Fabrication of Digitalized Spin Coater for Deposition of Thin Films

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***Abstract*—This paper describes the fabrication of digitalized spin coating system to deposit thin films on glass substrate. The digitalized spin coating system has been integrated with an automatic control arrangement, where a microcontroller unit, a character display, a matrix keypad and a dc motor has been employed. A dc motor has been used to spin the substrate. It is needed a controlling circuit to maintain the desired speed. To give control pulse to microcontroller, which has overcome the difficulty of conventional SCR based controlling circuit. It is possible to rise up the speed of the motor from 0 to 3300 rpm. The required speed (in rpm) and spinning time can be given as input from the matrix keypad. LCD Character display plays the role of showing the desired rpm and time. Zinc oxide thin films have been deposited on glass substrate with the proposed digitalized spin coater. It has important features that it can operate immediately at different speed and time after finishing the previous settings. This system is very simple, light and cheap in price.**

Keywords—Spin coating, zinc oxide, thin films, film deposition, substrate.

I. INTRODUCTION

Recently semiconductors with novel microstructure have attracted much attention due to their novel properties, which make them potentially ideal functional components for nanometer scale electronics and optoelectronics [1]. Thin film technology has been developed primarily for the need of the integrated circuit industry, to reduce the cost of photovoltaic (PV) systems, to apply solid state lithium polymers [2]. Thus, knowledge and determination of the nature, functions and new properties of thin films can be used for the development of new technologies for future applications [3]. The production of thin films for device purposes has been developed over the past 40 years [4]. Thin films as a two dimensional system are of great importance to many real-world problems. Their material costs are very small as compared to the corresponding bulk material and they perform the same function when it comes to surface processes [5]. Several methods to grow semiconductors thin films are taking vital roles in the advancement of technologies. Therefore many sophisticated techniques, namely radio-frequency magnetron sputtering [6, 7], spray pyrolysis [8, 9], sol-gel process [10, 11], pulsed laser deposition [12], are being used. These processes are energy intensive and involve high temperature, pressure and vaccum. But spin coating is one of the most suitable, fast and simple method to deposit thin film and the way of preparing uniform and homogeneous thin films [13, 14]. The deposition of thin film by spin coating is a very simple and widely used technique to create thin films as insulating layers for microcircuit fabrication, magnetic disk coatings, flat screen display coatings, compact disks [2]. One of the most important factors in spin coating is repeatability. Our groups already succeeded to fabricate manually-controlled analogous spin coater [3, 15]. Recently, we are modifying and proposing the digitalized spin coater, which has used microcontroller, based precise controlling unit and LCD display unit. Moreover, commercially available spin coater without rotary pump (Model: **KW-4A**) has price around $700.0 (BDT. 56000.00/-), which is very expensive. Whereas our proposed spin coater has very less price around (BDT. 3000/-) only, which is approximately 95% cost effective than the commercial one. Moreover, there is no time consuming delay and it is easy to clean after each operation. The ZnO thin film has been prepared by this proposed digitized system and optical property of thin films has also investigated and discussed.

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II. SPIN COATING METHOD

Spin Coating is a method to produce thin organic films that are uniform over large areas. Usually a small amount of coating material is applied on the center of the substrate, which is either spinning at low speed or not spinning at all. The substrate is then rotated at high speed in order to spread the coating material by centrifugal force. Rotation is continued while the fluid spins off the edges of the substrate, until the desired thickness of the film is achieved.

Figure 1 shows the spin coating process, which can be broken down into the four stages. Four different stages of the spin coating process:

I. Deposition of the coating fluid onto the wafer or a flat substrate.
II. The substrate is accelerated up to its final, desired rotation speed.
III. The substrate is spinning at a constant rate and fluid viscous forces dominate the fluid thinning behavior.

IV. The substrate is spinning at a constant rate and solvent evaporation dominates the coating thinning behavior. After evaporation of the whole solvent, a solid film is generated.

