Deposition and Characterization of ZnO Thin Film using a Lab-scale Fabricated Spin Coater

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***Abstract*— Spin coating is one of the most common techniques for applying thin films of desired thickness on the substrates. It involves the application of a thin film evenly across the surface of a substrate by coating/casting a solution of the desired material in a solvent while it is rotating. In this work, one such spin coater is designed and fabricated at the lab-scale. This fabricated spin coater is used to form Zinc Oxide (ZnO) thin film on the glass substrate. Zinc oxide (ZnO) thin films have become technologically important materials due to their wide range of electrical and optical properties. The ZnO thin films were deposited on a glass substrate by sol-gel and spin coating technique. The crystallographic structures of ZnO films were investigated using X-ray diffraction (XRD) studies. The result shows the formation of a uniform thin film on the substrate using spin coating technique.**

***Index Terms*—sol-gel process, spin coater, ZnO thin film.**

I. Introduction

Spin coating is one of the most common techniques for applying thin films on the substrates. It is very safe and easy to use technique. The spin coating was pioneered by Emil et al more than fifty years ago [1-3]. In many cases the coating material is polymeric and is applied in the form of a solution from which the solvent evaporates. Spin coating was first studied for coating of paint and pitch. Later it has been used for several decades for the application of thin films. Spin coater is used in a wide variety of industries and technology sectors. This process has been widely used in the manufacture of integrated circuits, optical mirrors, color television screens and magnetic disk for data storage [4, 5].

To perform spin coating, an excess amount of a solution is placed on the substrate, which is then rotated at high speed in order to spread the fluid by centrifugal force. This centrifugal force drives the liquid radially outwards. The viscous force and surface tension forms a thin residual film on the flat substrate. This is as the result of combination of outward fluid flow and evaporation [6]. The applied solvent is usually volatile, and simultaneously evaporates. So, the higher the angular speed of spinning, the thinner the film. The thickness of the film also depends on the concentration of the solution and the solvent.

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Thus, final film thickness and other properties will depend on the nature of the solution (viscosity, drying rate, percent solids, surface tension, etc.) and the parameters chosen for the spin process. Factors such as final rotational speed, acceleration, and fume exhaust contribute to how the properties of coated films are defined. One of the most important factors in spin coating is repeatability. The advantage of spin coating is its ability to quickly and easily produce very uniform films, ranging from a few nanometres to a few microns in thickness [7-9].

Today, when the world is surmounting on the roof of technology and electronics, mostly dominated by compatible electronic equipments and thereby creating the need for materials possessing versatile properties. After digging the pages of history for the search of such type of material a very common category of material comes out that is "semiconductor". The world therefore now demands a material that should possess inherent properties like larger band gap, higher electron mobility as well as higher breakdown field strength. So on making investigation about such a material the name of compound comes out is "Zinc Oxide" which is a wide gap semiconductor material and well satisfying the above required properties. ZnO is an important electronic and photonic material because of its wide direct band gap of 3.37 eV and high exciton binding energy of 60 meV [10]. At present, the ZnO materials are widely applied in the field of optoelectronics, such as in ultraviolet laser of light-emitting diode (LED), surface acoustic wave (SAW) components, varistors, piezoelectric materials, photocatalyst, gas sensors, transparent conductive film and solar cell, etc [11]. Recently, several seed coating techniques have been used for the growth of well-ordered ZnO structures, such as atomic layer deposition (ALD), pulsed laser deposition (PLD) [12], electron beam evaporation (EBE) [13], the successive ionic layer adsorption and reaction (SILAR) method [14], spray pyrolysis [15], and RF sputtering techniques [16,17]. Although there have been many existing preparative techniques for this material, we have employed sol-gel method to for ZnO synthesis.

In this paper we have fabricated an easy to operate and low cost programmable spin coater based on the brushless dc motor of hard disk drivers (HDDs). Highly efficient and compact, the control of the motor is achieved by a simple circuitry. Zinc oxide solution was prepared using sol-gel process and is coated onto the glass substrate. The thin film formed on the glass substrate was characterized by UV-VIS spectrophotometer and X-Ray diffraction studies.

