STUDY ON THE HYDROTHERMAL GROWTH OF ZnO NANORODS FOR PIEZOTRONIC APPLICATIONS

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Abstract:The capability of a certain material to generate an electric charge in response to applied mechanical stress is called as piezoelectric Effect. Metal oxidesemiconductors having high piezoelectric coefficient can be cost effectively manufactured by a simple hydrothermal methods at low temperature. These nanostructures are capable of transforming mechanical deformation into electrical power. The nanostructure morphologies and dimensions can be controlled by controlling the growth conditions. When subjected to mechanical deformations, these nanostructures are capable of transforming mechanical deformation into electrical power. Due to the structural noncentralsymmetry,ZnO nanostructures exhibit anisotropic piezoelectric properties. High aspect ratio ZnO nanostructures can be merely designed using hydrothermal methods and these nanowires or nanorods show piezoelectric properties. When subjected to mechanical deformations, these nanostructures undergo a charge separation due to inherent structural asymmetry. Tapping of the separated charges and subsequent accumulation can give a manifestation of mechanical to electrical energy transformation and lead to energy harvesting.

***Keywords*:ZnOnanorods, piezo-electric, Hydrothermal method**

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I. INTRODUCTION

With the decrease in energy consumption of transportable electronic devices, the conception of harvesting renewal energy in human surrounding arouses a renewed interest. From many decades People have studied for ways to store the energy from heat vibrations .The first generator, was invented in 1831 by British scientist Micheal Faraday [1]. After that the batteries became the most power supply for wireless electrical devices. These batteries had vast sizes and weighed enormously too[2]. One propulsion behind new energy harvesting devices is that the need to power sensing element networks and mobile devices while not batteries.

Energy gathering is approaching an interesting technological juncture wherein the power requirements for electronic devices are reduced whereas at an equivalent time, the potency of energy gathering devices have augmented. Out of assorted attainable energy harvesting technologies, piezoelectric vibration energy harvest has emerged as a way of other for powering meso-to-micro scale device[3]. Piezoelectric materials are often used as mechanisms to transfer energy, typically ambient vibration, into current which will be kept and accustomed to power various devices. A piezoelectric material is one that generates an electrical charge when a mechanical stress is applied. Conversely, a mechanical distortion is formed once an electrical field is applied.

With the evolution of medicine engineering, in vivo observance, detection and treatment of cells and organs appear to be a close-by reality albeit the actual fact that all this still need power supply. With the dimensions, weight and use of hazardous materials of current batteries don’t serve the purpose [4]. Realization of self-powered nano systems will result in new avenues during this direction.Piezoelectric nanoparticles can be economically fabricated in metal semiconductor form. Within the last decade about, these nanostructured metal chemical compound semiconductors (ZnO) had drawn worldwide interest for their path breaking properties [5]. Furthermore, ZnO is a broad band-gap (3.37 eV) compound semiconductor which is proper for short wavelength optoelectronic applications[4].Structurally, it has a number of alternating planes stacked along the central axis. These planes are made of tetrahedrally synchronized O^{2-} and Zn^{2+}ions [6]. The shortage of a centre of symmetry in wurtzite, combined with massive mechanical device coupling, results in sturdy piezoelectric and pyroelectric properties and conjointly the following use of ZnOin mechanical actuators and electricity sensors.Because of these positive and negative ions, ZnO has distinctive polar surfaces with the basal plane (0001) being the most common polar plane[7]. One end of the polar plane ends with partly positive Zn lattice tip and the other end ends in partly negative oxygen lattice points [7]. These polar surfaces when mechanically disturbed, produces electrical energy.

Electrically charged particles in substances are circulated in space in a way such that the opposed charges cancel eachotherout[9,10]. Which makes matter electrically equitable or they do not have excess electrical charge and are hence neutral.Certain materials undergo a forced charge unbalance at their surfaces, when a mechanical force is produced in the form of a physical deformation, which in other words is termed as piezoelectricity[11].Depending on certain attributes of the material,the surface charge separation can occur.These include the crystal structure of the material and the dielectric capacity or in other words how it is aligned with respect to the central axis of the crystal [12].

II. Experimental

A. Hydrothermal growth of ZnO nanorods

One dimensional ZnO nanostructures were synthesized using hydrothermal process. Different conducting substrates were used like FTO and ITO coated glass, cover slip etc. Already synthesized ZnO nanoparticles are used for seeding the substrates. For dense nanorods, nanocrystallites are grown on the substrate itself. The dip coating techniques and dropping techniques were used for making the seed layer on the substrates. The seeded substrates are placed in equimolarsolution of hexamine or hexamethylenetetramine ($C_6H_{12}N_4$) and zinc nitrate ($Zn(NO_3)_2.6H_2O$) and at 90^{o}C, such that the seeded side faces down. The chemical bath is changed every 5 hours because the growth rate progressively falls. Annealing is done finally at about 250^{o}C for removal of residual hexamine and nitrate from the surface. Hexamine or hexamethylenetetramine ($C_6H_{12}N_4$) discharges OH anions in water when treated thermally and reacts with Zn cations released by zinc $Zn(NO_3)_2.6H_2O$ and produces ZnO.

