Design and Construction of a Spinner using Low Cost Materials

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In this paper we show how to build equipment spinner applied to the deposition of thin films by spin-coating process, using inexpensive components easily found on the market and allow for easy assembly. This equipment allows us to control the speed of rotation of the sample holder, causing the substrate to rotate at a constant speed and acceleration through the centripetal effect of the thin film is deposited on the substrate surface. Details of the construction of the mechanical, electrical and a method for the calibration are presented. We found a linear frequency versus the electrical potential of the engine reaching speeds above 2000 rpm.
Keywords: spinner;frequency; thin film; spin-coating

Neste artigo mostramos como construir giratório equipamentos aplicados à deposição de filmes finos por spin-coating processo, utilizando componentes de baixo custo facilmente encontrados no mercado e permitir uma fácil montagem. Este equipamento nos permite controlar a velocidade de rotação do suporte da amostra, fazendo com que o substrato para rodar a uma velocidade constante e aceleração através do efeito centrípeta da película fina é depositado sobre a superfície do substrato. Os pormenores de construção do mecânico, eléctrico e um método para a calibração são apresentados. Encontramos uma freqüência linear versus o potencial elétrico do motor atingir velocidades acima de 2000 rpm.
Palavras-chave: giratório; freqüência; película fina; de spin-coating

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1. INTRODUCTION

The science relating to thin films has grown around the world becoming an important area of scientific research. The importance of the coatings and the synthesis of new materials for the industry resulted in a large increase of innovative thin film processing for applications in microelectronics, optics and nanotechnology [1-2-6-7]. Currently, the rapidly changing needs of coating materials is creating new opportunities for the development of new processes, materials and equipment for the development of technology associated with obtaining thin films [3-6].

The thin films must possess characteristics highly controlled. The atomic structure, chemical composition and the thickness should be uniform, with minimal defect density, minimum particle contamination, have good adhesion, low stress and enable a good coverage of the substrate [5-6]. In this context, the process of deposition of thin films plays a key role, because it interferes directly in the properties and physical and chemical characteristics of thin films. In the deposition from solutions or sols, a common technique is to drip the fluid onto a substrate and then apply a rotation in the substrate so as to create a thin, uniform layer of fluid on the substrate surface as a result of centripetal acceleration imposed. This technique is called spin-coating [3-4-7].

In the deposition technique spin-coating, fluid viscosity and speed are vital parameters that interfere in a direct way on the properties of thin films obtained [5]. Thus, it is evident the need of using equipment that has the following characteristics: (a) have a disk (sample hold) which may rotate at a constant speed; (b) the speed of the disc can be varied over a wide range and is maintained, always constant; (c) the electric motor that is connected to the disk must have starting torque and steady-suited to the application; (d) motor-drive assembly must be stable and vibration-free; (e) to supply the engine of the equipment should be regulated and stabilized.

In this paper, we present the details of the construction of a spinner for deposition of thin films by spin-coating. This equipment has been designed from materials and parts readily available in local market and low cost. The equipment has as its centerpiece a DC motor taken from a mainframe that was no longer in operation. The equipment has a stabilized voltage source and electronically regulated that is to allow varying the speed of the motor shaft with great precision. For tuning and calibration, we used a speed measurement system that uses an infrared sensor, enabling the measurement of the relationship between supply voltage and speed of the motor shaft.

The equipment was designed and built in the laboratory of the Physics Department, Federal University of Sergipe, the main advantage the low cost, simplicity in design and construction techniques and features fully geared for use in research related to obtaining thin films.

2. EXPERIMENTAL

The equipment was designed to scale in a metal box, where they were packed the DC motor, the regulated power supply and stable electrical and circuit protection. The metal case has an appropriate place to fix the engine, through a variety of stainless steel screws into a rubber base, thus ensuring a good stability, vibration-free.

