OPTIMIZATION OF THE PROCESS OF DEPOSITION OF THIN ANTI-REFLECTIVE COATINGS BASED ON A LIBRARY _ DATABASE OF THE CONTROL SYSTEM IN LABVIEW

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Abstract

The paper presents a system to optimize, control, visualization and data storage PVD processes. The system has been designed based on LabVIEW and has been successfully used in the optical industry. Visualization is very intuitive for the operator, provides an easy opportunity to control all process parameters. Saved data allow to create a library that allows to improve the quality of coatings and gives you the ability to analyze processes. The low cost of the introduction of the system also makes it a very useful tool for modifying older vacuum coaters and gives a chance to its gradual expansion. The collected libraries allow you to recreate and optimize the process of applying layers of materials.

Keywords: Process control system, library processes, LabVIEW graphical programming, antireflective coatings, thin films

1. INTRODUCTION

The optical properties of multilayers thin film coatings obtained by PVD methods are very dependent on the process conditions. The properties depend not only on the thickness of individual layers, but equally important are their physical properties, and in particular their refractive indices. Stable substrate temperature [1], strictly selected and controlled speed of a deposition of a material is indispensable to obtain reproducible values of a refractive index. In the case of reactive evaporation is also required continuous control of the dosing process gases [2]. Presented in this paper system for storage of PVD data process works in graphical LabVIEW programming environments. The system was dedicated for production of antireflective coatings and was implemented in optical industry. Laboratory that tested the system specializing in the production multilayers AR coatings for optical parts made of glass. The system performs acquisition parameters such as pressure inside the vacuum chamber, substrate temperature, deposition rate, layer thickness, and the actual dosing process gas [2, 3]. Flexibility of LabVIEW environment allows to create a library. Easy access to data enables fast recovery process and intuitive visualization allows for accurate analysis of the impact of various parameters on the physical properties of the AR coating.

2. DESCRIPTION OF THE TEST SYSTEM

Tests on usability of the library was carried out using the following devices. The Vacuum coater Leybold-Heraeus A700Q shown in **Figure 1**, where was applied the presented system, comprises of the vacuum chamber linked with the pumping system. The pumping system includes of turbomolecular pump and two stages backing pumping by the valves system. In this vacuum chamber there are two types of evaporation sources: three thermal and one electron gun with four crucibles. The vacuum coater is coupled with four basic sources of process signal data: the system vacuum control based on the vacuum head Inficon BPG400 (2) paired with the controller Pfeiffer TPG261 (5) dosing process gases valve MKS Mass Flow Controller 1179 (1), temperature controller is supervised by the regulator Apar AR650 (6), while thin film controller Inficon XTC/2 (4) used to measure rate and thickness of deposited coatings, it is used to measure the thickness of the deposited film and the speed.

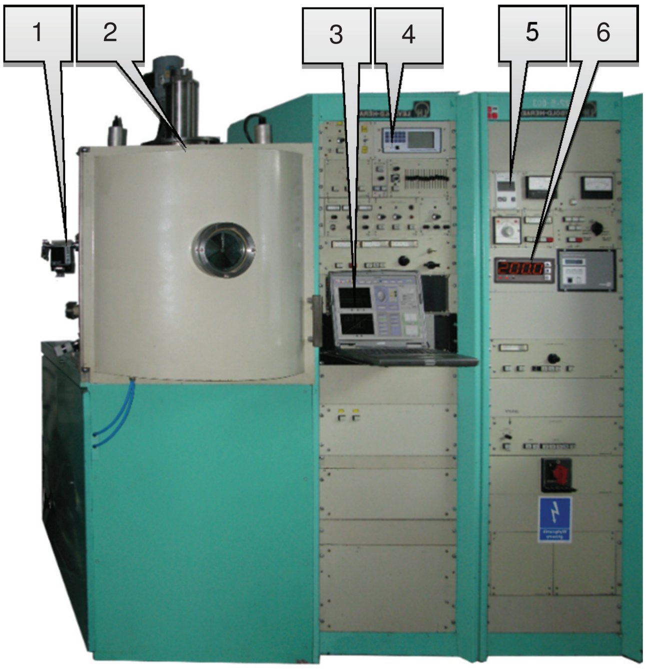

Figure 1 Vacuum coater A700Q, 1-Flow Controller 1179, 2-BPG400, 3-PC, 4- XTC/2, 5-TPG261, 6-AR650

All above mentioned elements are connected to a computer PC (3) via USB. Used transmission media apart from the function data transfer also act as the separation of actuators from the PC [4]. System block diagram is shown in **Figure 2**.