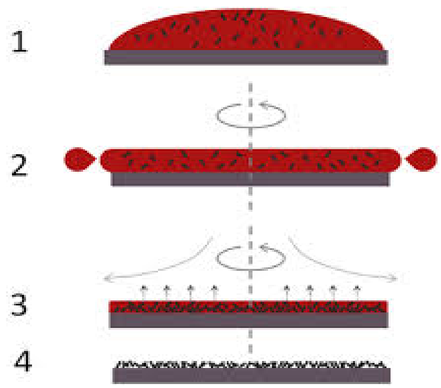

Fig. 1. Schematic diagram of different steps for spin coating system.

III. PROPOSED DIGITALIZED SPIN COATING SYSTEM

Fig. 2 shows the basic block diagram of proposed spin coating system. An ac to dc converter converts 220V ac power supply into 12V and 5V dc power. 5V has been used as power supply for microcontroller ATmega32 and LCD display unit. For giving desired input to control the speed and time, a matrix keyboard has been employed. A motor driver circuit has been used to control and continue the rotation of motor. ATmega32 microcontroller drives the motor driver circuit that in turn drives a 3300 rpm motor powered by 12V dc. Pulse Width Modulation (PWM) technique has been used in this work to control the speed of motor, where its signal is generated in microcontroller. The PWM signal will send to motor driver to vary the voltage supply to motor to maintain at constant speed.

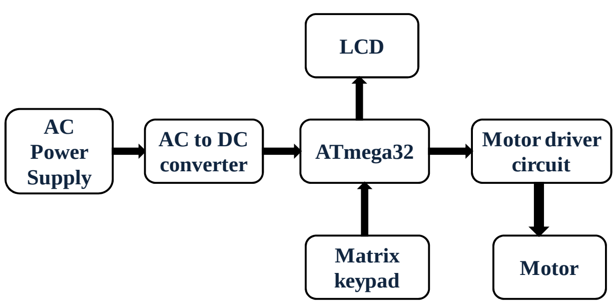

Fig. 2. Basic Block diagram of proposed device

Fig. 3 shows the complete circuit diagram of the digitalized spin coating system. Since all the ICs and the motor used in this work need dc power, hence a rectifier circuit is implemented as shown in Fig. 3(a). At first the ac voltage is stepped down to 18V rms across bridge transformer. A full-wave bridge rectifier and capacitor filter then provides an unregulated dc voltage shown as a dc voltage, with an ac ripple of a few volts. This voltage acts as an input to the voltage regulator of LM7805 and LM7812 those gives the regulated dc output voltage.

Fig. 3(b) shows the electrical interconnection of microcontroller ATmega32 with motor, motor driver which is actually a NPN transistor, matrix keypad and LCD display. The software program for microcontroller has been written in C Language and then complied to 'HEX-file' using the WinAVR software. The complied program has been burnt on ATmega16L chip using STK200 Programmer which is a parallel port/printer port burner. The simulation of the work has been carried out using Proteus simulator.

Among four 8-bit input/output ports of microcontroller, in this work, PortC have been used as input port connected to matrix keypad. While PortB and PortC has been used as output port connected to motor driver and LCD display respectively. Necessary connections of the equipments are shown in Fig. 3(b). A NPN transistor is used to vary the motor speed by pulse width modulation (PWM) signal.

Figure 4 shows the complete setup of proposed digitalized spin coater. The circuit and the motor are mounted inside a box with the axis of the motor passing through one of the walls. On the outside, a convenient arrangement of a matrix keypad, LCD display and spinning circular disk is shown. It has stainless stand to hold the solution holder and to put solution drop-wise at the center of substrate (as shown inset of Fig. 4). LCD display shows rpm and time (Seconds), which is given by Matrix Keyboard. It has needed 220V/ 50 Hz as power supply and a power switch has been employed to ON/OFF the system. The spinning disk is connected to the motor shaft by pulley and substrates are placed on the centre of the flat disk.

The substrate is connected to the spinning disk using a small piece of double sided adhesive tape. To avoid sprinkling of the solution and isolate film deposition from undesired air current, it is enclosed by a plate made of glass. The plane of the disk that supports the substrates is perfectly leveled horizontally and the substrate must be clean and free of dust particle for the film will not be uniform [11].These compatible, easy-to-use devices provide a convenient step-by-step method for precise and uniform deposition of thin films.

