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THE DEVELOPMENT OF A LOW COST AUTOMATED PIECE OF EQUIPMENT FOR SPIN-COATING FILM

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Abstract: *There are several technologies for the formation of polymer films, as most commonly used to produce the same require sophisticated equipment and techniques that are often an obstacle for researchers who do not exist for the lifetime to sponsor them. Spin-coating is a simple technique and widely used in the preparation of polymer films of uniform thickness. The technique is to deposit the initial solution onto a substrate which is rapidly accelerated to a desired speed of rotation. The liquid flows radially, due to the action of the centrifugal force, and the excessive ejection of the edge of the substrate. The Equipment is not manufactured in Brazil and according to the Ossila Dealer, its cost is more than R $ 7,000.00, without addition of import taxes, to Brazil. Thus, we propose the construction of low cost equipment of simple components found in electronics stores and discarded equipment (such as printers and DVD). We also investigate its effectiveness in the production of fine film materials.*

Keywords: *Deposition of materials, Film, Microcontroller Arduino, Polymers, Spin-coating*

1. INTRODUCTION

There are several technologies for forming polymer films, the most commonly used to produce the same are extrusion and solvent casting. The latter is the simplest and basically consists of the deposition of the solution forming the film in a mold and the subsequent evaporation of the solvent, leaving only the film adhered to the container. It is a viable, simple, low cost method and commonly performed only in the laboratory. For manufacturing on an industrial scale, many parameters must be optimized, especially the thickness of the finished product and the drying rate, which is very long in this process. That is, films made by this method take many days to dry, even deposited in small molds.

Another existing process is spin coating. This technique is widely used in the manufacture of CDs and microelectronic devices. After addition of the polymer solution on a substrate, it is rotated at a speed of 1000-5000 revolutions per minute (rpm), so that the fluid is spread by centrifugal force (Mouhamam et al., 2014). In this method, a minimal change in the speed or concentration of the solution can lead to large changes in the final film thickness. To control the morphology of the polymer films, the polymer ratio, the speed of rotation and, if necessary, the use of thermal or solvent hybridization techniques must be adjusted in addition to the concentration. However, the final thickness is a function of the angular velocity and concentration and / or viscosity of the solution.

The spin coating has four stages (fig. 1). The first stage consists of depositing the solution in the rotating circular plate and accelerating it. The solution is applied in excess and can be deposited in different ways: by flooding the rotating plate; applying the solution in one go or continuously only in the center of the disc; depositing continuously in the center or center towards the end. In the second stage, the plate is accelerated to the desired final velocity. At this time, the expulsion of the fluid from the plate occurs due to the rotational acceleration. In the third stage, the fluid undergoes rotational movement continuously and the viscous flow dominates the decrease of the film thickness evenly. The last stage occurs when the formation of the film thickness is dominated by solvent evaporation (SAHU; PARIJA; PANIGRAHI, 2009), resulting in the finished product.

This method has a low process cost and a fast operation system. The control of the parameters can be complex, but the films become progressively uniform during the process after the determination of the correct parameters. The main disadvantage of this method is the inefficiency in the use of the material, that is, only 2% to 5% of the material disposed on the rotating plate is used (SAHU; PARIJA; PANIGRAHI, 2009) since the remainder is expelled and discarded during acceleration to achieve the desired speed.

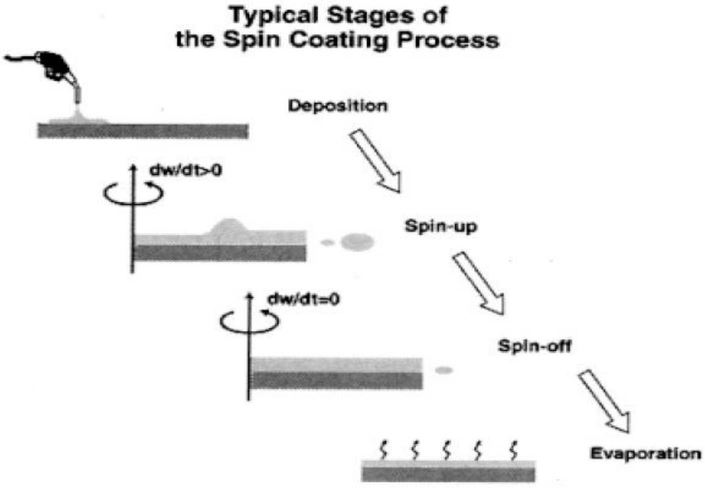

Fig. 1: Stages of a process *spin coating* of SAHU; PARIJA; PANIGRAHI (2009).