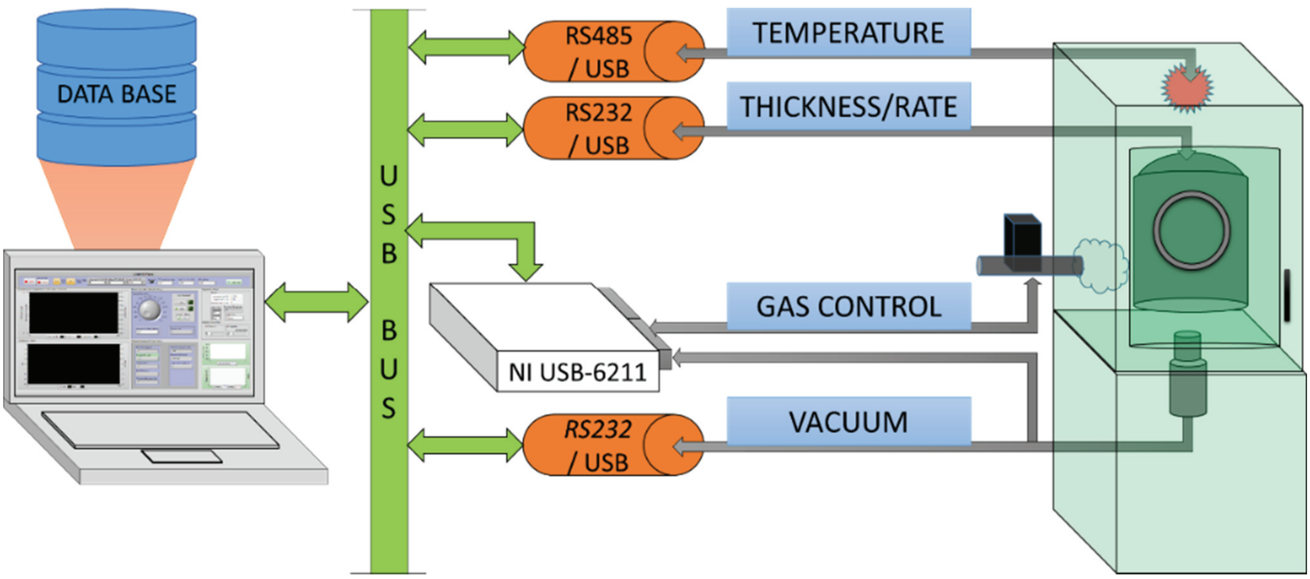

Figure 2 Schematic diagram of the acquisition system

This paper presents process control system which has been prepared in graphical programming environment National Instruments LabVIEW 2015 [5]. The process uses 3 communication media from the sensors and actuators. The driver XTC / 2 exploit RS232 serial interface. Then the temperature AR650 interface is a differential RS485. To control the gas flow MKS used multifunction data acquisition (DAQ) module optimized for superior accuracy at fast sampling rates, National Instruments USB-6211. However, regarding the head used to determine the pressure to ensure the correctness of the process and the security of reading the data is redundantly. This is done using the digital values that are transmitted by the way the RS232 interface using the analog signal measured by the measuring module NI USB-6211. [6]

3. PROGRAM FOR DATA ACQUISTION

Presented system enables saving data in many ways and in many formats. The recording format is determined by the system for further processing and the amount of data you want to save. Examples of formats are: binaries (the fastest service, and read files in the environment, National Instruments), CSV, XML, Database, TDM, TDMS. Saved data of measurements create a library of waveforms the production processes and settings made to the executive devices [7, 8].