In the assembly process, the metal was prepared with a corrosion product and subsequently subjected to a painting. The DC motor was put inside, fixed by stainless steel screws on a rubber base. The power supply was placed inside the back of the box, and the power transistors were fixed externally on the back along with a heat sink. The engine protection and power supply is made through two fuses, put on the back of the box. One of the fuses has the protective function of high electrical fluctuations from the AC grid and the other external fuse protects the DC motor directly. The operation is quite simple spinner, the drive is via two keys at the front, one of which leads directly to another power supply and DC motor drives directly. The speed control is done through a linear potentiometer, also located in front of the spinner. The details are shown in Figure 1.

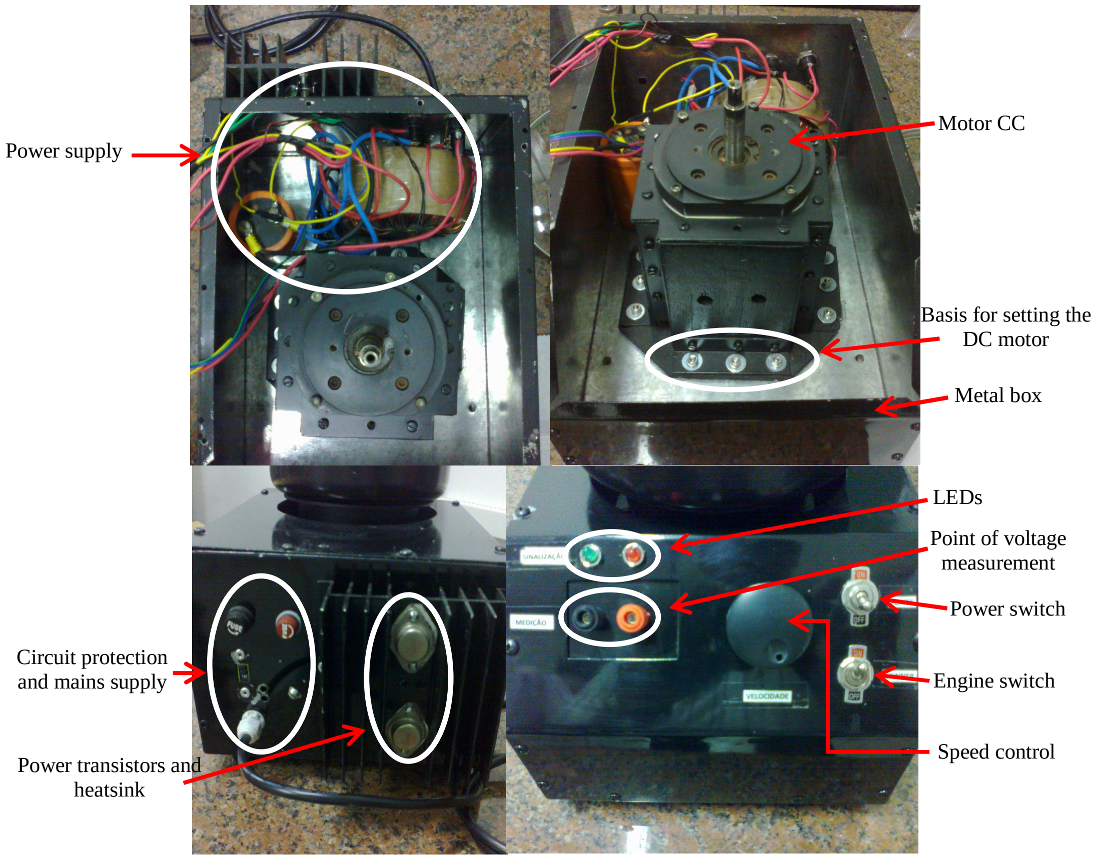

Figure 1: Details of the electrical and mechanical spinner.

Internally, the power supply comprises a toroidal transformer, a rectifier, the control loop and current gain circuit formed by two power transistors connected in cascade, and a high capacitance capacitor to ensure a minimum ripple. With this setting you can perform fine control of output voltage, making it possible to apply a voltage stabilized at the entrance of the DC motor to achieve speed control on its axis. The scheme is shown in Figure 2.