Figure 5 clearly depicts the step by step working procedures for proposed digitalized spin coating system. It has mainly four steps [16]. Figure 6 shows the Speed versus time curve of proposed digitalized spin-coater. From this figure it can be said that desired speed will be obtained within 10 seconds.

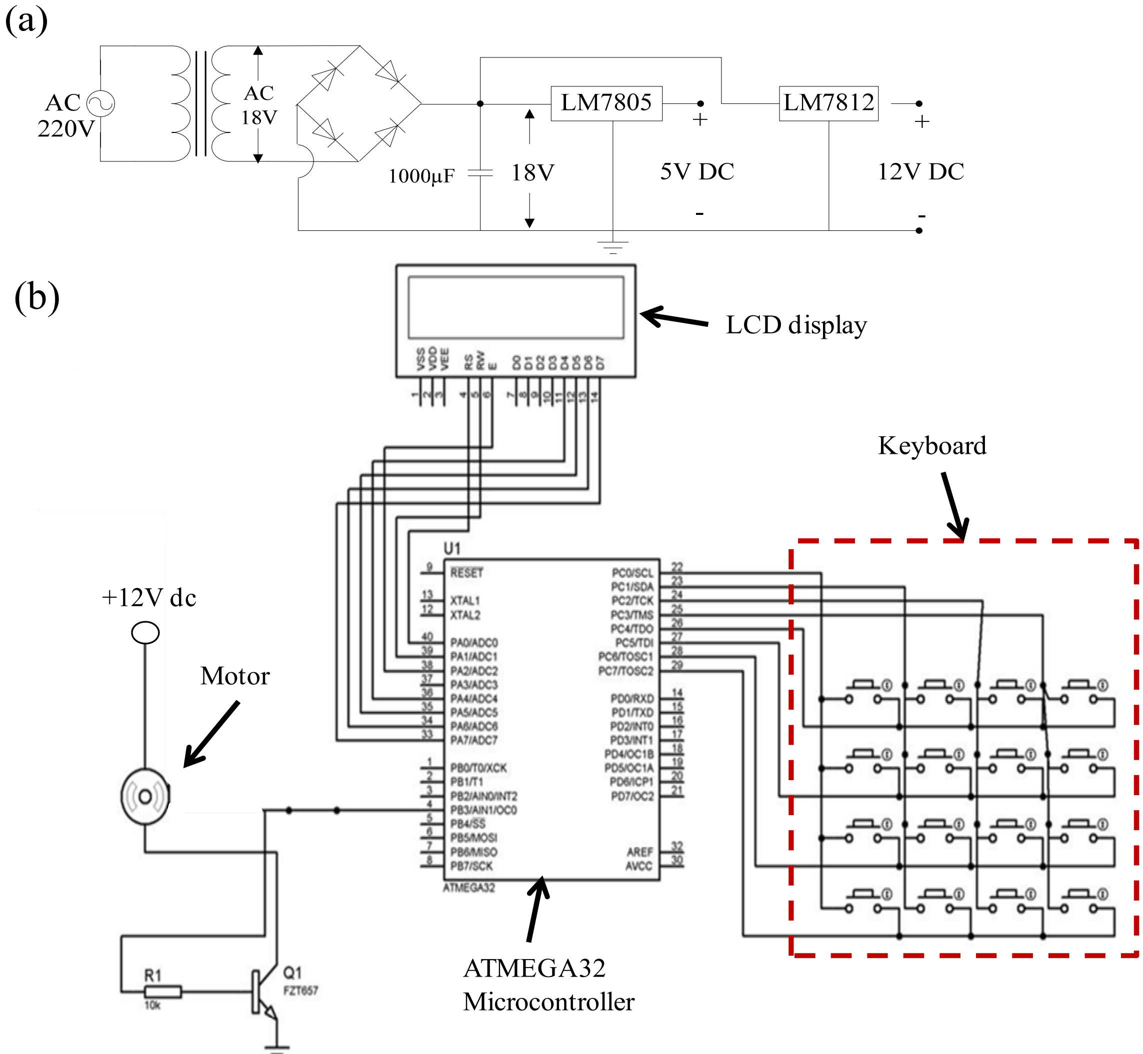

Fig. 3. Circuit diagram of microcontroller based spin coater

IV. Depostion of ZnO Films using this Proposed System

ZnO porous films were prepared according the reference [17]: Firstly, zinc acetate [$Zn(CH_3COO)_2.2H_2O$] was dissolved in 50 ml of absolute ethanol and stirred with a magnetic stirrer (50°C) to be mixed thoroughly, when the solution changed into an emulsion, an amount of diethanolamine [$NH(CH_2CH_2OH)_2$: DEA] as chelating agent and deionized water were added into the emulsion. The molar ratio of DEA/zinc acetate was 1:1 and de-ionized water/ zinc acetate 2:1, respectively. The emulsion became clear after a certain period of stirring. Spin coating method was used to deposit ZnO films on clean glass substrate with 2000 rpm speed for 10 minutes. The obtained films were calcined in air up to 500 °C at a heating rate of 2 °C/min and left at 500 °C for 2 h. The optical properties of the films were measured with HALO SB-10 UV/VIS spectrophotometer at room temperature within the wave length range (300–900) nm.

