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Design and Fabrication of a Simple Cost Effective Spin Coater for Deposition of Thin Film

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ABSTRACT

This paper describes the design and fabrication of an economical spin coater for depositing thin films.Spin coater is a machine that can dispense a liquid onto a substrate uniformly. Some desirable properties of Spin coater such as ability to make defect free and uniform thin film, accuracy in rotation control together with a closed optimized process chamber etc. are maintained in this prototype spin coater.The materials used for making thin filmliquefied in a volatile solvent. Here the system is fabricated by using a dc motor and simple electronics circuit, in which the spinning speed can be controlled very easily. In this design the spinning speed is up to 3,000 rpm that can be controlled step by step manually. ZnO thin films are successfully prepared through this spin coater by sol-gel process. This thin film isa mixture of Zinc acetate dihydrate, ethanol anddi-ethanolamine. Thin filmdeposition by this cost effective spin coater is a very simple technique and can beused widelyfor preparing films of uniform thickness.

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INTRODUCTION

Now a day's thin film science and technology started to play an important role in the advanced technological industries. Initiallythe only purpose of the development of thin film technology wasto satisfy the requirement of the integrated circuit industry. But day by day the demand for high speed smaller and smaller devices increases, so for development ofhigher speedsmaller and smaller devices especially in new generation of integrated circuits requires advanced materials and new processing techniques appropriate for integration technology. Thin films technology can play a vital role to achieve this goal as they are capable of satisfying those requirements. Over the past four decades the making of thin films for device purposes has been industrialized. In many real-world problems thin films are very important as a two dimensional system. Their material costs are very lowwhereas the price of corresponding bulky materials are high and they perform the same function and sometimes even betteraccording to surface processes [1]. So, information and determination of the nature, functions and new properties of thin films can be used for the development of new technologies that are appropriate for future applications.The layers of thin films are ranging from fractions of a nanometre to several micrometres in thickness[2]. Thin film deposition has mainly three major technique such as solid, liquid and gas deposition technique. Chemical Vapour Deposition and Physical Vapour Deposition are gas deposition method. These methods are comparatively expensive. Spray pyrolysis is another popular method of depositing thin film. But it has some limitations such as surface thickness is uncontrollable, not crack free, processing time is high etc.In thin film deposition temperature control is very essential, but in spray Pyrolysis it is very difficult to control temperature. Compare to others Spin coating is a fast and simple method for producing thin and homogeneous organic films. Inproduce uniform thin is technique thin filmsare produced on a flat substrate. The equipment for spin coating process is known as spin coater, or simply spinner. In short, more than necessaryquantity of a solution is employed on the substrate, then it starts rotating and the rotation speed continuously increases and finally rotated at high speedfor spreading the fluid due to centrifugal force.This process was first explained by a number of authors [3,4] using several simplifications. Fabrication and Manufacturing techniques of these devices are comparativelyeasybecause of the availability of the necessary equipment.Repeatability is one of the most vital factors in spin coating. Several methods to grow inorganic

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compound semiconductors are compelling vital roles in the advancement of modern technologies. To obtain the performance of thin film based devices control over the film properties is necessary.

Many sophisticated techniques, namely laser assisted evaporation, molecular beam epitaxy, ion beam sputtering, thermal evaporation, vacuum deposition, chemical vapour deposition, chemical bath deposition etc. are being used depositing thin film [5]. But these methods have some limitation in temperature and uniform thickness controlling and they are energy intensive and involve high temperature and pressure.

Spin-coating method is really specialbecause of themerit of conveniences, reproducibility, use of low cost equipment and fast operation speed. Due to its huge advantages It has applications in various industries, such as the use of polymeric photo resist for photolithography, Sol gel films for dielectric application, planner structure for different optical applications and microelectronic industries for fabrication of integrated circuits[6]. Here thedesigned and developed prototype is very cost effective than the market available spin coating system. The price of the market available spin coater ranges from USD $ 50 to USD $ 4000, where the developed prototype spin coater costs only USD $ 15. This spin coater has no time delay and it is easy to clean after each operation.