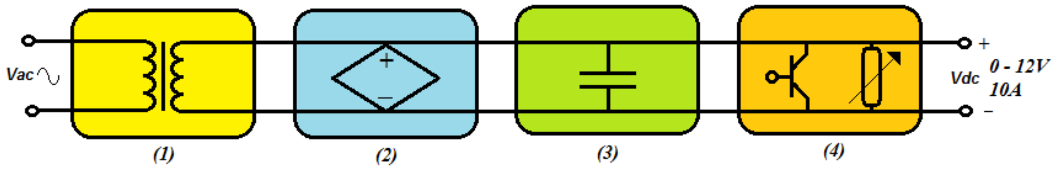

Figure 2: Schematic of power supply voltage control: 1) Toroidal transformer - 127/16V, 2) Bridge rectifier power, 3) capacitive filter - 4700µF, 4) control loop and voltage control.

The DC motor when coupled to power supply and subjected to a voltage change, responds with a proportional variation of speed on its axis, while maintaining the torque. The spinner disc is located at the top of the equipment, protected by a closed container coated in Teflon, making it easier to clean. Figure 3 shows the finished product.

Figure 3: Spinner in its final configuration: (a) front view, (b) control panel, (c) lateral view, (d) sample holder.

3. RESULTS AND DISCUSSION

The control of the rotation axis of the spinner is essential to ensure the formation of thin films with desired characteristics. This control is possible by associating the change in voltage at the terminals of the DC motor with the speed on its axis, i.e., for each value of applied voltage, the DC Motor spinner responds with a specific value of speed on its axis. To determine the relationship voltage vs. speed, the calibration was performed using the Basic Unit COBRA3 PHYWE-System, which allows through an infrared signal to determine the frequency dependence of the axis of rotation of the spinner with the applied voltage. The COBRA3 has an infrared sensor that the U-shaped disc attached to the spinner can detect the rotation period of pulses sent through the PC. The infrared sensor consists of a transmitter and a signal detector positioned opposite each other, when the detector receives the infrared signal, a voltage signal is sent to the PC at the time the infrared signal is interrupted, the signal voltage sent to the PC falls to the level "zero." Data are collected by Universal Writer Software Cobra 3 and stored in the PC file in txt format.

Figure 4 shows the calibration scheme spinner. In this scheme, the multimeter is used to measure the voltage signal applied to the DC Motor. The sensor is attached to it and through a small plate on the edge of the disk; it is possible to interrupt the infrared signal at every turn. The COBRA3 receives the sensor signal and sends pulses to the PC. The signal received by the PC consists of the voltage measurements from the sensor associated with time of each measurement, allowing obtaining the period of rotation of the disk. For each value of input voltage DC motor, was performed to measure the period of rotation of the disk, as shown in Figure 5. For each value of rotation of the disk, COBRA3 performs several measurements in sequence, requiring then calculate the mean and uncertainty.

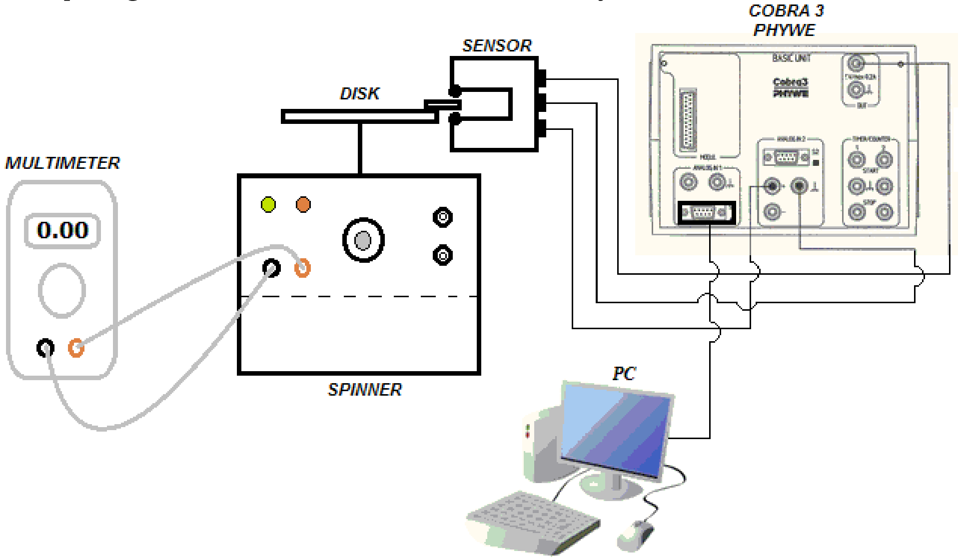

Figure 4: Scheme used for calibration of the spinner.