Although it is a simple technique and low process cost, it requires expensive equipment, varying in Rotations Per Minute (RPM), Substrate Diameter and level of automation of the equipment. According to Reseller Ossila the cost of spin-coater is over R$ 7.000,00, without adding import taxes, to Brazil. Thus, we propose the construction of a low-cost piece of equipment made from simple components found in electronics stores and discarded equipment (such as printers and DVD's). We also investigate its efficiency in the production of thin film deposition of materials.

2. MATERIALS AND METHODS

Initially a general survey of all existing equipment and suppliers that sell the spin coater was performed, then we analyzed the characteristics of each piece of equipment and designed the model of the machine with the help of 3-Dimensional Computational Modeling Software (fig. 2). The structure of stainless steel plate and parts in acrylic and Nylon were designed.

Fig. 2: three-dimensional modeling (Author)

The side of the equipment box was made of 1.5 mm thick stainless steel with a simple wooden lid and an acrylic ejector part 10 mm thick. A 12v printer engine, optical printer sensor, Tx 450W computer source, DVD player base, 3.2-inch TFT display module of Ultra HD 320X480, Arduino MEGA 2560 R3, joystick keyboard for Arduino, connectors, and cables were also used.

In the construction of the equipment structure, we started by cutting the 1.5 mm thick stainless-steel plates in the shape of 4 rectangles 300 mm wide and 200 mm long (fig. 3).

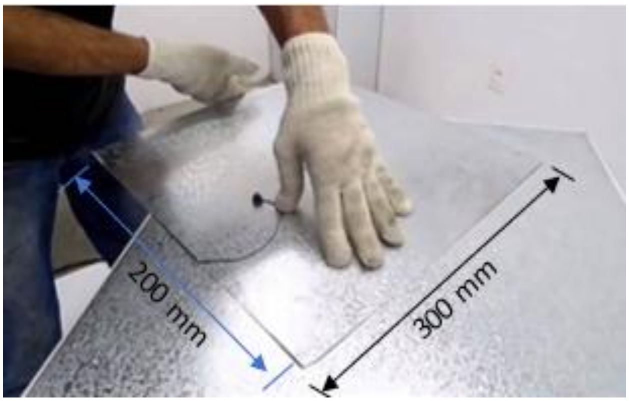

Fig. 3: steel cutting (Author)

After it was cut 4 pieces of wood in rectangular shape of 300 mm of width with 200 mm of length to cover the sheets of steel, and drawn and cut entries for PTO, selector of voltage 110V / 220V, air passage for cooler of computer and potentiometer motor speed regulator output (fig. 4).

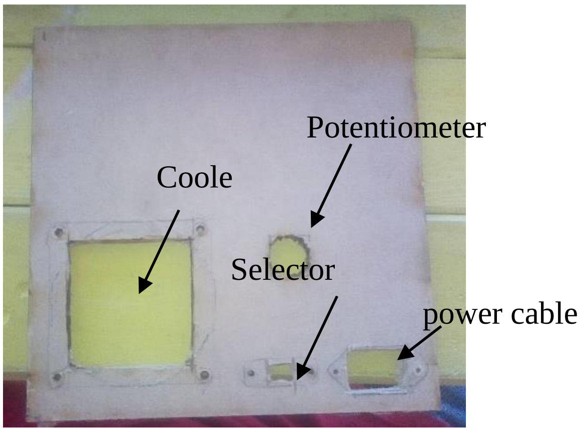

Fig. 4: MaPallet wood cutting (Author)

The structure of the equipment was assembled and adapted a Teflon (fig. 5) shaft coupled to the shaft of the printer motor 12V and Support DVD holder (fig. 6)

Fig. 5: Teflon adapted (Author)

Fig. 6: Support DVD holder **(Author)**

To finish the structure of the machine was cut the acrylic in cover shape and added the 3.2 inch TFT display module of the Ultra HD 320X480, Arduino MEGA 2560 R3, joystick keyboard for Arduino, encode and its sensor for motor removed from the printer reused (fig. 7).