B. Piezoelectric power generating device using ZnO nanorods

The Au sputtered electrode was placed on top of the substrate with ZnOnanorods and firmly affixed using glue at the edges. Leads were taken out from the conducting sides of both the gold coated electrode and the substrate with the piezoelectric nanorod array on it using silver pastes. The gold sputtered electrode is then placed on top of the nanorods array. We used a Keithley meter for measurement of piezo voltagegenerated.Thearrangement for extracting energy from the ZnOnanorods is shown schematically in Figure 1.

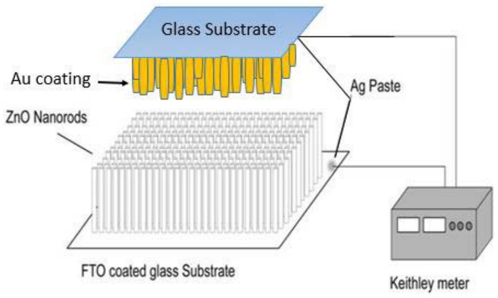

Figure 1: Schematic illustration of the process to produce and extract a piezopotential from an array ofZnOnanorods

III. Results and Discussion

A. Effect of growth conditions of ZnO nanorods

The growth of the Zinc Oxide nanorods was observed for four different concentrations:5mM, 10mM, 20mM, and 40mM for growth times of 15h, 20h and 25h.

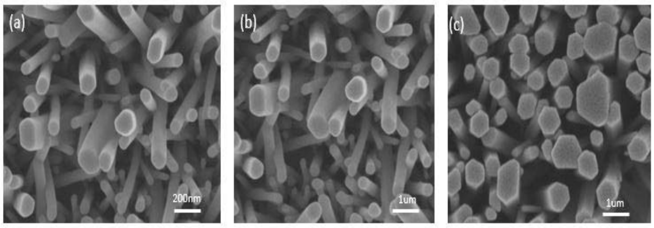

Figure 2: SEM images of ZnOnanorods when grown at a concentration of 5mM for(a) 15h(b) 20h (c) 25h

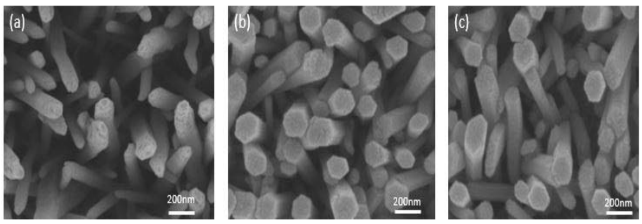

Figure 3: SEM images of ZnOnanorods when grown at a concentration of 10mM for(a) 15h(b) 20h (c) 25h

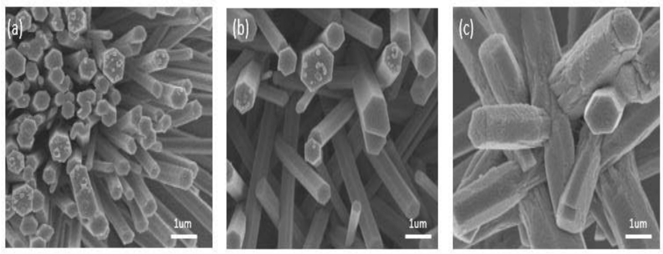

Figure 4: SEM images of ZnOnanorods when grown at a concentration of 20mM for(a) 15h(b) 20h (c) 25h

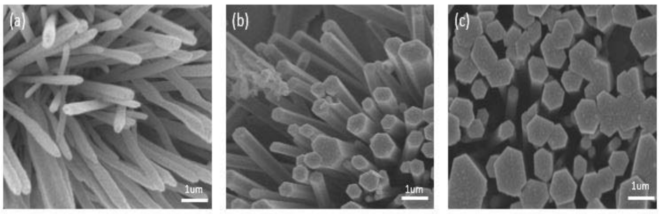

Figure 5: SEM images of ZnOnanorods when grown at a concentration of 40mM for(a) 15h(b) 20h (c) 25h

The rod dimensions grown on substrates can be controlled considerably by controlling certain growth conditions. A measure of the dimensions of the ZnOnanorod is shown in the figure 6. Nanorods grown using different concentrate solution showed that the molarity affects the thickness of the rods significantly. Rods grown under decreasing molarity gave thinner rods. Based on the measurementcarried out on the SEM images, 10mM concentration was selected for remaining part of the work as a width of the nanorods of 10mM sample was in the range of (100-200) nm and was appropriate for vibration without breakage.