To determine the standard uncertainty of a quantity, which is a function of several measured quantities, is necessary to consider the combined uncertainty associated with each of its variables. To do so, you must use the notion of propagation of uncertainties [9]. When some physical quantity **z** is calculated as a function of other quantities x_1, x_2, x_3... and the combined uncertainty magnitudes are given by σ_1, σ_2, σ_3... i.e., **z** is a function of x_1, x_2, x_3... we have

$$z=f(x_1, x_2, x_3....) \tag{1}$$

The uncertainty of the magnitude calculated σ_z is obtained from Equation 2 [9],

$$\sigma_z = \sqrt{\left(\frac{\partial z}{\partial x_1}\sigma_{x_1}\right)^2 + \left(\frac{\partial z}{\partial x_2}\sigma_{x_2}\right)^2 + \left(\frac{\partial z}{\partial x_3}\sigma_{x_3}\right)^2 + ...} = \sqrt{\sum_i \left(\frac{\partial z}{\partial x_i}\sigma_{x_i}\right)^2} \tag{2}$$

where σ_x is the combined uncertainty.

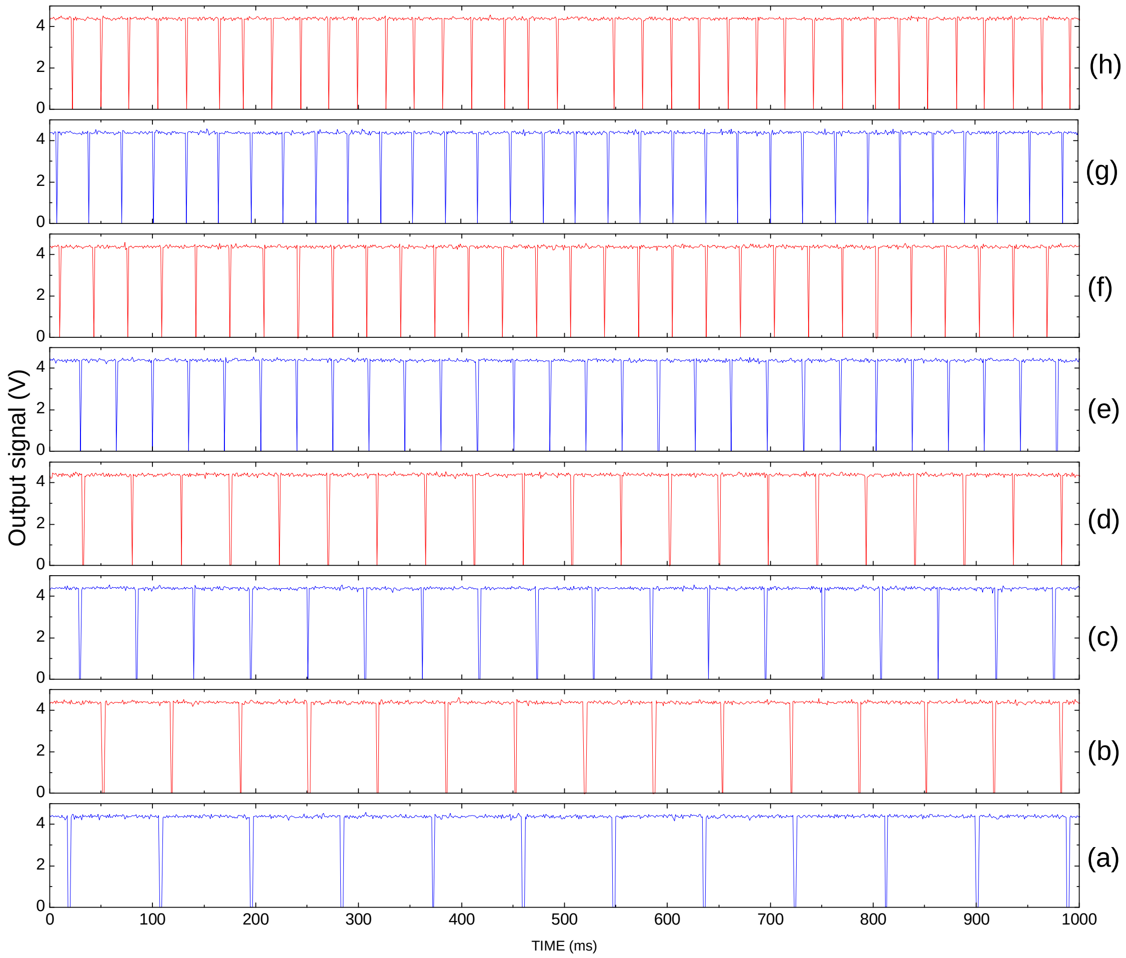