II. EXPERIMENTAL DETAILS

A. Fabrication of Spin Coater

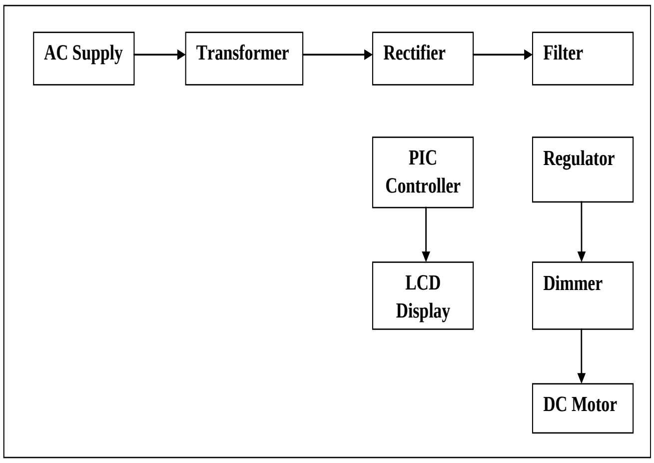

Fig.1. Block Diagram of Spin Coater.

The above fig.1 explains the block diagram of Spin Coater. In this system the 230V AC supply is applied to the step down transformer. The step down transformer converts the 230 V AC supply to 16 V. Then this step downed voltage is applied to the rectifier circuit. The rectifier converts the 16 V AC supply voltage to the DC voltage. The DC voltage obtained from the rectifier has harmonics. Those harmonics are reduced by the filter. The filter removes that noise and gives the pure DC voltage. To get the constant DC voltage the output of the filter is given to the regulator. At the output of the regulator two outputs are taken out. Out of those two outputs, one is given to the PIC microcontroller and second is given to the dc motor through dimmer. To calculate the rotations per minute, the opto coupler is used. An opto coupler is a semiconductor device that uses a short optical transmission path to transfer an electrical signal between circuits or elements of a circuit, while keeping them electrically isolated from each other. When the input voltage of a LED is forward biased, the LED emits light, this transmitted light turns on the photo sensitive device (photo resistor, LDR, photo diode and LASCR) which produce nearly the same voltage at the output. The opto coupler is placed in the position that the light of the LED gets cut by the movement of the shaft of the motor. The opto coupler gives the signal to the PIC controller when the light is gets cut by the movement of the shaft of the motor. Then the PIC controller calculates that in how many times the light gets cut in one minute and that RPM is gets displayed on the LCD.

Fig. 2 represents the finally designed low cost spin coater, wherein the LCD display has been used to display the rotation per minute (RPM). The disc was placed on the shaft of the motor. By using the movement of the shaft of the motor RPM was calculated.

16F676 PIC controller was used in order to control the speed of the motor. The PIC16F676 microcontroller from Microchip Technology has 1K of code space, 12 I/O pins, internal clock oscillator, easy to program (only 35 single word instruction) CMOS flash based 8 bit microcontroller.

Fig.2. Spin Coater.

B. Preparation of ZnO Solution

In order to prepare ZnO solution, firstly 5 gms of zinc acetate dihydrate is added to 50 ml of isopropyl alcohol. This solution is stirred for 1hr at 60^0 C. 2.66 ml of ethanolamine was added drop by drop into the above solution until the transparent solution was obtained. This solution is further stirred under same condition of 60^0 C for 1h. Next the solution was allowed to cool at room temperature. The obtained solution is Zinc Oxide solution.

In order to coat a thin film of prepared ZnO solution on the glass substrate, the spin coater is used. For this, first the glass substrate is placed on a disc of the spin coater and the prepared solution was added drop by drop onto the surface of the glass substrate. The substrate was then allowed to spin with 1800 RPM for 1 min. Next the glass substrate was placed into the oven at 130^0 C for 10 min. The above process is repeated 9 times in order to obtain a uniform coating of the solution on the substrate. After this process the glass substrate was kept into the muffle furnace at 450^0 C for 10 min. The formation of thin film was observed on the substrate. Fig. 3 shows the thin film of ZnO deposited on the glass substrate using the as fabricated lab-scale spin coater. The obtained thin film of ZnO was characterized by X-Ray Diffraction (XRD) studies.