Fig. 5: 3.2 inch TFT display module of the Ultra HD 320X480, Arduino MEGA 2560 R3, joystick keyboard, encode and its sensor **(Author)**

3. RESULTS AND DISCUSSION:

The Initial budget for the cost of the materials bought in local electronics stores was low and there was no difficulty finding them. See Table 1. The same materials can be found at no cost in workshops except for the 3.2 inch TFT display module of Ultra HD 320X480, Arduino MEGA 2560 R3 and the joystick keyboard for Arduino.

Table. 1 - Initial budget Materials used, quantities and cost.

Material	Quantity	Cost (R$)
1.5 mm thick stainless steel	700 x 300 (mm)	150.0
MaPallet wood	1 unit	6.00
Acrylic plate	200 x 300 (mm)	100.00
12v Printer Engine	1 unit	10.00
Optical printer sensor	1 unit	4.00
Tx 450W Computer Source	1 unit	60.00
DVD Player Dock	1 unit	5.00
Display 3.2 Inch TFT Module Ultra HD 320X480	1 unit	65.00
Arduino MEGA 2560 R3	1 unit	50.00
Arduino joystick keyboard	1 unit	25.00
Connectors and cables	10 unit	30.00

In total, the materials cost R$ 505 (approx. 155 US dollars) The box and the rotor were machined at the Centro Profissionalizante de Camaçari - CPC, a technical school in the town of Camaçari-BA, and the service was not charged.

The machine looked friendly and easy to use, due to difficulties in assembly, some changes in its layout were necessary making it a little simpler and more operational. The materials used were donated by technical institutions and found in old iron and few were purchased in stores specialized in electronics. changing the budget in Table 2.

Table. 2 - Materials used, quantities and cost.

Material	Quantity	Cost (R$)
1.5 mm thick stainless steel	700 x 300 (mm)	Donation
MaPallet wood	1 unit	Donation
Acrylic plate	200 x 300 (mm)	100.00
12v Printer Engine	1 unit	Donation
Optical printer sensor	1 unit	Donation
Tx 450W Computer Source	1 unit	Donation
DVD Player Dock	1 unit	Donation
Display 3.2 Inch TFT Module Ultra HD 320X480	1 unit	65.00
Arduino MEGA 2560 R3	1 unit	50.00
Arduino joystick keyboard	1 unit	25.00
PWM	1 unit	35.00
Connectors and cables	10 unit	Donation

In total, the materials cost R$ 275 (approx. 85 US dollars). In the operating part two types of speed adjustment were implemented, the first one directly added to the RPM in the human machine interface (HMI) screen and the second one manually controlled via the potentiometer, both ways allow the use of time to complete the rotation process. In the equipment there was a need for the addition of Pulse-Width Modulation (PWM) controller, which could control the motor from 0 to 18000 RPM.

In the first tests the equipment proved to be efficient of the product spreading being deposited while generating the rotation, but it was also clear that the viscosity of the deposited product is very important to obtain films without failure in its layer.

4. CONCLUSION:

This new piece of equipment was similar to a commercial spin coating machines, however, without the process of an external vacuum, reducing the cost considerably. The equipment could be reproduced in a technical school or university without the need for high investment. Despite not having the same quality as the equipment sold in the market, the developed equipment created fine films of high quality. So, if the viscosity of the products is not very low and its process done in a controlled and gradual manner.

5. REFERENCES:

AGUILAR, R. G.; LÓPEZ, J. O. "Low cost instrumentation for spincoating deposition of thin films in an undergraduate laboratory". Lat. Am. J. Phys. Educ. vol. 5, n. 2, pág. 368 373, 2011.

Hall, D. B.; Underhill, P.; Torkelson, J. M. "Spin coating of thin and ultrathin polymer films, Polymer Engineering & Science," v. 38, p. 2039-2045, 1998.

MOUHAMAD, Y. et al. "Dynamics of polymer film formation during spin coating. "Journal Of Applied Physics," [s.l.], v. 116, n. 12, p.123513.1-123513.8, 28 set. 2014.

SAHU, Niranjan; PARIJA, B.; PANIGRAHI, S.. "Fundamental understanding and modeling of spin coating process: A review." **Indian Journal Of Physics,** [s.l.], v. 83, n. 4, p.493-502, abr. 2009.

6. AUTHORAL RESPONSIBILITY

"The authors are solely responsible for the content of this work."