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DESIGN AND ASSEMBLING OF SIMPLE HOMEMADE ELECTROSPINNING DEVICE FOR NANOFIBERS PRODUCTION

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Abstract

A high technology is required in the production of nanofibers by electrospinning technique. This paper presents the work to implement design of the novel low-cost electrospinning system with inexpensive components. This home-made electrospinning device composed of three main components. They are Zero Voltage Switching (ZVS) flyback converter based home-made adjustable high-voltage power supply, stepper motor based homemade automatic injection pump and metallic collector plate. After a brief explanation to build the device using unexpansive components, the production zinc oxide (ZnO) nanofiber using low-cost homemade electrospinning device. The zinc oxide (ZnO) nanofibers were prepared from znic acetate and poly vinyl alcohol (PVA). The fibers were deposited onto the aluminum substrate and calcined for 1 h at 600 ℃. The properties of ZnO nanofibers were characterized by X-ray diffractometer (XRD) and field emission scanning electron microscope (FESEM).

Keywords: Nanofibers, electrospinning technique, Zero Voltage Switching (ZVS) driver and home-made automatic injection pump

Introduction

Electrospinning is a manner used for fabrication of nanofibers and based on the electrostatic phenomena used. The Basic components of electrospinning instruments are High voltage power supply, solution reservoir with frame and collector to collect nanofibers [Ayşe Gül Şener et al (2011)]. Electrospinning is a spinning technique using an electrostatic force approach to produce fibre from a polymer solution or fused [Dian Ahmad Hapidina (2017)]. The fibres produced from this method have a diameter range from nano to micrometers and a wider surface area than conventional spinning methods [Muhammad Miftahul Munir (2015)]. This method is in great demand because it can control production, fibre structure, porosity, orientation and dimensions of the fibre produced [Pravin Bhattarai (2014)]. Zinc oxide (ZnO), an II-VI compound semiconductor, has a wide energy band gap of 3.37 eV, and large exciton binding energy of 60 MeV [Arini Nuran Binti Zulkifili (2015) & I. Jinchu (2015)]. It has a hexagonal wurtzite-type structure and is non-toxic and relatively cheap. ZnO in one-dimensional (1-D) nanostructures offer extra characteristics such as high aspect ratios, high electron mobility and possess both electrical and optical anisotropy. These unique multiple characteristics make ZnO suitable for various applications including solar cell, gas sensor and photodetector [Ngurah Ayu Ketut Umiati (2019)]. In this research work, the design of electrospinning device for production nanofiber material was carried out. The development of an electrospinning system is carried out using raw materials and components that are available from the local market. The material used for testing is zinc acetate with a mixture of polyvinyl alcohol (PVA). Characterization of the nanofiber structural and morphological were carried out using X-ray diffraction (XRD) and field emission scanning electron microscopy (FESEM).

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Experimental Procedure

Design of home-made electrospinning device

This home-made electrospinning device composed of three main modules. They are zero voltage switching (ZVS) flyback converter based home-made adjustable high-voltage power supply, stepper motor based homemade automatic injection pump and metallic collector plate.

ZVS flyback converter based home-made adjustable high-voltage power supply

The power supply was composed of four main parts. They are timer switch for automatic on/off system, 0-24 V AC to DC power supply, ZVS flyback converter and flyback transformer. The connecting diagram and the photo of automatic on/off variable high voltage power supply was shown in figure 1 (a) and 1 (b). So, the on/off time of this power supply can be programmable by the user easily. The input voltage is 12-36V and will give high voltage of direct current (DC). The differences between the input and output voltage is about 1000 V. When the input voltage applies 12 V, the output voltage can reach 50-100 W. If 24 V input applies the output voltage can reach more than 200 W.