Fig. 3. ZnO thin film deposited on glass substrate

III. RESULTS AND DISCUSSION

A. UV-Visible Spectroscopyof ZnO Solution

The ZnO solution was prepared as explained in the above section. The optical characterization of the sample was recorded on UV-Vis absorption spectrophotometer. Figure 4 shows the UV-Visible absorption spectra of ZnO solution as a function of wavelength.

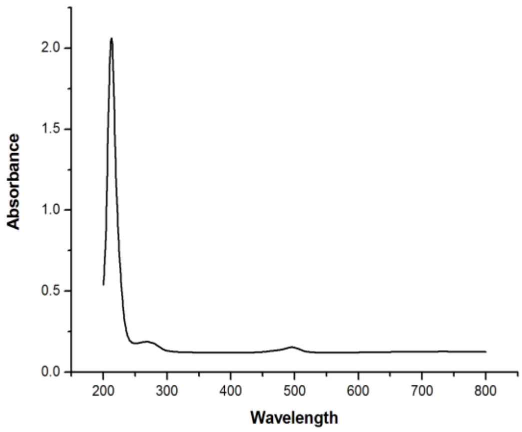

Fig. 4. UV-VIS Spectra of ZnO solution

The UV-Visible absorption spectroscopy of ZnO shows an excitonic absorption peak at about 214 nm, which lies much below the band gap wavelength of 388 nm of bulk ZnO. The peak centered at ~214 nm in absorption spectra may be due to the transition of electrons from the more inner shell to the uppermost shell as time passes.

B. X -Ray Diffraction Analysis of ZnO Solution

Figure 5 shows the XRD diffraction pattern of ZnO thin film coated on the glass substrate. Substrates with thin film layers were placed on a stage and struck with x-rays to obtain *2θ* diffraction angles. ZnO samples synthesized using the optimized sol-gel method have visible peaks for many crystal phases.

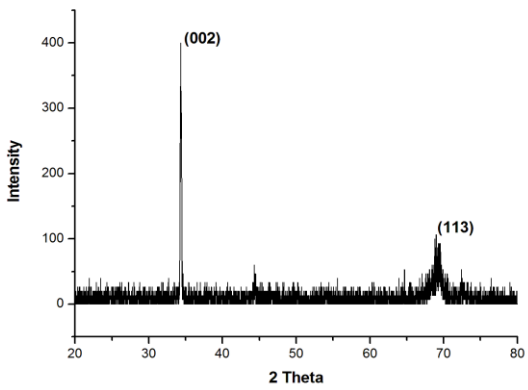

Fig. 5. X-Ray diffraction of ZnO thin film

X-ray diffraction (XRD) was used for crystal phase identification for ZnO thin film prepared by sol-gel technique. The peaks are indexed at the 2θ values of 34.54° (002), and 69.60° (113). All the diffraction peaks of sample correspond to the characteristic hexagonal wurtzite structure of zinc oxide.

IV. CONCLUSION

Spin Coater was successfully fabricated in the laboratory. ZnO solution was prepared using zinc acetate dehydrate as precursor. The solution was characterized using UV-VIS spectrophotometer. The absorbance peaks clearly indicated the formation of ZnO solution. Further, the ZnO solution was coated on the glass substrate using the fabricated spin coater at 1800 RPM which resulted into a thin film deposition of the solution the substrate. The deposited ZnO thin film was then characterized by X-Ray diffraction studies. The 2 theta values of the peaks indicated the crystal phase of ZnO on the substrate. Thus, the results obtained reveals that the ZnO solution prepared was successfully coated upon the glass substrate in the form of thin film. And this was possible with the help of the spin coater instrument fabricated within the laboratory. This spin coater machine can thus be used for the microfabrication of oxide layers on the substrates in the form of uniform thin films using sol-gel precursors.

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