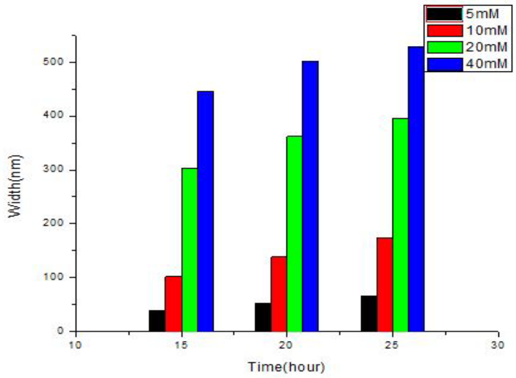

Figure 6: Comparative growth of ZnOnanorods grown at different concentration for different growth time

B. Top electrode febrication

The SEM image of the metallic gold was sputtered on ZnOnanorods grown on glass substrate is shown in figure 7. ZnOnanorods when subjected to physical deformation producea charge separation such that the elongated side gets a net positive voltage while the compressed side gets a net negative voltage.

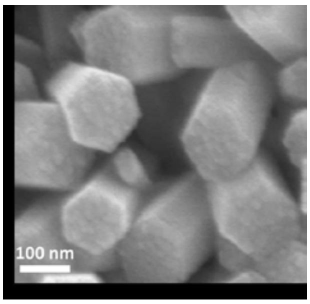

Figure 7: SEM images of Au sputtered ZnOnanorods

In order to ensure proper electrical contact between the nanorods and the FTO coated glass substrate, IV characteristics were studied for applied positive and negative voltages before the integrationof the nanorods with the electrode as shown in the figure 8.

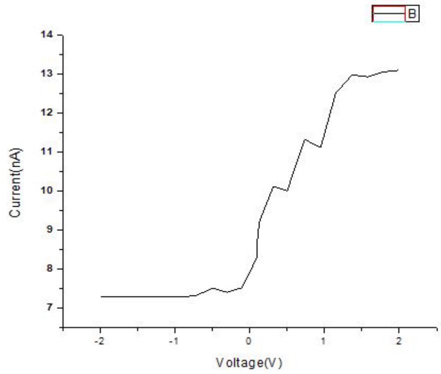

Figure 8: I-V characteristics of the ZnOnanorods grown on the FTO coated glass substrate

We used a Keithley meter for measurement of the current.Application of linear voltagesincreasing from 0 V to (+/-)2V showed increase in current with increase in voltage establishing the fact that aSchottky contact was formed betweenZnOnanorods and FTO conducting glass substrate.

C. Piezo voltage measurement

Whenever a small pressing force is applied on the top electrode of the device,a corresponding voltage is measured by the measuring setup.

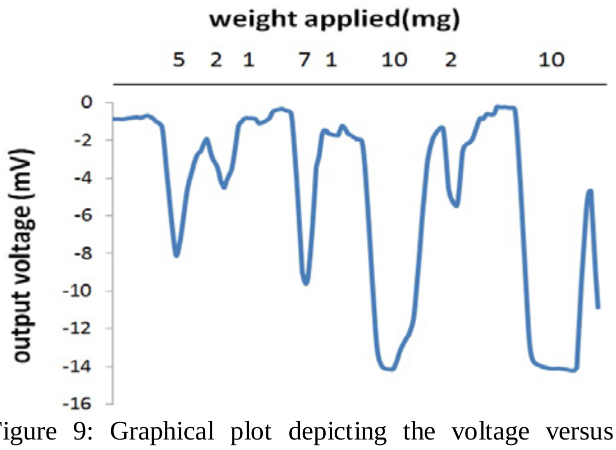

Figure 9: Graphical plot depicting the voltage versus weight plot for piezoelectric potential generated when weight is applied on them

More the applied force more is the generated potential across the nanorods and hence more is the voltage measured in the measuring setup. That is, the piezo voltage generated and detected is dependent on the amount of pressure applied or in other words, the amount of bending of the ZnO nanorods. The pressure force was created by placing weights on top of the electrode, resulting in bending of the rods. Figure 9 shows the voltage-weightgraph for the voltages measured for various weights applied. When the pressure was released, the voltage dropped, signifying that the resilient nanorods return to their original neutral state.

IV. Conclusion

ZnOnanorod arrays were built on conducting substrates. Top electrodes were designedand integrated with the piezo-electric nanorods to form piezo-energy harvesting units.When pressure is applied on the top electrode, the ZnOnanorods get bent due to applied force. Charge separation occurs in the ZnOcrystals and multiplies to the entire nanorod in such a way, that the elongated side has excess positive charge while the reduced size has excess negative charge.These potentials are picked up by the top electrode, and are detected by the Keithley meter connected across it. When the pressure was released, the voltage dropped, signifying that the resilient nanorods return to their original neutral state.

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