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USER INTERFACE FOR AUTOMATIC SPRAY PYROLYSIS ROBOT PROGRAMMING

M. Enescu[1], C. Alexandru[1]
[1] Department of Product Design, Mechatronics and Environment, Transilvania University of Braşov, Braşov, ROMÂNIA, monicaenescu@unitbv.ro

Abstract: *The paper presents the user interface for spray pyrolysis deposition using an industrial robot. Besides being a cheap and simple deposition technique, the spray pyrolysis technique it also allows deposition on larger areas and on complex profiles surfaces than traditional techniques. The main objective of this paper is to achieve an optimal trajectory for spraying on a planar surface. To realize this optimal trajectory it is necessary to create the geometrical model of the robotic system (robot, spray nozzle, surface) in a CAD (Computer Aided Design) software environment. In this paper, we propose a solution to coat a planar surface by using UI (User Interface). Interface made by authors allows the setting/choosing of specific parameters of spray pyrolysis process (spraying angle, height of spraying cone, trajectory step, number of consecutive passes on the substrate, time between two passes, carrier gas pressure and the substrate temperature. It was used AFM (Atomic Force Microscope) to investigate the morphology of the surface which was obtained by control the spray pyrolysis conditions.*
Keywords: *coating process, user interface, robotics, spray pyrolysis, spray nozzle*

1. INTRODUCTION

Automatic spray deposition operations are often used in product industries. Robotic manipulators are used in spray deposition process to traverse around the objects to be sprayed. The spray pyrolysis deposition (SPD) technique consists in forming an aerosol of liquid precursors dispersed in the carrier gas, deposited on heated substrates. Principle of SPD technique includes a nozzle tube connected to a gas that creates pressure in the precursor solution is sprayed onto a surface and heated to a temperature of 100-500 °C. The heated plate is necessary to maintain constant the substrate temperature throughout the spray pyrolysis process [5, 6]. Pyrolysis is necessary for crystallization nano-coating. Reduce production costs and increase product performance realized by using the robotic spray pyrolysis are obtained by choosing optimal parameters path, characteristic parameters of the spraying process and the high degree of repeatability of the system [1, 3, 9]. Sensitivity of the spray pyrolysis process relative to environmental conditions (e.g. pressure, relative humidity, ambient temperature) and the corresponding parameters of the spray pyrolysis process (e.g. temperature of the substrate, height of spraying cone, position and orientation of the sprayer) makes getting a constantly high quality to be a difficult task [1, 7, 8, 10].
To obtain a complete coverage and a minimum thickness variation, the sprayer trajectories must be planned in a better way [2]. In large scale production lines, robots are often used to position and move the nozzle along a surface to be covered [4, 11]. In such an environment, it is common learning method defined path and manually moving of the sprayer along the surface to be sprayed while a computer records its position and orientation. To realize this optimal trajectory it is necessary to create the geometrical model of the robotic system (robot, spray nozzle, surface) in a CAD (Computer Aided Design) software environment. The CAD (Computer Aided Design) software is used to create the geometrical model of the robotic system (robot, spray nozzle, surface). To achieve this goal, CATIA software was used to model the robotic system and RobotStudio software has been used to generate the program. RobotStudio facilitates a rapid and easy programming.
The objective of the present research is to develop a simple algorithm (a user interface - UI) for the spray pyrolysis technology. The paper is structured as follows: firstly, the characteristic parameters of the trajectory (path and tool models) and the automatic spray pyrolysis methodology are introduced and explained. Secondly, the experimental robotic system used to test the proposed solutions is presented, along with the conclusions including also future work.

2. USER INTERFACE

The user interface (UI) eases the effort of the human operator and allows the manufacturing of pieces that possess complex geometry with high precision. On the obtained solid models from CAD software is implemented the program that will be simulated and then imported on the physical robot by using the user interface. The required parameters to automatically generate a trajectory for the coating process are: the CAD model of the substrate to be coated, the spray nozzle model which determines the spray distribution on a heated substrate, the raster trajectory, spray pyrolysis requirements, meaning thin film thickness, the value of the pressure, the temperature of the substrate, number of passes, spray pyrolysis planning with position, the orientation and the velocity of spray nozzle.
All these parameters are defined using the user interface. The user (mean human operator) will choose, the working conditions according to the type of precursor solution used (alcoholic solution or aqueous solution), as follows:

- choosing the required number of successive passes on the substrate,
- setting the required number of successive passes on the substrate,
- spray angle (45, 75 or 90 degrees can be chosen),
- height of spraying cone (this size is kept constant throughout the coating process),
- areas of glass substrate, as defined by the length and width,
- the step between two paths.

