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MULTILEVEL CONTROL SYSTEM FOR LOW-PRESSURE PLASMA PROCESSES

Key words

Control system, PVD test stand, Modbus communication module.

Abstract

The article presents a multilayer control system for test stands designed for PVD (Physical Vapour Deposition) technological processes used for depositing thin surface layers. This system provides control of the test stand via the HMI (Human Machine Interface) control panel and by using specialized supplies of plasma sources. The primary control system that utilizes a PC computer with a dedicated application allows a full automation of surface layer deposition technology. Developed and implemented on a test stand, the systems have been tested based on sample technological processes used in material engineering.

Introduction

The development of technology increasingly relies on the production of new materials or on the modifications of their surface layers, due to the demand for materials with specific physicochemical properties. An important role in this area belongs to the devices utilising the technology of physical deposition of thin layers from vapour phase (PVD – Physical Vapour Deposition). The modification of surfaces provides an improvement of material properties through the alteration of their physical and chemical properties [1]. It produces ultra-hard coatings, or coatings with a very low friction coefficient, or high resistance to abrasion. Another rapidly developing field is the production of Thermal Barrier Coating – TBC, and an important direction in the development of surface engineering is the production of layers of nano-metric structure [2]. A broad range of PVD technologies, including hybrid layer production [3] in a single technological process, is a challenge for the construction of devices and production lines. The development of innovative technologies forces the modernization and re-construction of the devices used for production.

To increase flexibility and convenient up-grades of these types of devices, they need to be constructed as modular apparatuses, and it applies to both the software and the hardware aspects. This approach requires such an adaption of the control system that would allow possible future modifications and up-grades. A convenient solution for this task is to maximize the use of local industrial networks for the creation of the control system. Any change in the configuration of the stand requiring the addition of new modules using communication networks, in practice, is reduced to adding the power supply and updating the software, without having to interfere in the hardware of the control system.

1. The technological stand construction

The critical element of the stand is a dedicated vacuum chamber, where the technological processes take place (Fig. 1). A vacuum producing module is constructed to ensure a proper vacuum. The technological processes are conducted in various working atmospheres whose gas content is monitored and dispensed in the working atmosphere production module. For the the cooling (or heating) elements and components to work properly, the loading, unloading or possible shift of the input is managed by the working chamber management module. These four elements constitute the core of the stand for PVD technologies.

Depending on the purpose of the device and the range of the expected technologies, the test stand equipment can be modified in various ways, and depending on the technology, different plasma sources are available (plasma source module). They can be arc, a megatronic plasma source or electron guns, and their number and types depend on the type of technology. In the technological process, an important element is the proper polarization of the the processed element, whose value influences the properties of the produced

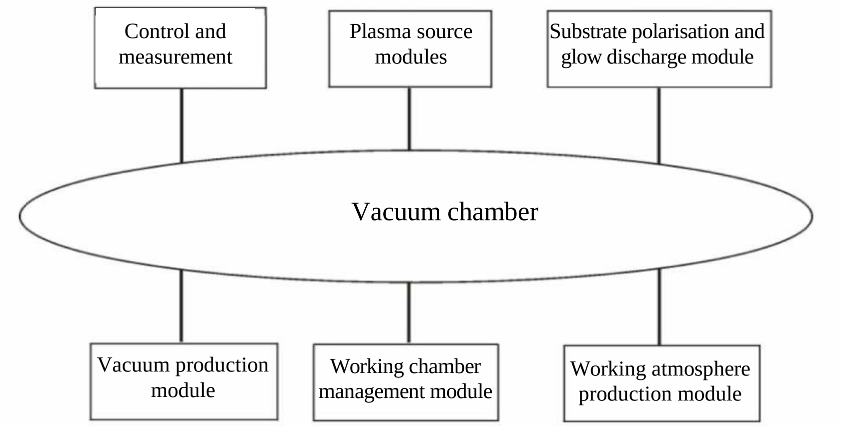

Fig. 1. The technological stand construction

surface layers. In the hybrid processes, layer deposition can be combined with the nitrating process, which can be conducted in glow discharge. The polarising and nitrating modules can be combined into one substrate polarisation and glow discharge module.