Methodology And Experimental Setup:

Methodology:

Spin Coating is a method or process to produce thin organic films that are uniform over large areas[7]. The spin coating process can be divided into the four stages .The deposition, spin up, and spin off stages and evaporation. The first three stages occur sequentially while the last stage i.e. evaporationstage occurs throughout the process, becoming the primary ways of thinning near the end.

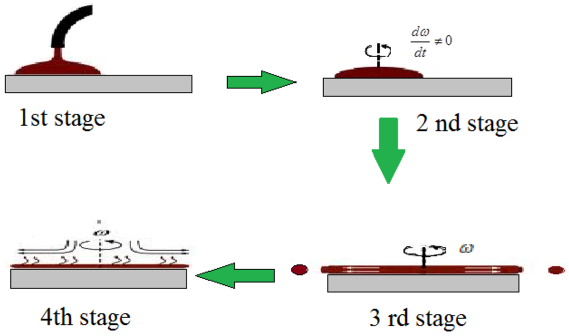

Fig. 1: Steps of thin film deposition in spin coating process.

There are four different stages of the spin coating process. In the first stage the coating solution is deposited onto the wafer or flat substrate by checking the suitable position of the substrate.In the 2nd stage the substrate is speeded up to its ultimate desired spinning speed.In the 3rd stage the substrate is spinning at a constant rate and fluid viscous forces control the fluid thinning characteristics. This stage is also known as flow controlled stage.In the last stage the substrate is rotating at a persistent rate and solvent evaporation controls the thinning characteristics of the coating. After completing the evaporation of the entire solvent, a solid film is produced. This stage is also known as evaporation controlled stage.

Experimental Setup:

The schematic diagram and complete set up of a simple spin coater system is shown in the fig. 2 and Fig. 3 respectively.This contains a DC motor, regulator, spinning disk, substrate, LED. The internal circuit fabrication is kept inside a box. In our design 12V, 3000rpm motor is used, to control the spinning speed by changing the voltage supply from 0 V to 12V which is accomplished by regulator.

The power supply is constructed with the help a transformer that attached to the ac supply to step the ac voltage to chosen amplitude, then rectifying that ac voltage, filtering with a capacitor. The connection of the complete voltage supply unit is shown on the figure .The ac voltage is step down to 12V rms across bridge transformer. An unregulated dc voltage is provided by a half-wave rectifier and capacitor filter which can be shown as a dc voltage where ac ripple of a few volts may be observed. This voltage acts as an input to the voltage regulator. The circuit fabrication and the motor are mounted inside a box with the axis of the motor passing through one of the walls. Overall internal circuit diagram of the complete system is shown in the following fig. 4.

In designing the circuit resistors of different values, capacitors, diodes (1N4007), zener diode, OP AMP (UA 741), transistors (D880) are also used. On the outside of the box,a suitable arrangement of a push button, regulator knob and spinning circular disk is shown. The disk is connected to the motor shaft by pulley. The push button functions as the start button. LED is used to indicate the power supply;substrates are located on the center of the flat disk. The substrate is connected to the spinning disk with the help of a small piece of double sided gluetape.

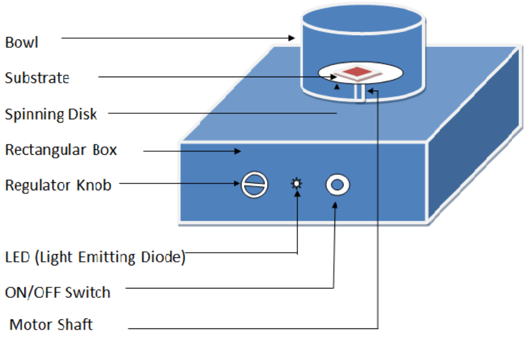

Fig. 2: Schematic diagram of prototype spin coater.

