Automated Platform to the Deposition of Thin-Films and Characterization Process in Fiber Optics Sensors

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Abstract. In the recent years the instrumentation has focused its development in devices fabricated in fiber optic applied as sensors; these devices are useful to monitorate physical, chemical and biological variables. By the previous, it is necessary its deposition of a thin- film sensible to temperature, humidity, pH, glucose, etc. There are two technics to deposit this into a fiber optic sensor: dip-coating and layer-by-layer. In both cases, is mandatory the application of a automated plataform to manipulate the fiber optic structure when it is immersed into the films to its depositon and the subsequent characterization in different liquid mediums; applying rutines stablished by times, positions and repetitions. The previous has been developed into a *Robot X-Y,* controlled by *LabVIEW* and its hardware *MyRIO* with an electronic arquitecture of low cost devices; also was applied the 3D impresion based on "open software" to design utensils to manipulate the devices and materials.

1. Introduction

Nowadays the instrumentation has interest in the development of devices based on the optical properties; one of those is the sensors fabricated on fiber optics. The preference by these devices has been by their characeterisitcs properties, sucha as: inmmunity to electromagnetic interference, small dimensions, and large bandwidths. Exist differents configurations of fiber optic sensors due its specific properties: Based on Grattins (Long Period and Bragg), Interferometers, Based on pulished regions. The present research has focus its attention in the SMS structures; based on SingleMode-Multi Mode-SingleMode Fiber Optics. The SMS structures have an operation based on a sensible region that posse an operational wavelenght peak that monitorates variables: physical, chemical and biological. A requirment to achieve sensitive the SMS structures to the mentioned variables is necessary to fabricate a sensible thin-film capable to distinguish the presence of different samples of pH, temperature, glucose, refractive index, etc. By the previous, is required the deposition of the thin-films by automated plataforms to realize the tasks under parameters, such as: temporization, position and repetions. In the case of thin-films there are two techniches to deposition in fiber optics: Dip-Coating and Layer-by-Layer. By the mentioned, in the Section 2, the authors will expose the theorical fundamentals of SMS strucures and thin-films deposition techniques. In section 3, will be exposed the robot that has been conditioned to realize the deposition of thin-films. A fiber optic sensor is a device that possess a micro metric dimensions, so is necessary the application of utensilums to manipulate these devices at the moment for depositing sensible materials and conteiners to contain them; therefore, it will exposed the design of 3D impression utensiliums and conteiners In Section 4, it will described the embedded architecture design applied to control the conditioned robot; where is segmented by: electrical-electronic using low cost devices, mechanical based on steppers-motors and computer desing by MyRIO microprocessor and LabVIEW to the Graphical User Interface (GUI). Then, in Section 5 will be presented experimental tests when in a SMS structure is deposited a thin-film by dip-coating and layer-by-layer. After that, will be exposed the results obtained when a SMS is tested in to different IR samples to the characterization the behavior of the sensor. Finally, in Section 6, the authors will propose their conclusions and the improvements to future.

2. Theory Fundamentals

2.1. Fiber Optic Sensors: The SMS configuration

The fiber optic sensors are fabricated by a configuration SingleMode Fiber (SMF)-MultiMode (MMF)-SingleMode Fiber (SMF); where an incident light is transmited in the structure at the SMF, then it gets to the sensible región (MultiMode Fiber) the light will be propagating in different modes; the MMF used is a special one called “Coreless (MMF-C)”, due its properties to interactuate with the surrounding media. Then the propagation modes are coupled into a spliced SMF. The theory fundamental of SMS structure configuration is based on the *Multi-Modal Effect*; it wich says, that due de presence of supported modes in MMF-Coreless (MMF-C) are excited, occurs an interference between each of them producing a replica image of the input at the end of the MMF-C. In the SMS configurations, this replica can be obtained as an operational wavelenght peak by the equation 1.

$$L = \rho\left[(n_{MMF-C}\, D_{MMF-C}{}^{2})/\lambda\right] \tag{1}$$

L means the length of *MM-C,* ρ is the replica's order (been the fourth), n_{MMF-C} is the refractive index in the core of *MM-C,* D_{MMF-C} is the diameter in the MMF-C and λ is the position of the operational wavelenght peak [1-3]. In section 6, will be exposed a SMS based on the parameters $D_{MMF-C} \approx 62.5\mu m, \rho = 4, n_{MMF-C} = 1.444, \lambda = 850nm$, where the length of MM-C $\approx 28mm$ is obtained by equation 1, where the diameter is reduced by etching [1].

