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Fabrication of zinc oxide nanoneedles on conductive textile for harvesting piezoelectric potential

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ABSTRACT

Keeping the fact in mind that different morphologies have strong influence on piezoelectric properties, ZnO NNs were synthesized on textile for harvesting piezoelectricity. Piezoelectric potential was captured from ZnO NNs grown on textile by using AFM in contact mode. Structural study was carried out by using FESEM, HRTEM and XRD techniques. The recorded output potential and current was more than 45 mV and 150 nA. The combination of ZnO NNs and textile can be used effectively for energy harvesting applications and the use of textile fabric can pave the way for cheap, flexible, wearable, washable and environment friendly nanodevices.

1. Introduction

In recent years the use of technology has been increased very rapidly worldwide as the population of the world. The development of society depends on the available amount of energy or electricity. Due to heavy consumption of energy in every field of life the available resources will not be sufficient in near future to fulfil the energy requirements [1]. Therefore, research community is trying to invent alternative and cost effective resources for generation of energy/electricity with several features like environment friendly, light weight, flexible, wearable, cheap and nontoxic with high power generation from small area [2,3].

Different techniques have been utilized for harvesting electricity such as electrostatic induction, photoelectric effect, thermoelectric effect, piezoelectric effect and electrochemical reactions etc. [4–8]. In all these techniques, the phenomenon of self-power generation has been utilized extensively for harvesting piezoelectric potential, because it is simple, cost effective, and nonhazardous and has capability to produce larger amount of electricity.

The backbone of this technique is the use of piezoelectric materials such as ZnO, GaN, CdS, and ZnS. But due to high electromechanical coupling coefficient zinc oxide (ZnO) was found to be more suitable candidate. Moreover, ZnO possess excellent properties such as large surface to volume ratio, high thermal and chemical stability, large exciton binding energy (60 meV), high flexibility and largest piezoelectric coefficient [9]. Beside this ZnO probably holds the largest family of nanostructures like nanorods (NRs), nanowires (NWs), nanoflowers (NFs) and nanotubes (NTs), which have been utilized for harvesting piezoelectricity [2,3,10–13]. Zhao et al. synthesized a new class of ZnO nanostructure as multipod, nanostructures of ZnO that exhibited excellent photoluminescence characteristics [14]. Another unique class of ZnO nanostructures called as multipod ZnO with nanonails was also used for analysis of optical properties [15]. Similarly a classical study was performed by synthesizing cage-like nano-tetrapods of ZnO nanostructure for the investigation of optical characteristics [16]. It is important to point out that ZnO NNs based nanogenerator was first developed on silicon substrate by using high temperature thermal evaporation growth technique [17]. But using textile as substrate no experimental report is available on low temperature growth of ZnO nanoneedles (NNs) for harvesting piezoelectric potential. Literature reveals that an extensive investigation has been reported regarding the piezoelectric properties of single crystalline ZnO NRs by using atomic force microscopic technique [2]. In another investigation Wang et al. have been investigated regarding the mechanical and piezoelectric properties of ZnO NWs by using AFM technique [18]. Kim et al. have performed an extensive investigation regarding the piezoelectric properties of ZnO nanosheets/nanowalls [19]. Similarly Khan et al. have investigated the piezoelectric potential generation from ZnO nanoflowers (NFs) [3]. In another study, Xi et al. demonstrated the piezoelectric properties of ZnO NTs by using atomic force microscopy [20]. Experimental results on the lateral bending of piezoelectric nanostructures have been reported by Wang et al. [21]. Beside these various theoretical investigations are also available on harvesting piezoelectricity from semiconducting materials. More importantly Falconi et al. first explained the

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Table 1
The amount of piezoelectric potential generated from different morphologies of ZnO nanostructures.

S. No.	Nanostructures	Piezoelectric potentials	References
1	Nanorods	10 mV	[2]
2	Nanowires	5-35 mV	[11]
3	Nanowalls	400 mV	[15]
4	Nanoflowers	600 mV	[3]
5	Nanotubes	36 mV	[16]
6	Nanoneedles	More than 45 mV	Present work

importance of different positions of contacts, types of mechanical input (e.g. vertical compression versus lateral bending), and morphology (e.g. nanowalls). They presented the theory for harvesting piezoelectricity from ZnO NWs and nanowalls (NWLs) related to the other experimental results and designed a highly efficient piezoelectric nanogenerator [22]. The advantages of tapered piezoelectric nanostructures (under vertical compression) have been first recognized by Araneo et al. They demonstrate that, how ZnO nanostructures like n-type and p-type cylindrical and conical NWs can be used successfully for harvesting piezoelectricity. Another theoretical calculation regarding the piezopotential in lateral bending of piezoelectric tapered nanostructures have been reported, which extensively discussed the possible crucial advantages [23]. Various studies have been published previously that, different morphologies of ZnO nanostructures have strong influence on their piezoelectric properties as shown in Table 1.