2. The structure of the control system

The core of the control system is the modular object controller whose structure can be adapted to the tasks required of the technological stand (Fig. 2). The main element of the controller is the central unit, which manages the functioning of the whole system. The management of specific modules occurs within the internal local network. Some of the tasks, particularly those requiring quick reactions, are carried out using specialised input and output modules. It applies to the digital as well as analogue signals (Module Input/Output Digital/Analogue).

Important elements of the control system are local industrial networks, and in order to use them, dedicated communication modules are used. In the described technological stand, the control process of the specialized supply of plasma source occurs through the Modbus communication module in the purpose-made Modus RTU network. The number of networks and their type depends on the required configuration of the stand. Depending on the technological requirements, selected types of sources can be installed in three technological passes. Specialized, high-powered power supplies are configured for the installed plasma sources.

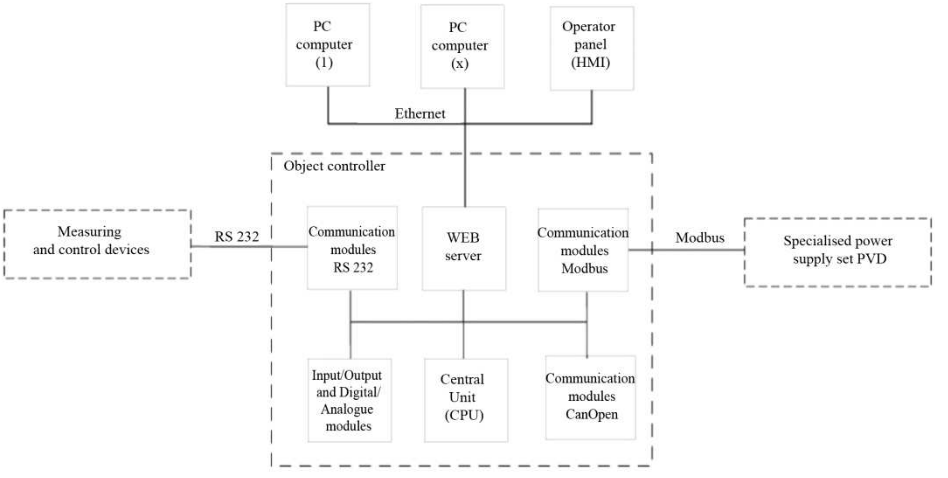

Fig. 2. General structure of the control system

In addition to Modbus network, the stand has two RS232 communication networks for the control and measuring devices. An important element of the system's structure is the WEB server module. This module creates an Ethernet network that constitutes a crucial communication element of the stand. The standard version of the stand includes the operator panel HMI (Human Machine Interface) and a PC computer with an application dedicated for the selected technological process. This design of the control creates a de-centralised control system [4] developed and constructed as part of the statutory activities in 2015 [5].

3. Multilevel control system

The technological stand can operate in two modes. The first is manual mode, and it is a mode for conducting single trial processes or tests. The parameters are given directly through the build-in operator panel. Turning on individual elements of the test stand, setting the parameters, and turning them off are all done manually by the operator on the desktop screen (Fig. 3).

The role of the control system is to perform an automatic process with given parameters. The control system has an on-line control of all the set parameters. All the parameters are simultaneously monitored and managed for the working components necessary for the planned operation. The most important working parameters of the device are displayed on-line on the main screen. The operator can access additional parameters through pop-up windows after selecting the required module on the main screen.