2.2. Dip-Coating

Based on the wet chemical thin-films the deposition by dip-coating represents one of the most popular coating processes. The process is based on three stages: First is the *immersion*, the device is immersed (in a vertical movement) into the wet thin-film at a speed constantly untill it is complety inside the container with the material. Then, the second stage is the *deposition;* the thin-film is incrusted on the SMS during at certain time. After that, the third stage is the *extraction*. The SMS is taken out from the container with sensitive material at a constant speed. During the whole deposition is necesary monitoring the spectral wavelenght responce to verify the process, waiting at least 6 hours that the thin-film in the SMS is dried. [4].

2.3. Layer-by-Layer

Is requiered the application of two films the fabrication of this technique, these most to posses' charges oppositely, after of the deposition of each material is mandatory a stage of washed dips. The SMS strucutre is required be immersed into each wet material, during a definited temporization; sucha as the dip-coating must to be immersed in a vertical movement. The movements to each step of fabrication in the horizontal must to be with a speed controllaed (such as the whole experiment) [5].

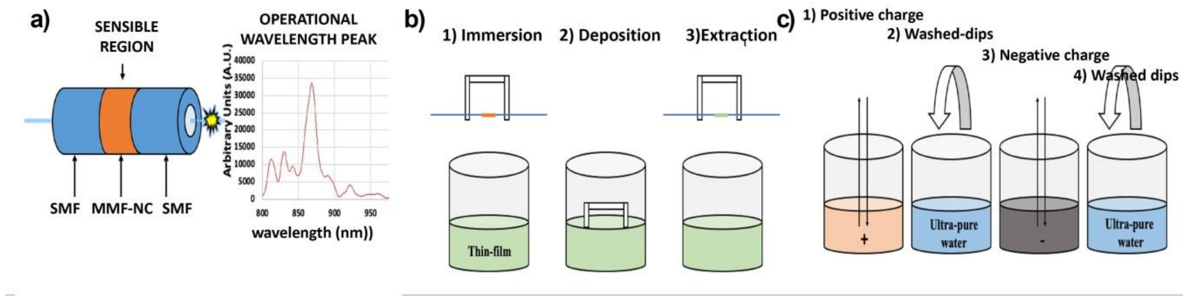

Figure 1. a) SMS structure with its operational wavelength peak.
b) Dip-coating process. c) Layer-by-Layer deposition.

3. Automated Platform and impressed utensils in 3D

A robot based on movement degrees on X-Y, has been adapted to realice such as an automated platform to deposite thin-films in SMS strucutres based on: dip-coating and LbL techiques; also to characterize the fabricated device on different liquid samples. To handle the device and the liqid samples, were fabricated by 3D desing and impression two utensils: a holder to manipulate de SMS embedded on the plataform and a container with 10 subdivisions to the diferent liquid samples. The previous ítems were designed on Sketchup and impressed on Anet A8.