Figure 3 shows the program desktop of created application and the dialog box of select settings (eg. setting parameters for dosing of oxygen). The system allows to create database libraries status of processes. The essence is that at the stage of creating a database process should to determine the number of measured values, and to construct the appropriate files to allow the assignment of the process parameter for setting devices. For example, the TDMS file format enables distribution of files on 3 hierarchies: files, groups, and channels. For example, files serve process description, title, author, etc., successively in the group of channels, procedures, test fixture, etc., and then the channel name, comment, unit, sensor info, etc. The use of the TDMS file allows it to skip creation own data structures [9, 10].

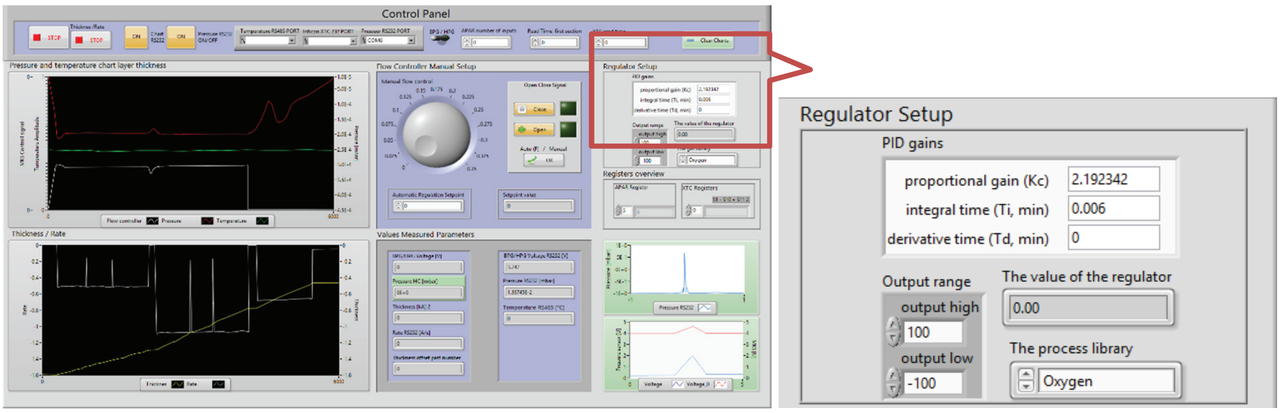

Figure 3 User control panel, menu of selection Libraries

The system consists of independent modules for measuring the values of various physical quantities such as temperature, pressure, evaporation rate, layer thickness. It also allows you to control actuators and enter settings for the driver [10]. The modules can be easily combined with each other, thus creating even very complex measurement systems (quantity depends on licenses and equipment components). Measurement system can be completed successfully, which greatly reduces the cost of its introduction. To make the measurements, all you need is a PC and basic measuring USB card and module for measuring a selected physical size. **Figure 4** shows one of the independently operating modules measuring the evaporation rate controller and measuring thickness.