V. Results and Discussions

Figure 7 shows the image of prepared ZnO films. Whitish space is ZnO films and transparent one is bare glass substrate. We assume an indirect transition between the top of the valence band and the bottom of the conduction band in order to estimate the optical band gap (Eg) of the films using the relation [18]

$$(\alpha h\nu) \propto A(h\nu - E_g)^2 \qquad (1)$$

Where, α is absorption coefficient, A is the edge width parameter and *hν* is the photon energy, respectively. The optical band gap of the ZnO films was determined from the extrapolation of the linear plots of $(\alpha h\nu)^{1/2}$ versus $h\nu$ at $\alpha=0$. Figure 8 shows the plots of $(\alpha h\nu)^{1/2}$ versus the photon energy of the ZnO films deposited on glass substrate prepared by digitalized spin coater. The optical band gap of the ZnO films has been found to be 3.16 eV [16] that falls on the satisfactory rage.

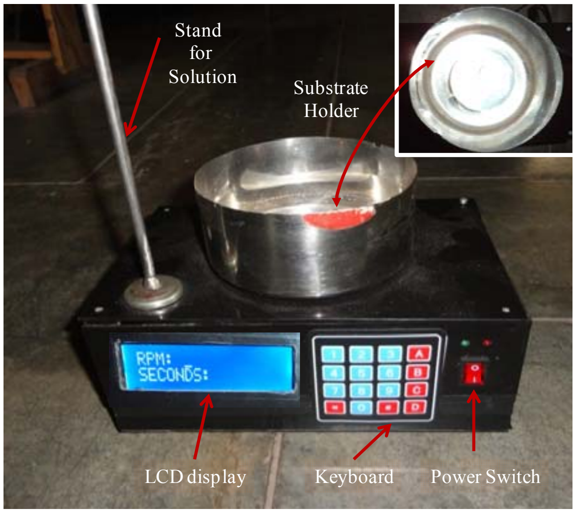

Fig. 4. Image of Complete setup of digital spin coater with LCD display and matrix keypad, and (inset) substrate holder.