Spray pyrolysis algorithm is designed so that it is easy to be used and understand by the user. Depending on the given dimensions, the program determines the optimal trajectory for the entered values. The user (namely the human operator) works in a 3D environment and through a series of simple and intuitive operations can obtain the program of the robot. This program is verified by means of simulation and can be implemented without any modifications to the physical prototype. To generate a trajectory, the position, orientation and velocity of the spray nozzle have to be defined. The substrate is a simple form (figure 1). The physical and virtual spray nozzle used is presented in figure 2.

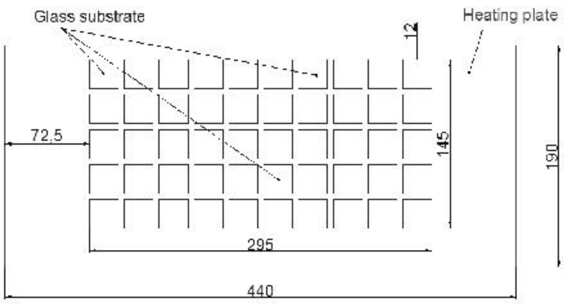
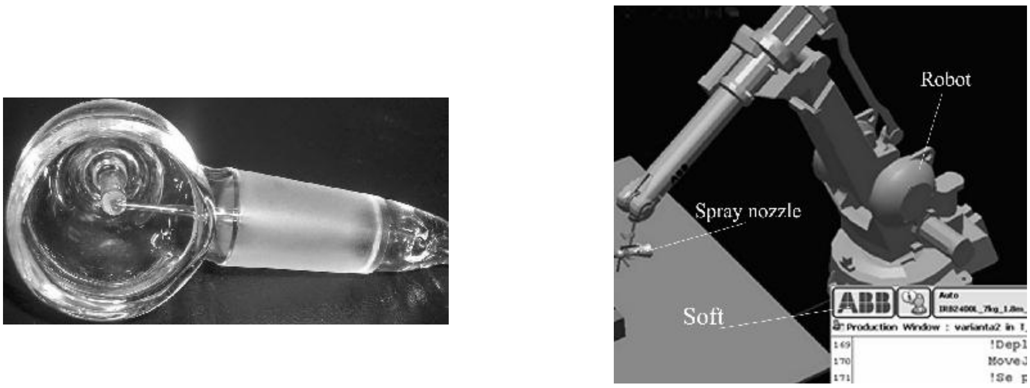


Figure 1: Figure caption CAD model of glass substrate



a. b.

Figure 2: The phisical and virtual spray nozzle

The figure 3 show a robotic system which includes: robot ABB IRB 2400L, control unit and computational system. The robot control unit are electronic is the electronic system that is responsible for moving and controlling the robot. A robot consists of mechanical part (speed reducers - gear box), some electronics (sensors, motors, controller – meaning the control unit) and a part of logic (program decides how the robot acts engines according to data returned by the sensors – computational system).

