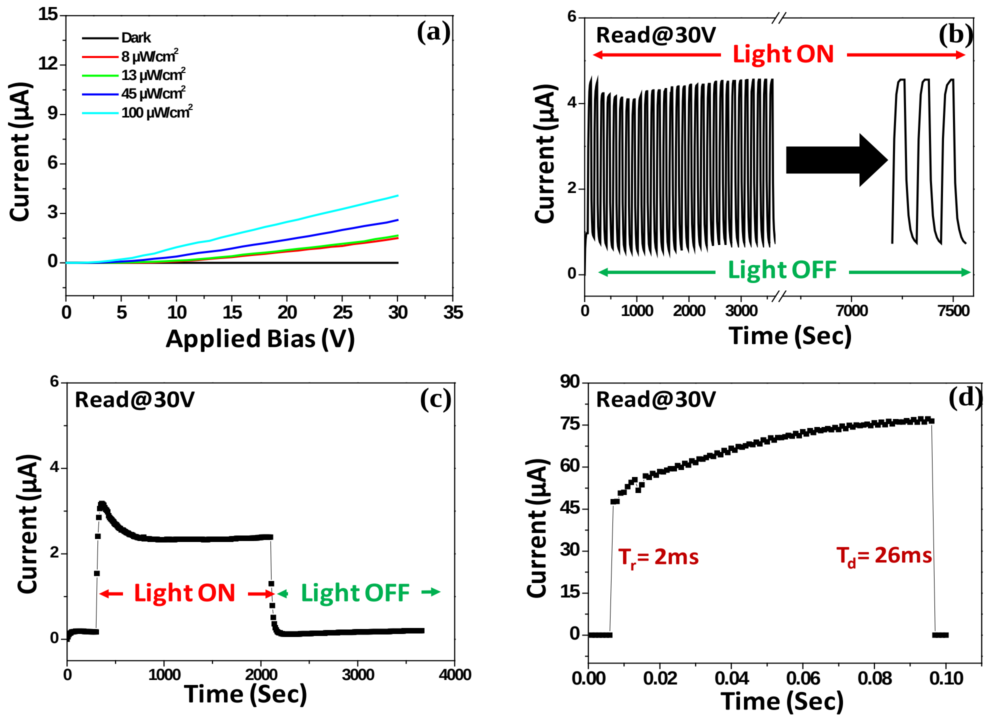

Figure 2: (a) Typical I-V characteristics, (b) cyclic photo-response, (c) time-dependent photo-response, and (d) real-time photo-response measurement to calculate response time of device under UV illumination.

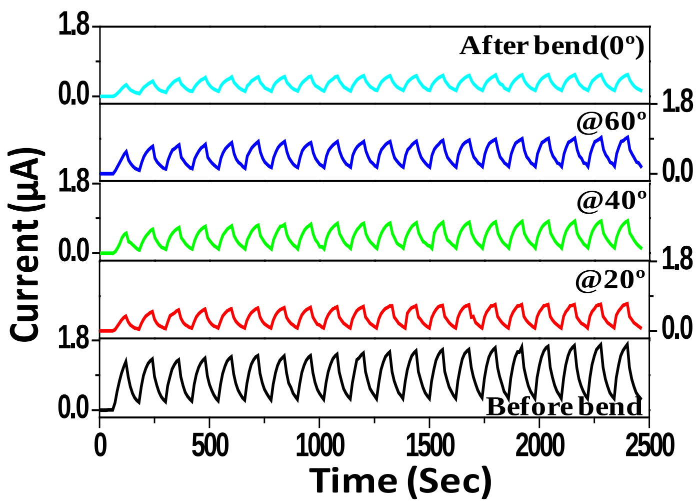

Figure 3: Bending measurements on the ZnO coated fabric device under various bending angles and consecutive light pulses.

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IV. CONCLUSION

This work demonstrates a straightforward process for fabricating a wearable UV photodetector device based on ZnO coated fabric fabricated using spray pyrolysis. Photo-detection measurements show that this device have an excellent photo-responsivity (0.8 A/W) with high photosensitivity (408) at UV intensity of 100 µW/cm^2 and even at very low intensity of 8 µW/cm2 it is 3.4 A/W and 150, respectively. The static and dynamic photo-detection measurement reveals the photo-fast detector's detection ability (rise and decay times of 2 and 26 ms, respectively). The present work presents a straightforward and low-cost process for producing a high-grade ZnO coated fabric based photodetector with outstanding photocurrent stability and reproducibility.

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