Figure 1 (a) The connecting diagram of automatic on/off variable HV power supply

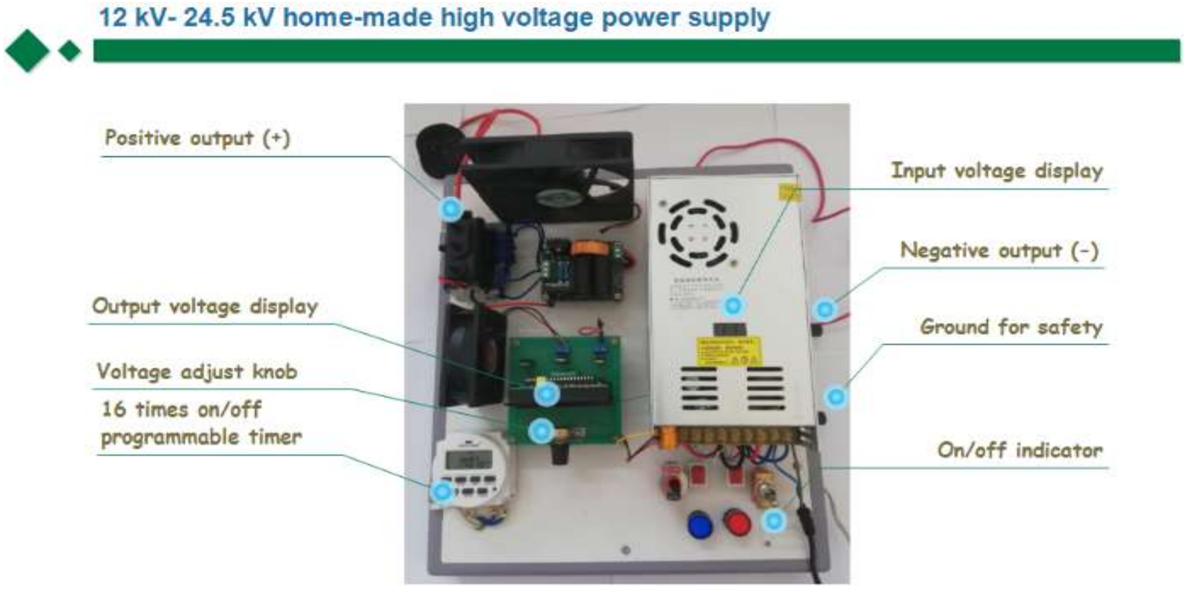

Figure 1 (b) The photo of automatic on/off variable HV power supply.

Homemade automatic injection pump

A small infusion pump used to gradually push small amounts of fluid from the syringe. Syringe pump flow rates can be adjusted by suing stepper controller. The standard volume syringe is 10 mL with an installed capacity of 1 syringe. In this syringe pump, Neam 17 stepper motor of restoration angle 180 degree was driven by Tb6560 stepper motor driver. The speed was control by stepper motor speed controller. The block diagram and the figure of injection pump was shown in figure 2.

Figure 2 The homemade automatic injection pump

Preparation of ZnO nanofibers

10% poly vinyl alcohol PVA solution was prepared with distilled water by conventional method. Firstly, poly vinyl alcohol PVA, 10g was dissolved in distilled water, 100ml for 3days at 60℃. And then, 5 g of zinc acetate was dissolved in 10ml of distilled water for 1h at 60℃. Finally, PVA solution 40ml was mixed zinc acetate solution for 3h at 60℃. The PVA/zinc acetate solution was filled into the 10 ml syringe. The block diagram for sample preparation was shown in figure 4. The tip of the emitter (needle) was connected to the positive terminal of high voltage power supply and the collector (aluminum foil) was connected with the ground. The collector (aluminum foil) was placed 7 cm below the emitter (tip of needle) to collect the nanofibers at a voltage of 24 kV and the running time was 15 min. The as-spun nanofibers were calcined at 600℃ for 1 h. The resulting fibers were analyzed by XRD and FESEM.