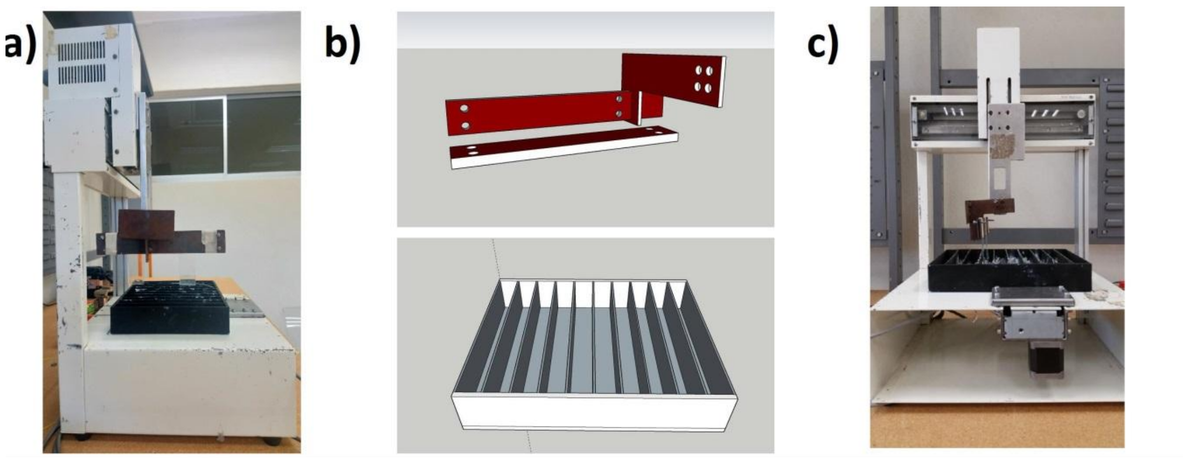

Figure 2. a) Lateral perspective of automated plataform.
b) Utensils based on 3D design and impression. c) Frontal perspective of automated platform.

4. Embedded architecture

In this section, the authors will explain the embedded architecture developed to manipulate the automated plataform. To communicate the instruccions established by the user, for the movements of the robot X-Z, has been used a National Instruments MyRIO; it wich, will controlate two steppers motors (by Sanyo Denki, 12V-1.4A and 2A). It is necessary, the utility for each stepper motor a Pololu A4988 Driver to assign the step direction and different microstep resolutions; also, an of power source (24V, 20A) to supply energy to the electric-mechanical instrumentation. In many ocassions, it is necessary to keep working the automated platform due the characterization process in the SMS devices; the MyRIO allows to stablish remote communications with the user without her/his prescence.

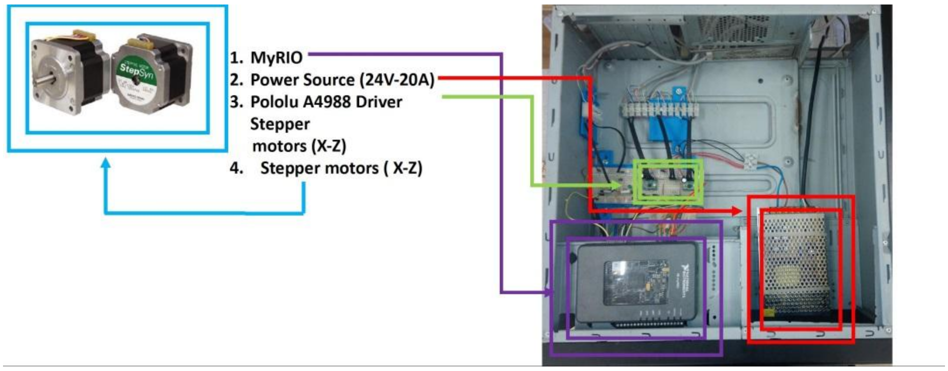

Figure 3. Embedded arquitechture mounted into a PC Desktop Case.

5. Graphical User Interface (GUI)

The Graphical User Interface (GUI), has been developed in National Instruments LabVIEW, due the user needs to establish a certain parameter to define the depositions routines; such as: position in X and Z, microstep resolutions, number of dips, times of steady state at up and down in X (inside or outside of the liquid sample), hystogram, number of samples and cycles. As most of all the automated machines is necessary to include virtual conditions of: Pause, Stop, Reset and Home; just in case of unforeseen scenarios.