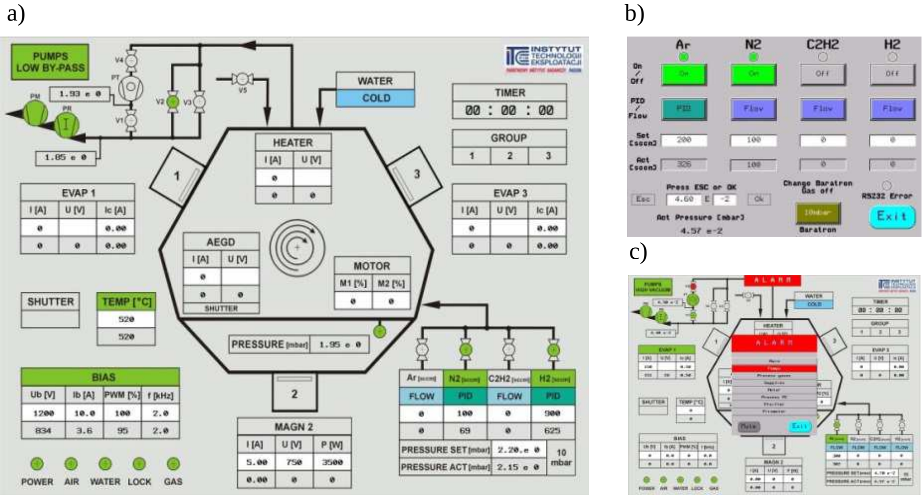

Fig. 3. Examples of the panel screen: a) during operation, b) pop-up screen, c) during an alert

The second type of control is process control, which uses the PC computer with a dedicated application. The task of this application is, first of all, to control the course of the technological process. The application is to prepare an appropriate program for a given technological process (Fig. 4).

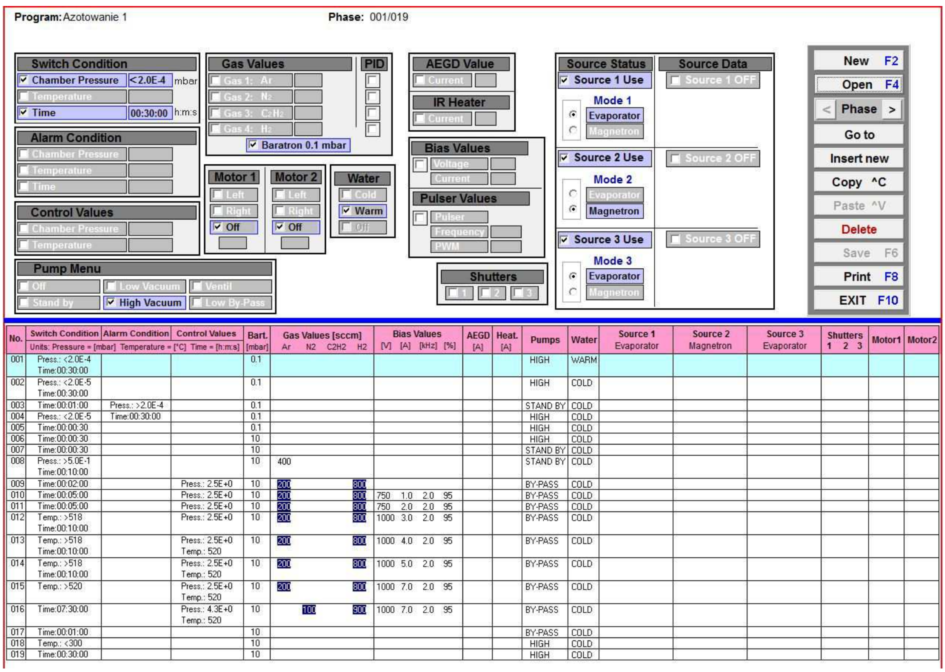

Fig. 4. Editing screen for the technological programme

The technological programme prepared in this way is controlled by the application, and the parameters of the process's specific phases are sent to the test stand control system, where the actual carrying out of the technological process takes place. The main programme, apart from controlling the individual phases of the process, presents a visualization of the actual operational state of the main component s of the device (Fig. 5).