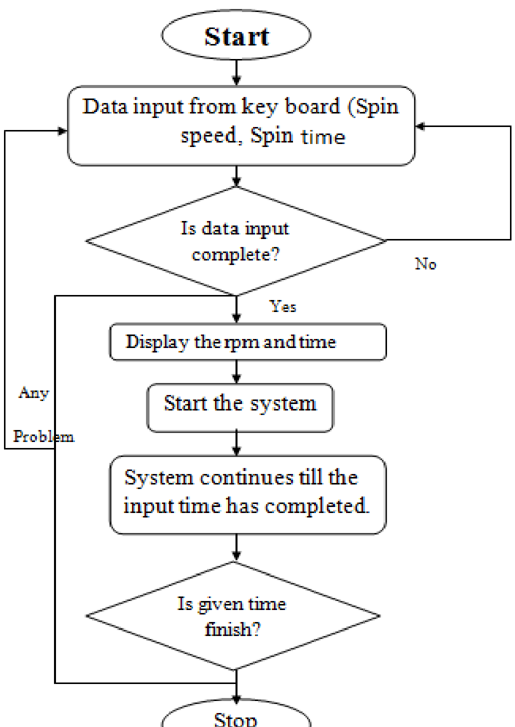

Fig. 5. Flowchart of controlling unit.

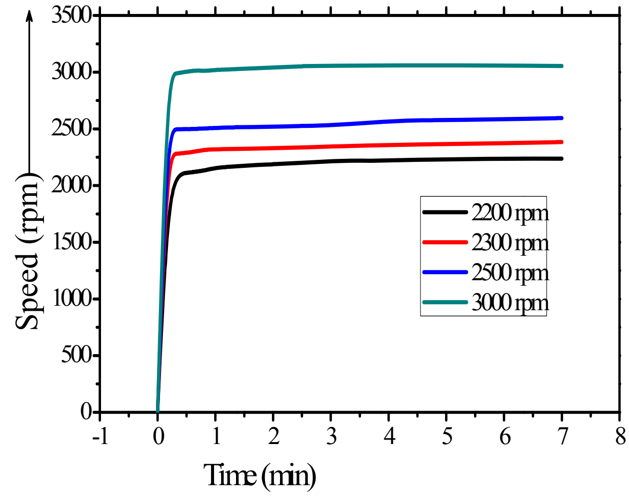

Fig. 6. Speed vs. Time curve for proposed digitalized Spin-coater.

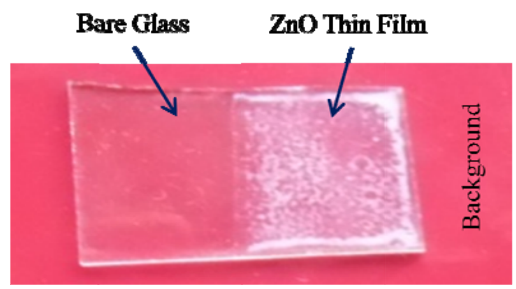

Fig. 7. Prepared ZnO films on glass substrate;

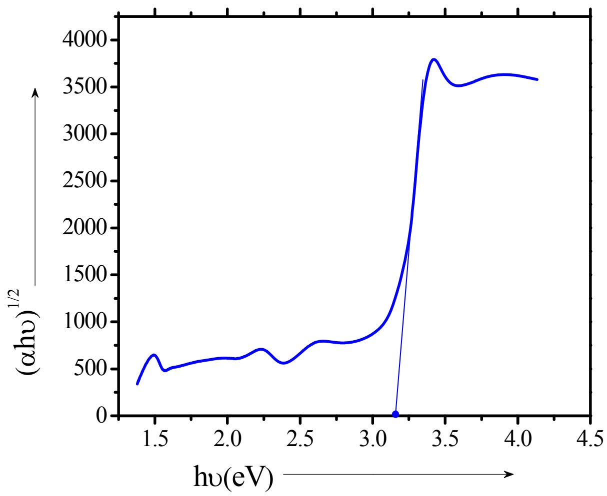

Fig. 8. Measurement of bandgap of the produced films

VI. CONCLUSION

Digitalized Spin-coating system has been successfully designed and fabricated using microcontroller unit with dc motor. LCD display unit has used to exhibit the value of speed and spinning time. Matrix keyboard is introduced to inputs the desired speed and time. The speed can be varied the ranges from 0 to 3300 rpm and desired speed can achieve within 10 seconds. This proposed spin-coater can be used for depositing ZnO film on glass substrate. The prepared films have been confirmed ZnO content by using optical band gap of 3.16 eV, In this work, authors are proposed this apparatus of easy implementation in a laboratory for the preparation of thin films using recycled electronic components.

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