Figure 5: Output signal of the infrared sensor on the period of rotation for different voltages applied to the DC motor: (a) 3V, (b) 4V, (c) 5V, (d) 6V, (e) 8V, (f) 8, 5V, (g) 9V (h) 10V.

The type B uncertainty of the measurement equipment is ± 0.001 s. The frequency associated with each measured period can be calculated using Equation 3,

$$f = \frac{1}{T} \tag{3}$$

where T is the period of rotation. We can then calculate the propagation of uncertainty for the frequency using Equation (4).

$$\sigma_f = \sqrt{\left(-T^{-2} \cdot \sigma_T\right)^2} \tag{4}$$

Figure 6 shows the frequency depending on the voltage applied to the DC motor. A good linear fit was found with an increasing uncertainty in frequency. The DC motor also showed the behavior as expected, maintaining good torque across the speed range for ensuring effective control.

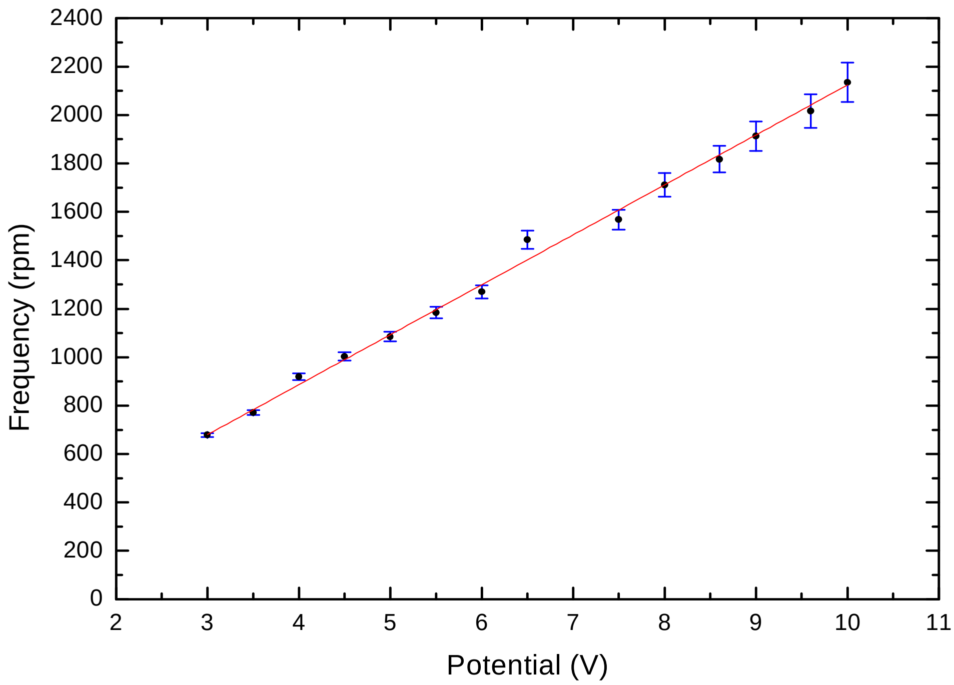

Figure 6: Frequency of rotation versus the applied voltage in the DC motor. The solid line corresponds to a linear fit.