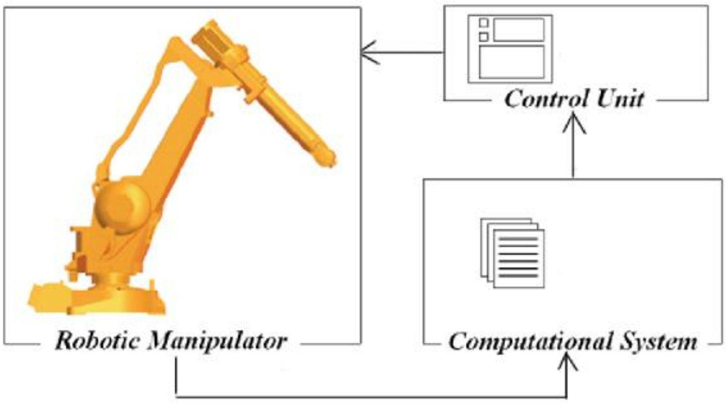


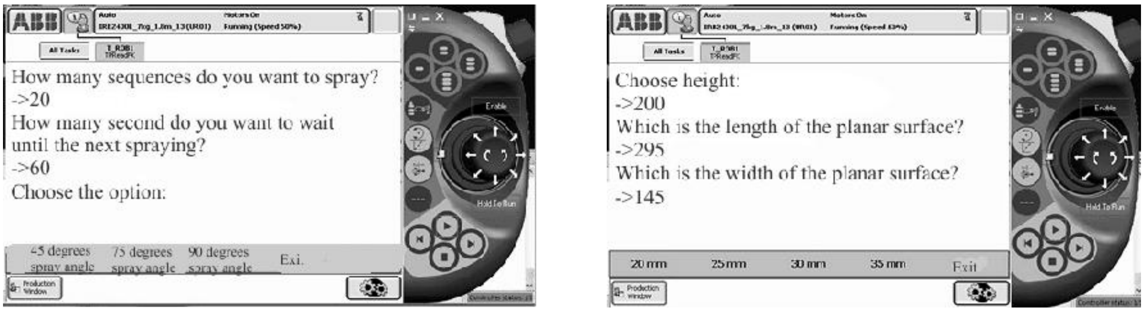
Figure 3: Block diagram of the robot system

To cover the planar glass substrate the raster trajectory has been used, as shown in figure 4. The optimal trajectory will be calculated in order to achieve less returns of the spray nozzle [3]. In this manner we succeed in spraying time attenuation. Another advantage is that through this process are fewer overlaps in those zones [9, 11].

Figure 4: Material deposition raster trajectory

3. TESTE CASE EXEMPLE

The laboratory set up is consisted of an ABB IRB 2400L industrial robot, equipped with the spray nozzle shown in figure 5, heating plate and PC. To design the model, CATIA environment was used. To generate the off-line programming, RobotStudio soft has been used. Using this program it is only necessary to draw the heating plate on which is sprayed the substrate namely a planar surface with a thickness of 0.7 mm.
The substrate is not necessary to be drawn, because the user defines just the start point meaning the position and the orientation of the spray nozzle. It depends on the user's commands for calculating the positions and the orientations of the spray nozzle, by the program. These start parameters are necessary for giving the trajectory.
In this practical research a precursor solution consisting in an ethanolic solution of $TiCl_4$, with 0.05 molar concentration has been used. Titanium tetrachloride (titanium chloride (IV), $TiCl_4$) is a salt obtained by the action of the chlorine on a mixture of coal and titanium dioxide. The precursor is a colorless or slightly yellowish solution, with a pungent odor, which fumes in the air. This precursor undergoes hydrolysis in contact with air humidity immediately.
In figures 5.a and 5.b are shown the dialog between user and robot through graphic interface which is realized for establishing the specific parameters of the spraying deposition process. In this manner, the user will establish the number of necessary sequences for realizing the thin film (for example 20). After this the time in seconds between two consecutive passes is determined, (in this case 60 seconds). The next phase consisted in choosing the desired spraying angle, such as 45, 75 or 90 degrees. In another step, the spraying height (in this case 200mm) has been selected. In the studied case a surface of 295 x 145 mm^2 has been chosen as depositing substrate. The last phase is to fixe the distance between two paths (for instance 25 mm). Finally, the program allows to user to leave the program by using the Exit option.



a. b.

Figure 5: Friendly user interface for the user

The pressure of the carrier gas was established at 1 bar, the substrate temperature at 300°C. For a better prominence of the flexibility offered by the program with user interface, the specific parameters of the spray pyrolysis deposition have been varied in order to obtain materials with different morphologies, as it is presented in table 1.

Table 1: The deposition parameters

No.	Spraying angle [deg.]	Spraying height [mm]	Deposition temperature [°C]	Number of sequences
1.	90	200	300	5
2.	90	300	300	5
3.	90	200	300	15
4.	90	300	300	15
5.	45	200	300	5
6.	45	300	300	5
7.	45	200	300	15
8.	45	300	300	15

The spraying depositions were performed at an angle of 45 and 90 degrees. The spraying height was selected at 200 and 300 mm and the number of consecutive passes over the substrate was established at 5 and 15 passes. The substrate temperature was constantly kept at 300°C, and the pressure was fixed at 1 bar.