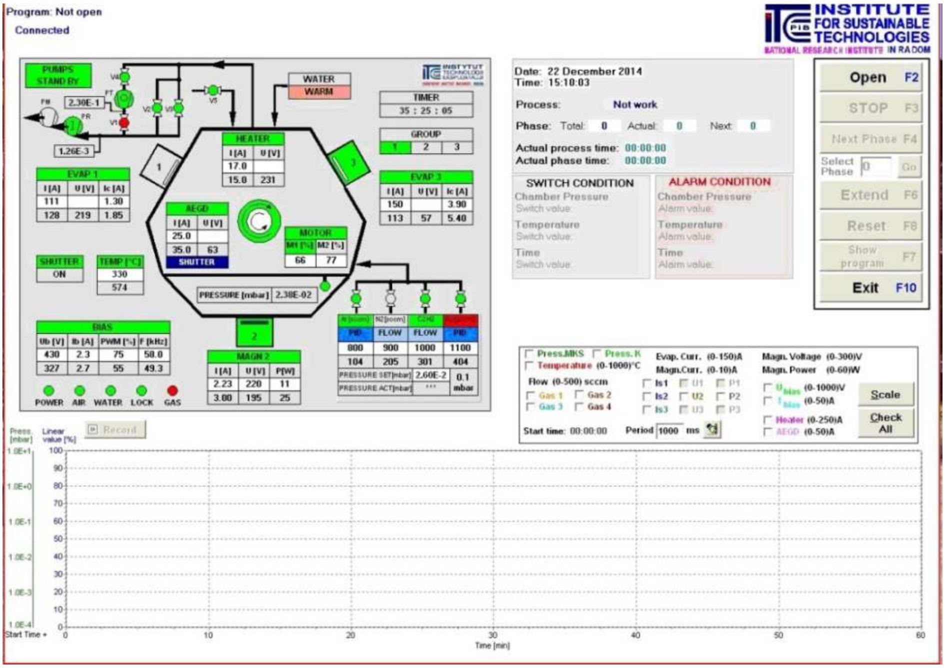

Fig. 5. A visualization of the operational state of the stand

The top, left corner of the screen shows the visualization of the work of the main components of the stand, which – for the operator's convenience – is visually similar to the main screen of the operator panel. On the right side, there are buttons and indicators that allow the operator an on-line control over the process of the technological programme.

The bottom part of the screen is for the visualization of the technological process in the form of graphs and fluctuations in the basic parameters of the process. The number and range of the parameter changes currently displayed is controlled by the operator. Moreover, this part of the screen can be switched to view mode of the course of technological input programme.

An important task of the application managing the technological process is not only visualisation of its course but also its documentation. It allows an analysis of failed technological parameters in the case of process errors.

Another way to use this is an analysis of the process from the point of view of its optimisation. The documentation of the changes in the process parameters is carried out for all basic parameters anticipated in the program, regardless of which parameters are currently being displayed on screen by the operator.

The main task of the control system is primarily to set and control the parameters determined by a given technological programme. Another task of the device control is managing emergency situations during the process. It is an important task, particularly in the environment of interferences caused by the work of high voltage source of plasma [6]. In an emergency situation, the process is stopped, the primary computer receives the relevant information, and the system awaits its instructions.

The realised programme must be suited to the hardware configuration of the stand. In the case of incompatibility, changes must be introduced in the technological programme or the configuration of the stand must be adapted to the planned technological process, which is appropriately indicated.

4. Control system verification

In order to check that the control system works properly, trial processes were conducted and the results were compared with analogous processes in a currently used PVD stand. One of such processes was nitrating glow conducted according to the same technological premises on the newly developed device as on the device currently in use. The results for both devices are presented in Fig 6, and the cross-section of both samples is presented in Fig. 7.

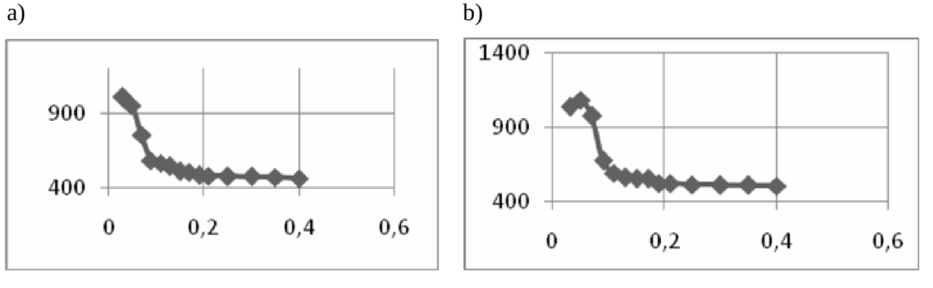

Fig. 6. Curves for the hardness of samples a) for the currently use stand (Std1), b) for the tested stand (Std3)