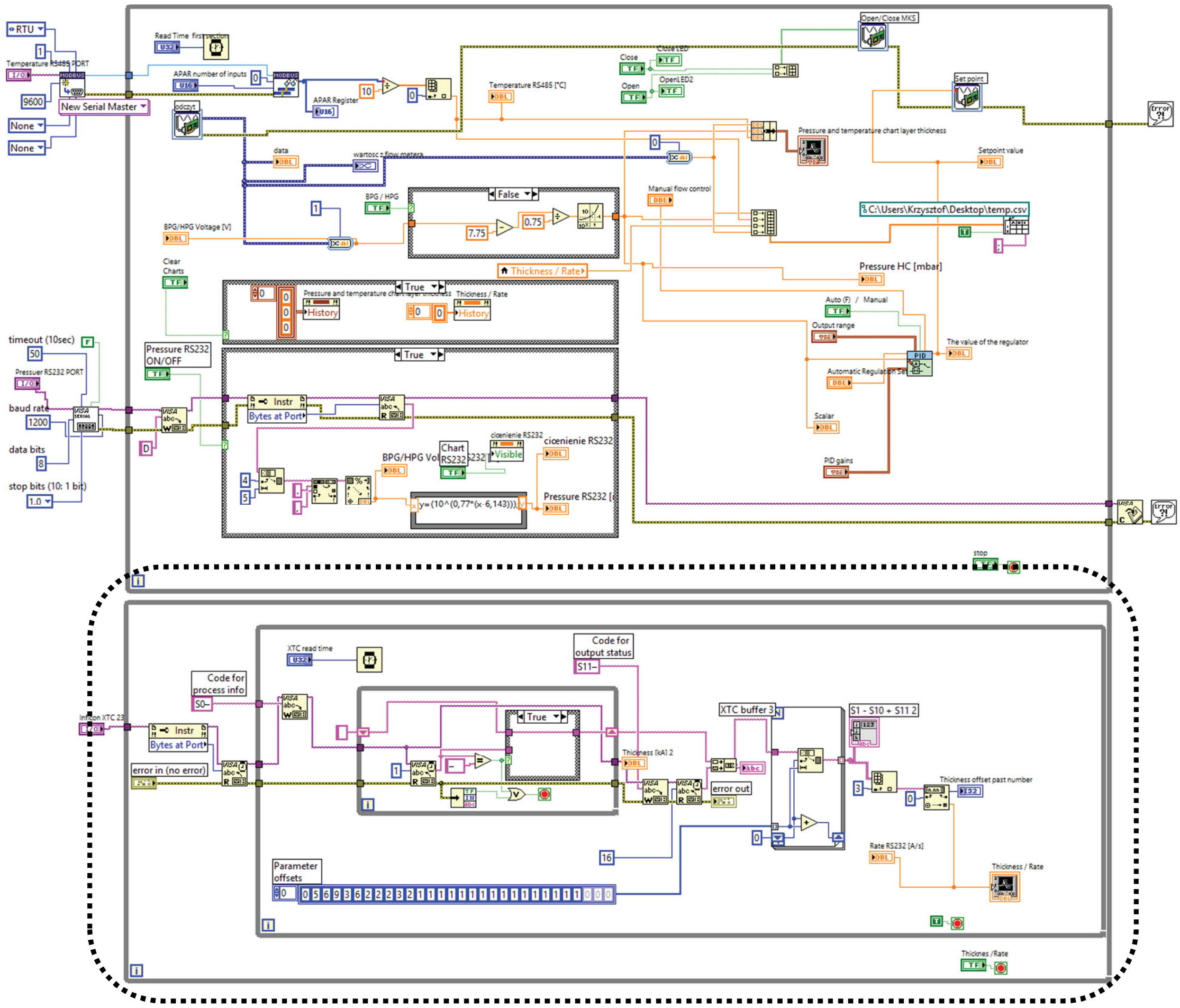

Figure 4 Full program diagram. Thickness control module highlighted by dotted line.

4. RESEARCH

The example of analysis of the impact of process parameters on the properties of the three-layer antireflective coating Al_2O_3 / HfO_2 / MgF_2 for UV region [11] are shown **Figure 5**. Basic construction of three-layer antireflection coatings is: 1M / 2H / 1L. The L, M and H symbols are well known quarter wavelength optical thickness (QWOT) for materials with low, medium and high refractive indices, respectively [14]. Physical thickness of the materials for each layer can calculated by means the formula (1).

$$D = \frac{\lambda}{4n} \tag{1}$$

where: D- physical thickness, n - refractive index of the material, λ - wavelength of light [nm].

In this case, the physical thicknesses of the materials Al_2O_3, HfO_2, MgF_2 calculated for 300 nm were 45.6 nm, 78.9 nm and 54 nm, respectively [12]. Optical investigations of the coatings were carried out by means of double beam spectrophotometer Shimadzu UV1601. Two reflectance spectra of the antireflective coatings are shown in **Figure 5f**. The coating presented by the black curve has better optical properties - reflectance of the structure is lower and wider than the blue one. During the analysis of the processes, it was found that the factor that influenced the difference of optical properties of the coatings was the temperature of the substrates **Figure 5b**.