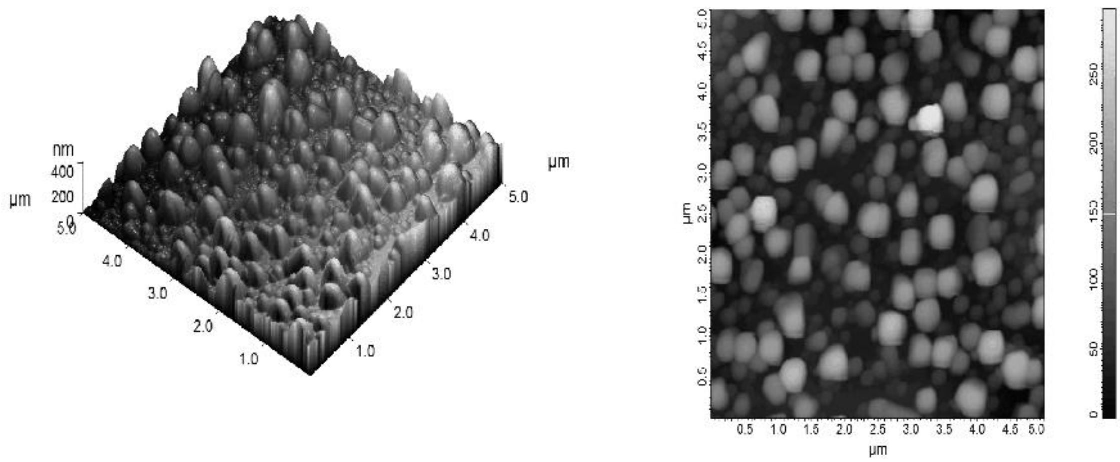


Figure 6: Morphological analysis of the obtained results for $\alpha_{spraying}=45^0$

In figure 6 is shown the morphological analysis of the thin film which was obtained at 45 degrees, at a spraying height of 300 mm and at a number of 5 passes over the substrate. It can be observed that the thin film has a thickness of 400 nm.

In figure 7 was deposited a thin film at a spraying angle of 90 degrees in comparison with the sample from figure 6. The results are presented in figure 8 and 9, with 2D and 3D pictures of the obtained thin films. From the morphological analysis made for the thin film presented in figure 7, it can be observed that it presents a thickness of 160 nm, being thicker than the film obtained at a spraying angle of 45 degrees. Therefore the film has less crystalline aggregates than the spraying of 45 degrees.

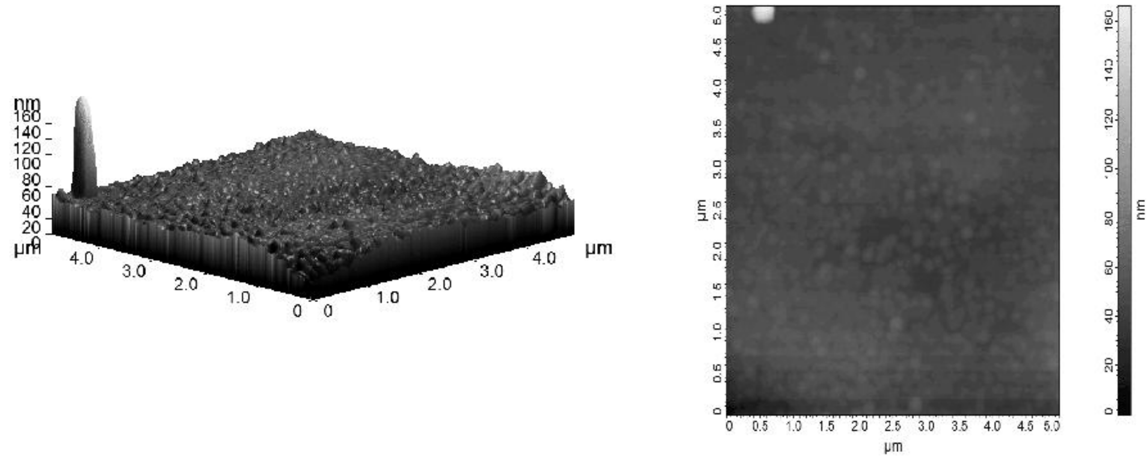


Figure 7: Morphological analysis of the obtained results for $\alpha_{spraying}=90^0$