Carrying out both of these processes showed that both were executed correctly. Moreover, in neither of the processes did the white layer occurred. In both cases, the character and the depth of the nitrated samples were similar.

a) b)

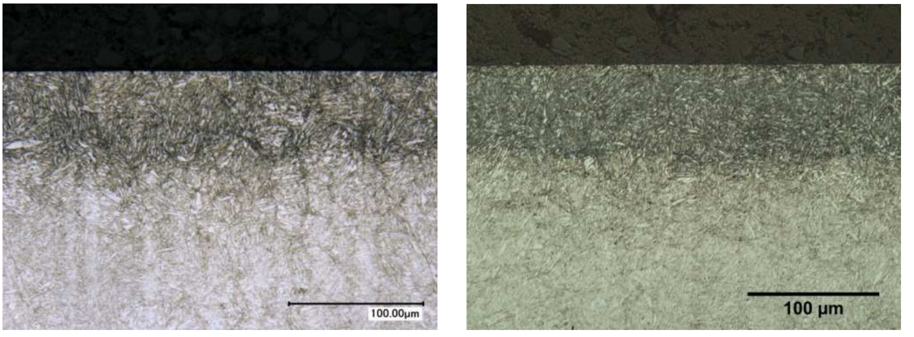

Fig. 7. Fragments of the cross-section of the samples after nitrating, a) for the currently used stand (Std1), b) for the tested stand (Std3)

In addition, a test of the TiN layer deposition was conducted for 3 samples in selected areas of the working chamber. The following thicknesses were obtained as a result of the process for each of the samples: sample G = 1.2 µm, S = 1.3µm, and D = 1.0 µm, and these results were as expected. Moreover, these samples were tested for adhesion using the scratch method. The tests were performed on the REVETEST CSM device in a mode of linear increase of ΔF = 10 N/mm. The results are shown in Fig. 8.

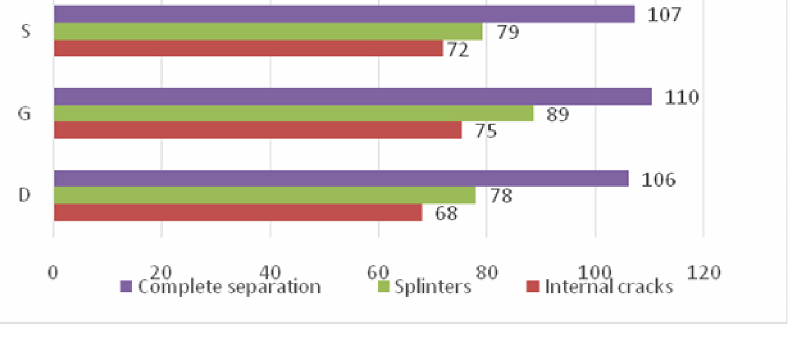

Fig. 8. Load values for which coating damage was observed

5. Summary and conclusions

The modular construction of the test stand and the applied multilevel control allow full and convenient control of the technological stand. The application of this solution in conjunction with the typical industrial networks allows a convenient alteration in the configuration of the stand, and it will facilitate its simple and easy upgrade in the future. The performed technological tests confirmed the usefulness of this solution for universal stands for nitrating in glow discharge and PVD. The developed and constructed system allows operation in both automatic and manual system control.

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Wielopoziomowy system sterowania stanowiska PVD

Słowa kluczowe

System sterowania, stanowisko PVD.

Streszczenie

W artykule przedstawiono wielopoziomowy system sterowania przeznaczony dla stanowisk do prowadzenia procesów technologicznych PVD (*Physical Vapour Deposition*) wykorzystywanych w nakładaniu cienkich warstw wierzchnich. System pozwala na bezpośrednie sterowanie stanowiskiem badawczym za pomocą panelu operatorskiego HMI (*Human Machine Interface*) oraz przy wykorzystaniu specjalizowanych zasilaczy źródeł plazmy. Nadrzędny system sterowania wykorzystujący komputer PC z dedykowaną aplikacją pozwala na pełną automatyzację realizacji technologii osadzania warstw wierzchnich. Opracowany i zaimplementowany na stanowisku badawczym system został przetestowany w przykładowych procesach technologicznych wykorzystywanych w inżynierii materiałowej.