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Printed Electronics: Screen Printing Technology –A Method for the Fabrication of Nano-Scale Electronic and Photonic Devices

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ABSTRACT

Researches in the recent past explain that semiconductor nanomaterials such as Zno, ZnS, CdS, CuS etc play a vital role in the fabrication of nano-scale electronic and photonic devices and also in the field of robotics and bio-medical field. The method for synthesizing nanoparticles is an important factor because that influences the reduction in size of the nanoparticles which in turn helps in the enhancement of their optical, electrical, magnetic and biological properties. It is quite interesting to know that screen printing method in printed electronics technology is a very good solution for making thin/thick films for device fabrication. Here in this work the synthesis of ZnO nanoparticle by simple solvothermal method and making thin films on glass and other substrates using screen printing technology are discussed. The XRD patterns of the thin films are discussed. The emerging trends and the future scope of fabrication of devices are reviewed.

Keywords: nanomaterials, nano-scale device, photonic devices, fabrication, screen-printing, ZnO nanoparticles(NPs)

1.0 INTRODUCTION

Semiconductor nanoparticles (NPs) have been extensively studied from experimental and theoretical viewpoints as their potential applications has increased in the field of optoelectronics, photo catalysis, sensors, solar energy conversion, ultraviolet-light emitting diodes and ultraviolet lasers [1-5]. The extensive study of the nanomaterials indicates that there is an enhancement in the optical, electrical and magnetic properties owing to the size dependent factor of the NPs. This is because of the surface phenomena of the NPs and the quantum confinement effect. Among all, zinc oxide (ZnO) is an interesting and promising material for semiconductor device[6-10] since 1960s. It has a direct and wide band gap in the near-UV spectral region and a large free-exciton binding energy. This property helps in the excitonic emission processes which can persist at or even above room temperature [11,12]. ZnO crystallizes in the wurtzite structure, the same as GaN and the researches show that ZnO could be considered as a substitute to GaN. The prospect of using ZnO nanoparticles as alternative to GaN in optoelectronics has driven many research groups worldwide to focus on its semiconductor properties, trying to control the unintentional n-type conductivity

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and to achieve p-type conductivity. This, in turn, has led to a revival of the idea of using ZnO as an optoelectronic or electronic material in its own right. ZnO which is an oxide semiconductor is transparent and the refractive index is high in the visible to infrared region. Due to this property ZnO can be used as a the window of a solar cell transparent electrode optical integrated circuit, and optical waveguide. Because of its wide band gap, it can be used for a light-emitting device. Considering the piezoelectric effect of ZnO it finds application in surface acoustic wave devices and ultrasonic transducer. Also the ZnO is used in gas sensor because of its metallic oxide properties [13-16].

ZnO NPs has been synthesized by chemical and physical means. The fabrication of the synthesized NPs into useful device with desired properties is the requirement at present as the microelectronics industry moves towards new-generation nano-devices. Most of the current technological applications of ZnO, such as varistors, transparent conductive electrodes for solar cells, piezoelectric devices and gas sensors, have made use of films that are prepared by a variety of deposition techniques, mostly on glass substrates. These techniques include sol–gel synthesis [17], oxidation and anodizing [18], chemical spray pyrolysis [19], screen printing [20] and electrochemical deposition [21]. However, we emphasize that for electronic and optoelectronic applications, high-quality single-crystal epitaxial films with minimal concentrations of native defects and controlled impurity incorporation are required. Printing technologies which include screen printing, flexography offset lithography and inkjet are considered as the best way to form uniform epitaxial films. The Screen Printing Technology is a simple, the most apt, fast emerging, multifaceted and eco-friendly technique of making quality ZnO films on the glass substrates for the fabrication of nano-scale devices. [22,23]. In this report, with the synthesized ZnO NPs, preparation of thin films using the Screen Printing Technology on different substrate with different adhesive is elaborated. Also the X-Ray Diffraction patterns obtained for the ZnO films are discussed.

2.0 EXPERIMENTAL SETUP

Synthesis of ZnO Nanoparticles

ZnO NPs are synthesized by simple Solvothermal method. Zinc acetate dihydrate and urea of AR grade are used as starting materials. Ethlylene glycol is used as a medium. The whole of the experiment is done in a domestic microwave oven (solo) operating at a frequency 2.45 GHz and power 800 W. A white precipitate is the end product and it is washed several times using de-ionized water and then with acetone to remove all the impurities. It is then dried in the atmosphere. The ZnO obtained is white in colour. It is then annealed at 200˚C and the characterizations were made. Since one could synthesize nanoscale materials, the solvothermal method is considered as one of the cheap and best method for synthesizing NPs[26, 27]. Also the ZnO NPs thus synthesized could be used for the fabrication of devices.

Thin Film Making

Making thin films with the ZnO NPs synthesized is a real challenge. Out of the many methods used in preparing thin films on the glass substrate, the Screen Printing Technology is one of the simple, powerful and affordable technology used [24].