Fig. 3: Complete setup of a simple spin coater.

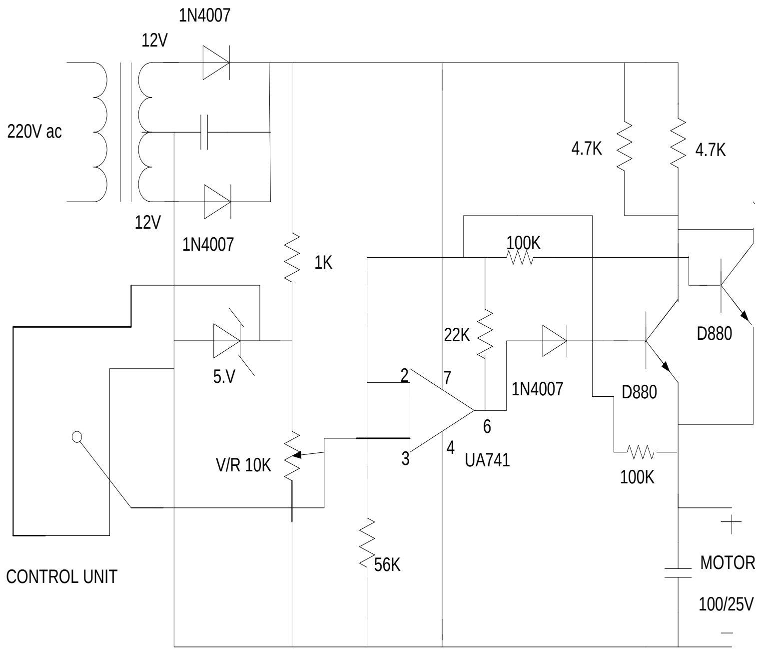

Fig. 4: Internal circuit diagram of spin coater.

After making the prototype spin coater, its performance is tested by making ZnO thin films[8]. These films are prepared by sol- gel process. For making desired ZnOsolutionZinc acetate dehydrate ($Zn(CH_3COO)_2.2H_2O$) was dissolved in mixture of ethanol anddi-ethanolamine (DEA). This solution was deposited on the glass substrate of the spin coater. DEA performs not only as base but also as a complexing agent.

Results:

In this work, ZnO films are made by using sol gelprocess, and deposited on glass substrates by spin coating method. The ZnO precursor solution are prepared by dissolving zinc acetate dehydrate (Zn (CH3COO)2·2H2O), in solution of ethanol and diethanolamine at room temperature. The solution is stimulated to about half an hour till a clear and homogeneous solution is found. ZnO thin films are made by spin coating process where the stored solution on a glass substrate rotates at different spinning speedsand spin time. The following ZnO films are obtained by using the prototype spin coater.

The ZnO thin films a can be prepared using various methods: sputtering, spray pyrolysis, chemical vapor deposition, pulsed laser deposition, oxidation of metallic films etc.In respect of other methods, the sol-gel spin coating method has some merits such as easy control of used chemical components, deposition of thin films at low cost, less complicated deposition equipment.Atpresent time, ZnObecomes very important have element and it has huge use indifferent engineering sectors, industries and various scientific research. ZnO is a wide band gap n-type semiconductorand it has hexagonal quartzite structure. It is really a beneficial substantial as they haveprospective use in many applications like solar cell, transparent conducting electrode, ultraviolet and blue LEDs, laser diodes, thin film transistor, surface acoustic wave devices and gas sensors. There must be some

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essential features of the thin film for their transparent conducting application such as low resistivity, high transmittance in the visible range and good stability against corrosive surroundings.

(a) 3000 rpm for 20S

(b)3000 rpm for 1 min

(c) 30S for 1500 to 2500 rpm

(d) 1500rpm for 30S

Fig. 5: ZnO thin films for different speed and time.