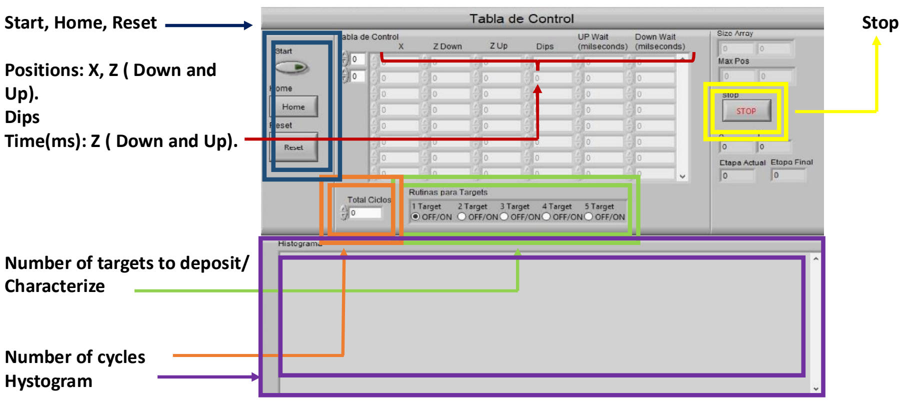

Figure 4. Graphical User interface of Automated Platform developed in LabVIEW.

6. Experimental tests

Using a SMS structure with $D_{MMF-C} \approx 62.5\mu m, L \approx 28mm$; the automated platform has been tested in two scenarios: The first one with a propuse to achieve in a SMS structure a Layer-by-Layer deposition using a Polycationic and a Polyanionic solutions at two layers, exposing a decreasing of power at the second layer; this deposition will allow to sense different liquid samples of physical, chemical and biological variables. The second application is based on a SMS device with the same diameter and length of $MMF - C$, but without any thin-film deposited into it; for a characterization based on different liquid samples of Refractive Index (RI) with the purpose for to know the absolute wavelength shift of the structure when the diameter is reduced at approximatly the half, $\Delta_{\lambda} = 19.63$nm

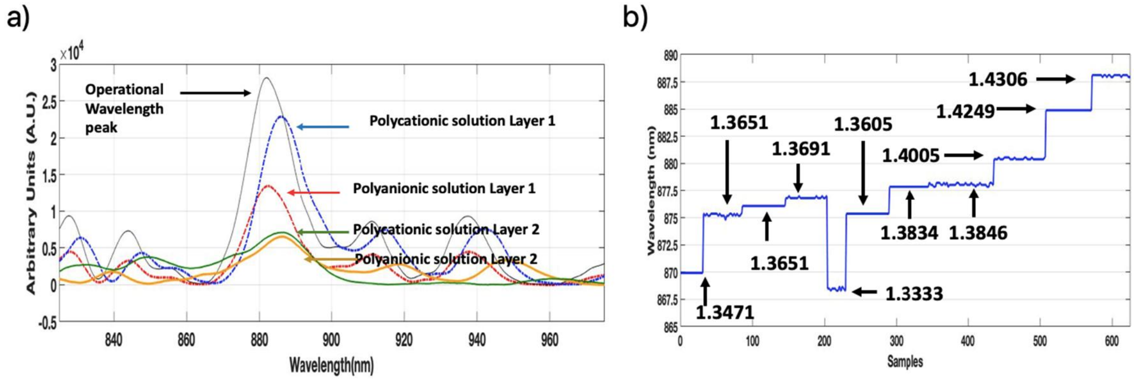

Figure 5. (a) Layer-by-Layer deposition. (b) Characterization of different RI samples.

7. Conclusions

The autors have developed an automated platform for deposition of thin-films to fiber optic sensores based SMS structures, where has exposed a Layer-by-Layer deposition and a characterization process by RI. The previous will be a great utility in the fabrication of fiber optic sensors, not only in SMS also in other structures; such as: D-shapes, MMF, Long Period and Bragg Grattings, etc. A future improvement will be the control by remote distance using a mobile device.

References

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