5019 Gold medium(GM), a thin dry white ink which is used in screen printing and Poly vinyl Alcohol (PVA) are used as adhesive. Thin/thick film paste (matrix) was prepared by mixing5019 gold medium, or PVA in pure ZnO NPs. Care must be taken while making the matrix as that the medium to be less so that the purity of the material can be maintained. The final paste was clear and homogenous, to serve as the coating substance for film preparation. No visible changes were observed in the paste at room temperature. A nylon mesh of 400μm is used as a screen. A small portion of the paste is squeezed over the substrates with printing angle of 45˚ to make a clear film. The simple model of screen printing technology is illustrated in Figure 2. The printed layer was cured in the atmospheric air. In the printing process, material specifications, clearance of the substrates, squeegee angle, printing speed, adherent ink properties, and pressure are the key factors which determine the quality of printed layers. The zinc oxide thin film is coated on the other substrates such as PET film and on sticker film to check the uniformity and the usability. Figure:3 illustrates the Zincoxide thin films on different substrates. The thin films are allowed to dry in the atmosphere. The thin films on glass substrate are annealed at around 150 ˚C for 60 minutes. As the gold medium is heated the complete substrate is smoked. But in the case of PVA added thin films are good and mostly free from PVA after annealing.

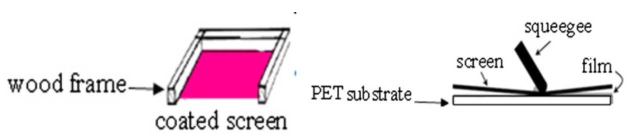
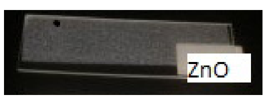


Fig: 2 The Schematic Diagram of Screen Printing Technology



(a) On Glass

(B) On PET film

(C) On Sticker film

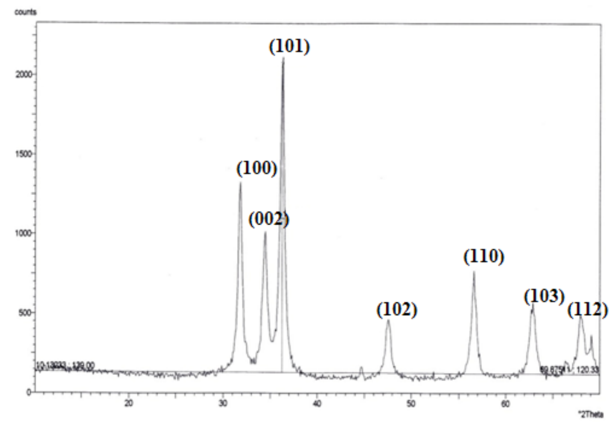
Fig: 3 Coating of ZnO Nanoparticles on Different Substrates

Characterisation Technique

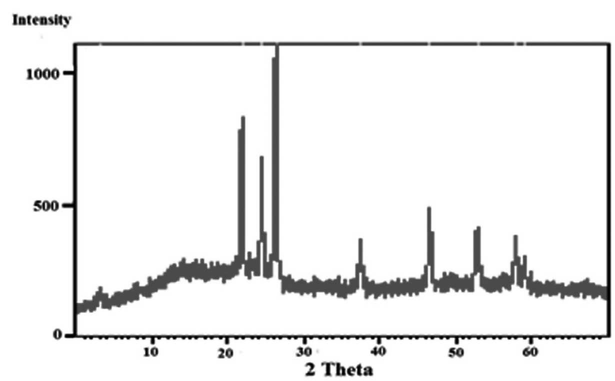
XRD can be utilized to evaluate peak broadening with crystallite size and lattice strain due to dislocation. In X-ray diffraction technique Cu radiation of wavelength 1.54060 Å, 40 KV and 30 mA, is used to scan the angle 2θ, between 10° and 80°. Here the XRD pattern of pure synthesized ZnO nanoparticles is compared with that of the ZnO thin films coated on the glass substrates. Figure 4 illustrates the XRD patterns of (a) Pure ZnO, (b) ZnO+PVA (as prepared), (c) ZnO+PVA (annealed at 150 ˚C) (d) ZnO+ 5019 gold medium (as prepared).

3.0 DISCUSSION

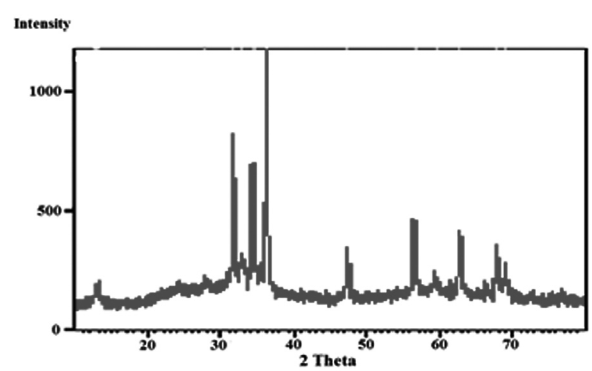
Figure 4 illustrates the XRD patterns of (a) Pure ZnO (synthesized using solvothermal method), (b) ZnO + PVA (as prepared), (c) ZnO+PVA (annealed at 150 ˚C) (d) ZnO+ 5019 gold medium (as prepared).



