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Structural, morphological and optical properties of ZnO nano-fibers

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ABSTRACT

Microcontroller aided electro-spin coating unit was designed and optimized to fabricate nano-fibers. Composite nano-fibers of ZnO were fabricated using this unit. The ZnO fibers were annealed at different temperatures from 200 °C to 600 °C using muffle furnace, all the continuous fibers were found to be defect free and beads free. The structural and composition of the fibers are analyzed using XRD and EDAX measurements. The X-ray diffraction peaks revealed that the fibers are wurtzite hexagonal structure. The composition of the fiber is confirmed as ZnO from the percentage of constituents of Zinc and Oxygen in EADX results. The optical properties of the fibers are studied by using spectrophotometer. The optical band gap energy is found to be 3.37 eV. The surface morphology of the fiber was studied using SEM and TEM analysis. The fibers are found to be defect free and they are excellent material for high sensitive optoelectronic sensors.

1. Introduction

Nowadays optoelectronic devices play vital role in this modern medical field. The materials of optoelectronic devices should have excellent physical and chemical properties and also inexpensive and biodegradable in nature. Nano-fibers of zinc oxide (ZnO) materials plays a dynamic role in fabricating light emitting diodes, photo detectors and solar cells and also it is used as substitute material for Si and Ge in optoelectronic devices [1–4]. ZnO is a biodegradable semiconducting material with band gap energy of 3.37 eV and excitation binding energy of 60 meV at room temperature [5,6]. ZnO thin films have an exceptional blend of interesting properties such as electrical, optical and excellent substrate adherence, hardness and piezo electric behaviors [7,8].

All the conventional preparation techniques of nano-fibers have a multitude of difficulties including long or complex procedures for preparation, high processing temperatures and residual organic solvent in the final polymer [9]. In addition, the control over pore size and interconnectivity are unsatisfactory that is the size of the base polymer and the pore vary from few micrometer to hundreds of micrometers. The electro-spin coating technique can avoid these difficulties and achieves self-assembly, phase separation, force spinning and flash spinning. This technology has numerous advantages like easily controllable, able to generate continuous fibers and especially to fabricate nano-fibers with diameters in the nanometer size

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[10,11]. Newly introduced programed microcontroller electro-spin coating unit has made the cost effective, portable and allow us to control the voltage preciously during the fabrication of fibers in this research and this is the pioneer in nano-technology. These motivated us to choose microcontroller interfaced electrospinning technology for the preparation of ZnO nano-fibers in this research.

2. Experimental details

2.1. Fabrication of microcontroller aided electro-spin coating unit

The microcontroller aided electro-spin coating unit is designed and constructed as shown in the schematic diagram Fig. 1. The system consists of three major units: i) variable power supply unit (0–30 kV), ii) spinneret-solution feeding unit and iii) nano-fiber collecting unit. The power supply unit which is connected to the tip of the syringe and the collecting unit is essential part in electro-spin technique to produce very high voltage (up to 30 kV) and to spawn the nano-fibers.

Spinneret-solution feeding unit is made up of syringe (with stainless steel needle of size 0.1 mm-0.3 mm) fitted with syringe holder and connected to the stepper motor. The stepper motor is used to generate the precise amount of forward and reverse mechanical force to move the piston of the syringe forward and backward using microcontroller unit and have Taylor cone formed, followed by aligned nano-fibers are fabricated as the substrate (fitted in the metal collector holder) The high voltage power supply unit is used to generate 30 kV DC between the needle and collecting unit. During forward motion the Sol-Gel comes out of the syringe needle tip.

2.2. Fabrication of ZnO nano fibers

2.2.1. Preparation of precursor solution

3 g purity tested (99% Sigma Aldrich) PVA, and 6 g Zinc acetate dihydrate (99% Merck) were dissolved with 40 ml triple distilled water in two separate beakers, and then the solutions were mixed in different ratios 1:1, 1:2 and 1:3 in separate beakers using magnetic stirrer for three hours at room temperature. The mixtures were stored for 24 h aging period at room temperature to form high viscous state for this sol–gel technique [12]. The prepared precursor solution was sucked without any air bubbles in the syringe. The syringe was fitted in the syringe holder setup and aligned to be in the same horizontal axis with shaft of the stepper motor.

2.2.2. Preparation of glass substrates

Glass substrates of size 2.5 × 37.5 sq mm were cleaned by the following process. i) the glass substrates were soaked in Sodium hydroxide solution for 25 min to remove grease and fat substances, ii) cleaned using detergent solution and running distilled water, iii) cleaned using ultrasonic agitator for 30 min in distilled water mixed with few drops of detergent solution to remove residues, iv) cleaned with pure Isopropanol for vapor degreasing and then transferred to a beaker containing distilled water and to the beaker containing acetone and v) the cleaned substrates were kept in oven for an hour at 423 K. Finally the well cleaned substrates were stored in the vacuum desiccators.

2.2.3. Optimization of electro-spin coating unit

Microcontroller (PIC 16F877A) fitted board was connected with computer and codes written in ‘C ‘language to operate the stepper motor were flashed (stored). The operating voltage was drawn from the 6 V DC power supply unit. Using test solution (appropriate viscous sugar solution) in syringe the expected movement of the piston and flow of liquid from the tip of the

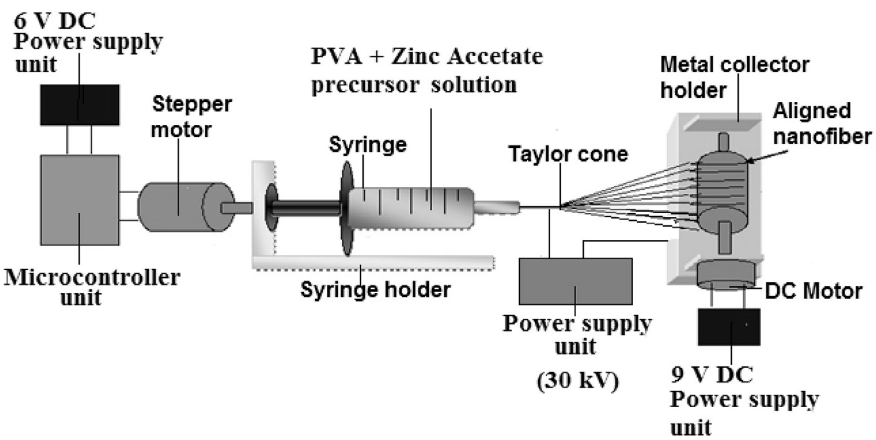

Fig. 1. Schematic diagram of electro-spin coating unit.