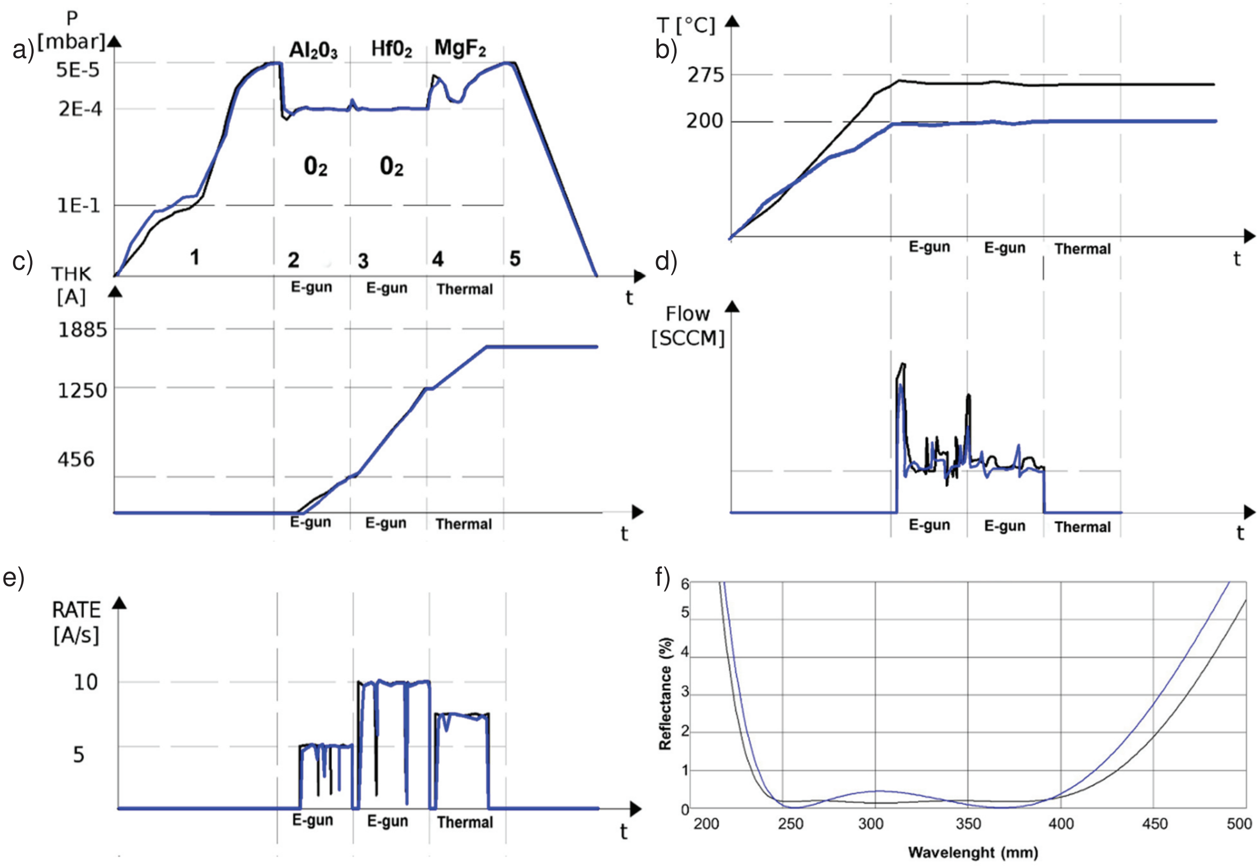

Figure 5 Data of Al_2O_3 / HfO_2 / MgF_2 antireflection coatings deposition processes

5. CONCLUSION

In addition to monitoring processes on a regular basis, we can also distinguish monitoring or in-depth analysis of the process in engineering. The data collected in the database are primarily used for routine process control, but there is nothing to prevent the data have been used to control more generally. During the standard process control, a control card is usually only a few measurements. The control card is measuring device of the current situation of the process. Production and quality engineer outside the production line is able to review the process in the long run, it is able to assess the long-term quality of the process. Control process is not only control, but also on the research for innovation, incentives that will improve him as if from scratch. Such actions are called long-term control and for a large automated processes is the essence of quality improvement. For example, the production of the element depends by the respective machine settings. In the long-term analysis of the measurement values collected by different processes shows that the results of the process 1 differ in the statistical sense of the results of the processes 2 and 3. If the process 1 produced better results it is concluded that the selected setting allow to obtain a product of higher quality. Presented system delivers elements of the monitoring and analysis of data based on measurements collected in the database and other information. On the one hand, allows the creation of libraries that may be used in subsequent processes, and on the other allows to carry out advanced analysis to help uncover eq. the relationship between parameters raw materials and the properties of the product. The system also allows to automate the process in older designs of vacuum coaters.

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