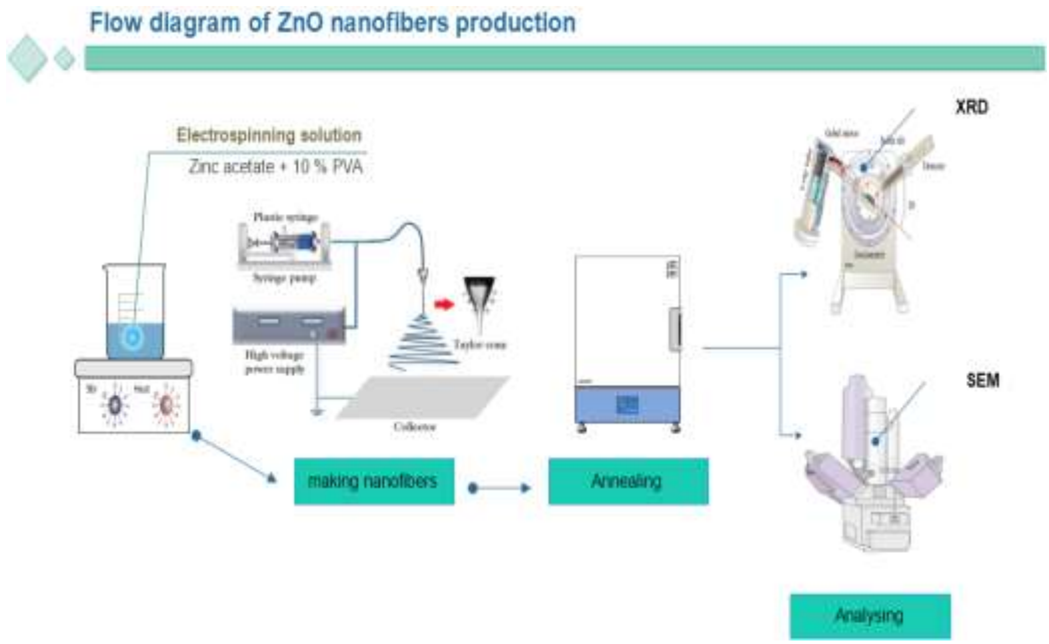

Figure 3 The flow diagram for the production of ZnO nanofibers production

Results and Discussion

High Voltage Power Supply (HVPS) Performance Test

The output voltage of HVPS was measured by Fluke 80k-40 and Fluke 179 multimeter. According to the measurement result the output voltage is about 1000 times larger than the input voltage. It was found that the single flyback can generate HV output voltage up to 34 kV but should not applied more than 24 kV. According to the stability test, there is no significant output voltage change within 3 h. The input voltage versus output voltage and the stability test result graph were shown in figure 4 (a) and 4 (b).

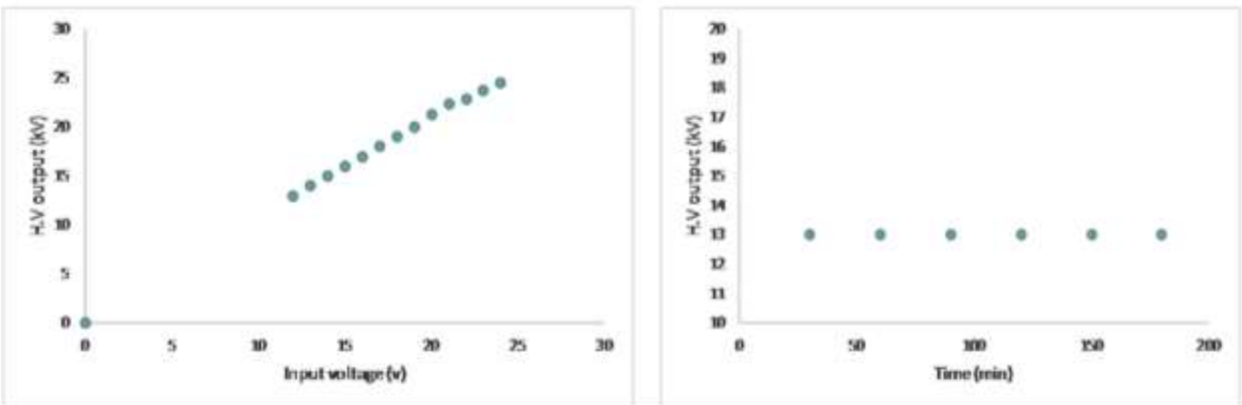

Figure 4 (a) The relationship between input and output voltage; (b) the output voltage stability test

XRD and FESEM analysis of ZnO nanofibers

The ZnO powder was determined by using X-ray Diffractometer (Rigaku RINT 2000). XRD was performed using monochromatic CuK_α radiation (λ= 1.54056 Å) operated at 40kV (tube voltage) and 40mA (tube current). Sample was scanned from 10° to 70° in diffraction angle 2θ with a step-size of 0.02°. The X-ray diffractograms of pure ZnO is shown in figure 5. The ZnO X-ray patterns present the higher crystallinity degree of investigated materials. The crystallite size (D) was calculated based upon on the all diffraction peak's (main peak's) broadening in the XRD pattern using the Debye Scherrer formula. The crystallite size is 42.69 nm. The FESEM images of ZnO nanofibers for different scale bar are shown in figure 6 (a) and 6 (b). It was observed that the high area density and there is no uniform distribution of diameter for all samples. The diameters of fibers change in between 46-106 nm. It was also found that some defects such as droplets, splitting and branched fibers. It could be due to the less flight time. Therefore, the fiber uniformity was significantly affected by the flow rate.