The equation resulting from setting the curve shown in Figure 6 is linear with a correlation coefficient R = 0.99496 (Equation 5),

$$F = 60,97 + 206,33 \cdot U \tag{5}$$

where F is the frequency of rotation of the disk (rpm) and U the voltage applied to motor.

The uncertainty of the result of a measurement reflects the lack of accurate knowledge of the value of the measured, means doubt about the validity of the result of a measurement [9]. In the measurements, the propagation of uncertainty for the frequency increases with increasing the frequency of rotation. We believe that this phenomenon is associated with fluctuations in measurements due to electronic equipment because of its precision. The machine reads the signal from the sensor at time intervals Δt, which means that in some passages disk, the equipment does not detect the signal sent by the sensor, and as a result, measurements of the period for high speed have small differences evident in the graphs of some pulse widths observed.

The test of viability and functionality of the spinner, it was performed using as a base to obtain a thin film of nickel oxide (NiO) produced by the proteic sol-gel process. The preparation of the sol was the use of nickel nitrate hexahydrate (Ni $(NO_3)_2.6H_2O$) which resulted in a sol with concentration of 0.5 mol / liter. The glass substrate to deposit the thin film underwent a thorough washing, consisting of application of detergent, soaking in acetone and then dried at 500˚C for 30 min. The deposition process consisted of applying the sol on the glass substrate and a rotation of 400 rpm for a time of 15 s. They were grown with 5 layers with heat treatment at 500°C for 15 min in each layer, and a final heat treatment at 500˚C for 30 min. Figure 7 shows the X-ray diffraction of the thin film of NiO. It can be seen that the three most intense peaks were measured and are consistent with the Miller indices (111), (200) and (220). Similar result for the same type thin film (NiO) was obtained by Ghamdi et al. using the sol-gel process, grown with a commercial spinner [1]. This result indicates that the product developed in this study has a great potential to obtain several other kinds of thin films in the form of oxides or organic materials such as paints and polymers.

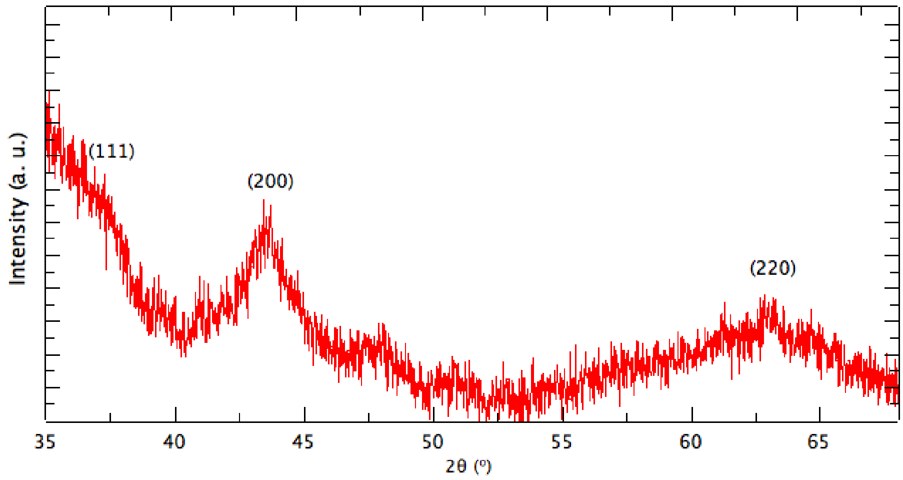

Figure 7: X-ray diffraction of the thin film of NiO.

4. CONCLUSION

We present the entire process of building the spinner, which is the equipment used to obtain thin films via spin-coating method. The spinner was built on a project that showed the use of materials and parts at low cost, easily found in the local market. It is an easy to operate equipment, which presents important characteristics and essential for the deposition of thin films, such as speed control, high torque and low vibration. Spinner calibration allowed us to obtain a linear fit of the relationship between frequency of rotation of the disk and the applied voltage, thus enabling operate within a well established range of rotational speed of the disc.

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