In future it is possible to make the Spin Coater more user friendly by adding some features such as making microcontroller based digital spin coating system, to digitally control the motor speed step by step process, LCD display unit can be used which will show spin time, spin speed etc. Additionally by analyzing some properties of thin film such as band gap, transparency, absorption, transmittance measurement etc. the performance of the simple cheap Spin Coater can be improved.

Conclusion:

Spin coaters are ideal tools for the preparation of thin films. Here the total spin coater system is very simple. In this work,ZnO thin films are successfully prepared by spin-coatingmethod, using a simple and convenient chemical route. This spin coater can also be used for film deposition of different types of precursor solution. So the problem of high instrumental costs of spin coater cab be solved the simple spin coater prototype designed here; in this work theeasy implementable equipment is developed in Bio mechatronics laboratory and it could be used for the making of thin films using recycled electronic components.

Discussion:

Spin coating is simple and easy technique, but some care should be taken to make uniform thin film. To avoid scattering of the solution and isolation of filmdeposition from undesired air current, it is enclosed a by a plate made of glass. The disk plane that supports the substrates is perfectly leveled with the horizontal and the substrate must be clean and free of dust particles [3]. Otherwise the film will not be uniform. Because of the compatibility and easy controlling of the devices,they provide a suitable step-by-step system for precise and uniform deposition of thin films and coatings.

There are some Initial conditions thoseare very emergency for making better thin film by thin film deposition method. In a spin coater the disk supports the substrates, so initially it is very important to check whether the disk is perfectly leveled with the horizontal. The substrate contains the depositing solution. So it should be confirmed that substrate must be wet by the depositing solution. Otherwise, due to the centrifugal force the substrate can't contain the solution properly and it will go away from the substrateand there will be no trace of material onthe substrate. The substrate should be flat. Its flatness and/or roughness factorcould affect the deposition method. The solution of the depositing material should be uniform andhomogeneous, there must not beany lumps and air bubbles .it should be confirmed that the substrate is perfectly cleaned. For a certain spinning speed and certain solution concentration, flow of the solution on the substrate during rotation is optimum. Care should be taken whether this relation is maintained or not. Otherwise viscosity may become a hindrance to the flow.

During the spinning of the substrate the fluids flows up to the edges of the substrate.The spinning of the substrate will not stop until the desired film thickness is realized. The used solvent is usually volatile, and simultaneously evaporates. The film thickness is proportional to the angular spinning speed. Other factors that affect the thickness of the film are the concentration of the solution and solvent.

Spin speed is a very emergency term in spin coating system. The spinning speed of the substrate affects thedegreeof radial that means centrifugal force applied to the liquid solution, not only that it also affects the velocity and characteristic turbulenceofthe air immediately above it.The acceleration of the substrate towards the final spin speed can also affect the coated film properties. The thickness of films depends on different factors. To get homogeneous films, several issues are significant and must be considered, such as solution viscosity and concentration, the evaporation rate of the solvent, spinning speed,spinning time.

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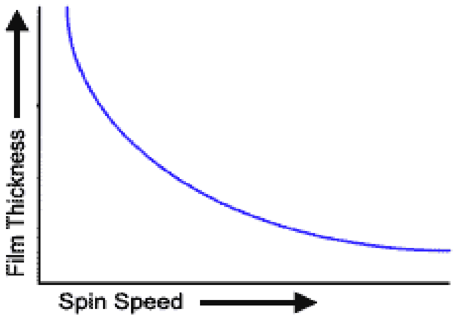

Fig. 2.4: Film thickness VS spin speed.

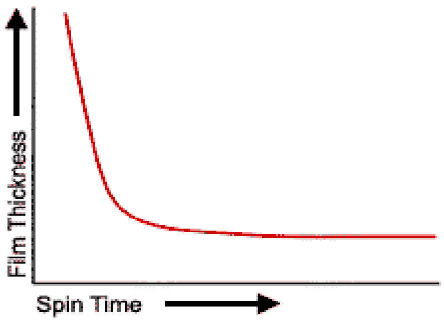

Fig. 2.5: Film thickness VS spin time.

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