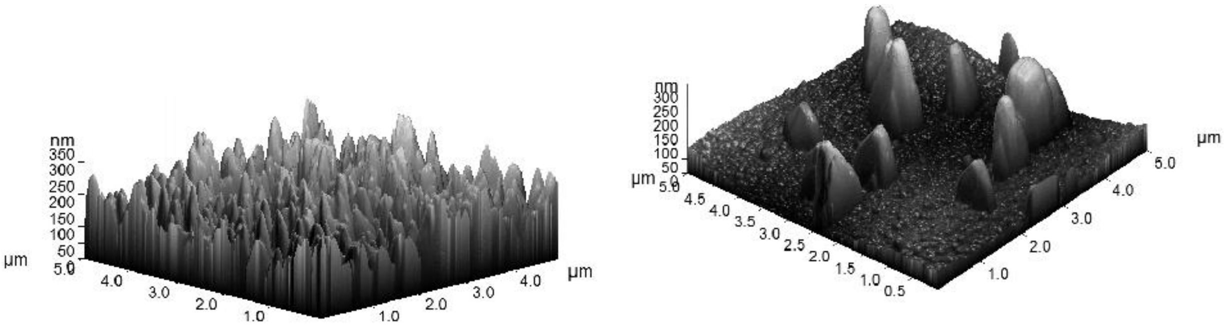


Figure 8: Morfological analysis of the obtained results for various height

As is shown in figure 6, 7, 8 and 9, the obtained thin films have been analyzed by using the AFM (Atomic Force Microscopy) technique. The research was made on a surface of 5μm. This morphology obtained allows further spraying of other solutions, which improve the absorbent properties of the material.

From figure 8 it can be seen that from a precursor solution of $TiCl_4$ sprayed at a height of 200 mm (see figure 8.a), resulted a film with of 350 nm thickness, greater than the film obtained at 300 mm spraying height (see figure 8.b), and having more crystalline aggregates.

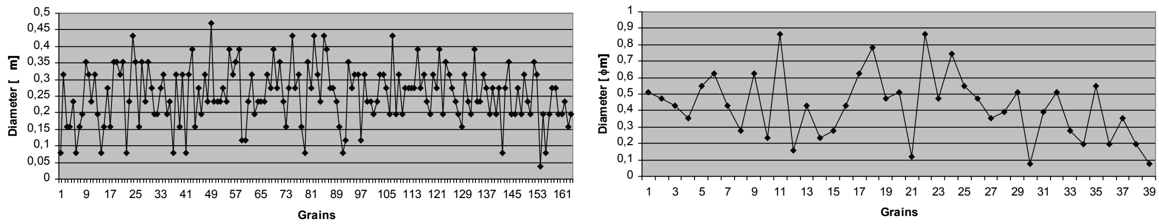


Figure 9: Diagram of the dimensions of crystalline aggregates

The figure 9 represents the dimensions of crystalline aggregates which were obtained by using the user interface made by the authors where the spraying was accomplished using a spraying angle of 45 degrees, and spraying height was set at 300 mm. The film illustrated in figure 9.a has been obtained by five passes and the film from figure 9.b by fifteen passes on substrate respectively.

By increasing the number of passes on the substrate in the spray pyrolysis process, the number of crystalline aggregates decreased but the diameters of these aggregates increased.

4. CONCLUSION

In this paper, we presented a user interface to deposit by the spray pyrolysis technique. We developed a user interface to simplify the task of human operator for spray pyrolysis deposition. The program for the planar surface has proved to be very user friendly. The realized program permitted a big reduction of the human factor involvement in the automatic spraying process. In this way, the production time was diminished, along with the defects made by the human factor in case of manual deposition. By using this user interface, it can diversify the spray pyrolysis characteristics parameters so that we obtain different morphologies of deposited film. The AFM images of TiO_2 films, which have been obtained in different conditions of spray pyrolysis, reflect significant changes in film morphology.

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