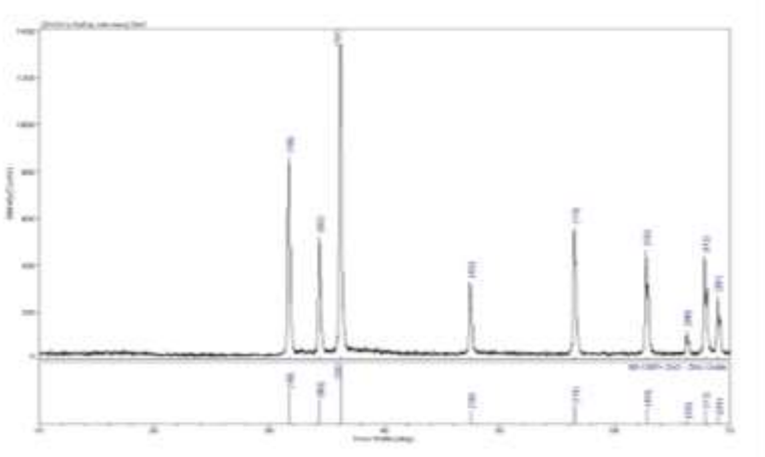

Figure 5 The XRD pattern of ZnO oxide

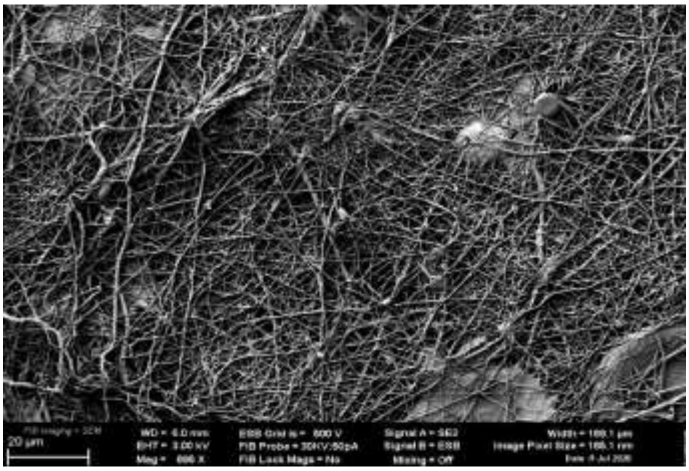

Figure 6 (a) FESEM image of ZnO nanofibers (20 µm)

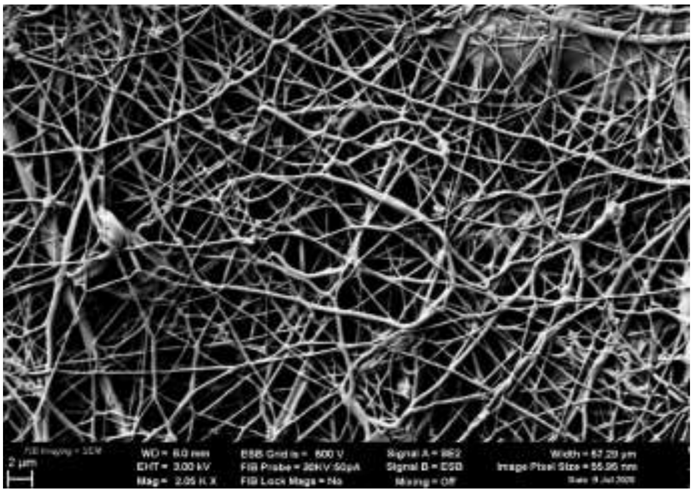

Figure 6 (a) FESEM image of ZnO nanofibers (2 µm)

Conclusion

The electrospinning system has been implemented with an electrical power supply to generate a constant dc high voltage dc, an adjustable syringe pump, and flat collector. The single Mazzilli converter could generate HV up to 24 kV and the performance test showed that the converter has good stability over time. Electrospinning tests have been successfully carried out. According to the XRD analysis the resulting ZnO nanofibers was indicated the good crystalline nature. The average crystallite size of 42.69 nm was calculated by XRD profiles. Observation using FESEM shows that the fibre produced by electrospinning device in this work was in a nanometer scale.

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