In this study, ZnO NNs were grown on conductive textile fabric substrate by using aqueous chemical growth method. Structural analysis like shape, diameter, length, growth orientation and crystalline quality were performed by using FESEM, HRTEM and XRD techniques. The measurement for harvesting piezoelectric potential was examined by using AFM in contact mode.

2. Experimental

ZnO NNs were grown on commercially available conductive textile fabric (ArgenMesh: Less EMF Inc. USA) substrate by using aqueous chemical growth method as shown in Figure 1 (a). A typical

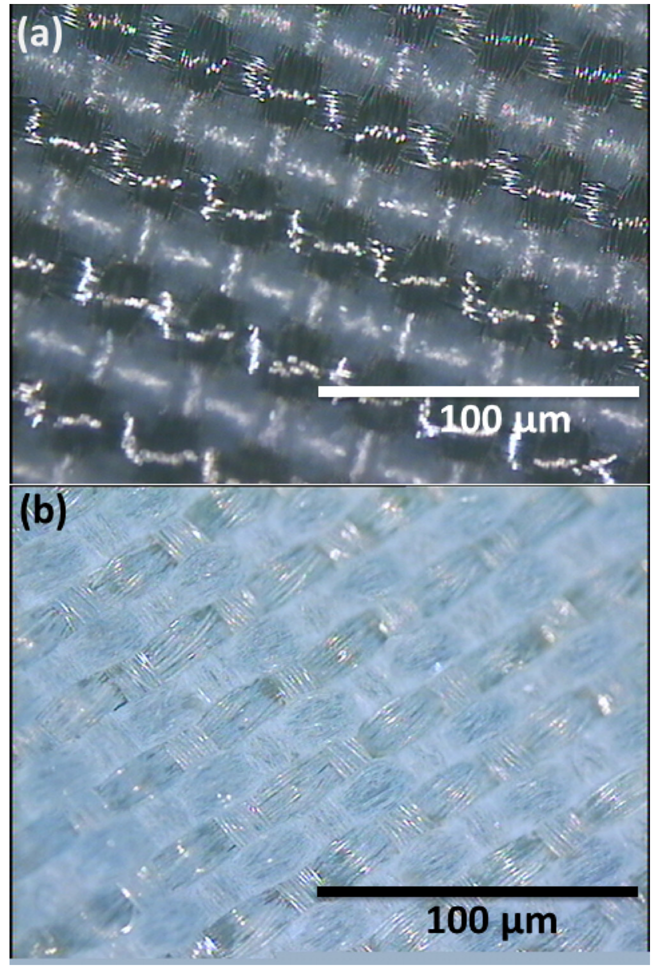

Figure 1. Micrographic images of ArgenMesh conductive textile: (a) prior to the growth of ZnO NNs and (b) after the growth of ZnO NNs.

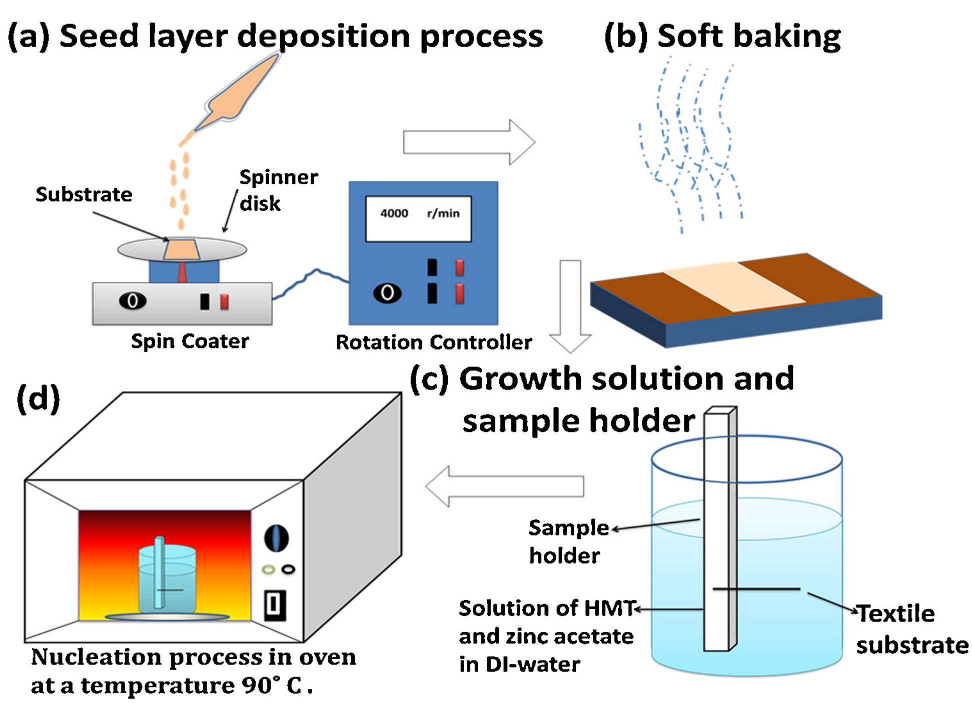

Figure 2. Schematic illustration of growth procedure for ZnO NNs.