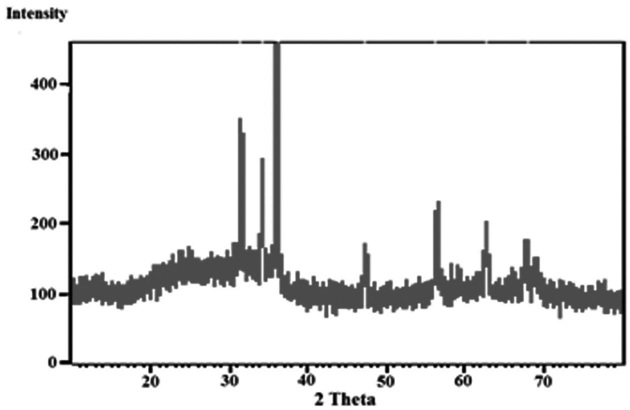
(a) XRD Pattern of pure ZnO Synthesised by Solvothermal Method



b) For ZnO + PVA



(c) For ZnO+PVA (as prepared) (annealed at 150 ˚C)



(d) ZnO+ 5019 Gold Medium (as prepared)

Fig: 4 XRD Pattern of ZnO NPs & ZnO Thin Films

XRD can be utilized to evaluate peak broadening with crystallite size and lattice strain due to dislocation. All the diffraction peaks can be indexed to a hexagonal structure of ZnO consistent with the JCPDS file No.36-1451. This is in agreement with the electron diffraction results. The peak broadening in the XRD patterns clearly indicate that small nanocrystals are present in the pure as well as in the films. Native or intrinsic defects are found as imperfections in the crystal lattice that involve only the constituent elements. Even though, we find sharp peaks corresponding to ZnO, uniform strain is obtained when the ZnO nanoparticles are mixed with PVA and the intensity counts is reduced compared to the pure ZnO nanoparticles as indicated in Fig:4 (b,c). In the Fig 4(d) the broadened distorted peaks are due to the gold medium used. The gold medium creates the non-uniform strain which is also called as RMS strain. Also the intensity count is very much reduced due to the strain. But the ZnO peaks confirm that the film has ZnO NPs. In general, the ZnO crystallizes in the wurtzite structure in which the oxygen atoms are arranged in a hexagonal close packed type with zinc atoms occupying half the tetrahedral sites. Thus the Zn and O atoms are tetrahedrally coordinated to each other and have equivalent position is proved in all the XRD patterns. It is inferred that PVA solution can be used instead of the GM for making the thin film. The particle size is calculated using Sherrer formula. The Interplanar spacing (dhkl) from XRD, JCPDS data card, Intensity heights in counts, particle size of ZnO (pure & films) for the corresponding (100) plane is given in the table.1. From the table it is noted that the Interplanar spacing (dhkl) from XRD matches well with the JCPDS data card.It also explains that the thin films can be prepared by Screen Printing Technology. It is clearly shown that the ZnO NPs can be mixed with minimum quantity of PVA to minimize the strain and then to be annealed to get very good film. The particle size of the ZnO NPs is calculated using Sherrer Formula $D = K\lambda / \beta \cos\theta$. The particle size of the ZnO NPs thus calculated are less than 50nm in size. Since we get nano-scale NPs, the solvothermal method is assigned to be one of the cheap and easy method to synthesize the NPs of small size. The thin films can be prepared using the Screen Printing Technology which is a very useful, simple method to form the thin films in any substrate and that films can be used in the Printed Electronics in near future.

Table :1 Interplanar spacing (d_{hkl}) from XRD, JCPDS data card, Intensity heights in counts, particle size of ZnO (pure & film) for corresponding (100) plane

SAMPLE	2 THETA	d_{XRD}	d_{JCPDS}	HEIGHT IN (CTS)	PARTICLES SIZE
Pure ZnO	31.9984	2.7964	2.8135	1435	44.0
ZnO+PVA (as Prepared)	31.7617	2.81737	2.8135	563.97	54.8
ZnO+PVA (Annealed)	31.6551	2.82661	2.8135	634.98	35.3
ZnO+ 5190 Gold Medium (as Prepared)	31.5262	2.83787	2.8135	212.53	41.1

4.0 CONCLUSION

From the above discussions it is clear that the simple solvothermal method can be used to synthesize the ZnO NPs and can be prepared as thin films on glass substrate using Screen Printing, a simple, apt, easy and affordable technique. Since ZnO is highly enhanced in optical and electrical properties which the author has already published in articles[24,26], it can be used in Quantum Dot Solar Cells and in sensor applications and in the fabrication of other electronic and photonic devices in future.

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