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Jan PRZYBYLSKI, Andrzej MAJCHER
Institute for Sustainable Technologies – National Research Institute, Radom
jan.przybylski@itee.radom.pl, andrzej.majcher@itee.radom.pl

THE STRUCTURE AND APPLICATION OF A TEST STAND FOR A PVD TECHNOLOGY RESEARCH CONTROL SYSTEM

Key words

Modular control system, PVD technology, research stand, technological devices.

Abstract

The construction of technological test stands is connected with the problem of the proper determination of the structure of the stands to enable the execution of technological processes with different types of instruments and devices. The article presents a test stand for Physical Vapour Deposition (PVD) technological processes. The configurability of the stand was achieved thanks to the modular structure of the stand and the use of appropriate software and hardware solutions. The authors present examples of the utilisation of the structure of the stand for the modernisation of existing technological devices and the development of new ones.

Introduction

Materials engineering utilises a wide range of technological processes enabling the procurement of thin surface layers with specific and defined parameters dedicated for individual applications. Therefore, specialised test stands compatible with the defined hardware sets need to be constructed to perform these tasks, or existing stands need to be extended with additional elements that are not directly connected with the control system implemented in them. However, this approach has one basic disadvantage, and that is it requires manual control and significantly reduces the researcher's comfort of work. Additionally, this solution does not allow full repeatability of conducted processes, and the lack of a homogenous control system makes the operation of the devices far less safe, because there is no synchronisation as far as the control is concerned, and no integrated security system is in place, among other inadequacies.

This problem can be solved by a modular, reconfigurable control system for a stand for PVD technologies [1]. As for hardware used in the control system, the requirements imposed by the variety of processes can be met by a modular controller with extended communication functions. The modularity of the controller enables the adjustment of its structure to the existing needs. Another great advantage in the development of this control system stems from the application of typical industrial protocols and a TCP/IP protocol, which enable easy exchange of data between different hardware units and stimulate communication with the main PC equipped with SCADA software. The Ethernet network is a convenient means of creating remote visualisation and remote access to the device. The structure of the stand should enable easy transfer of its verified components to commercial technological devices.

In the sections to follow, the authors present the developed structure and the examples of its practical application.

1. Modular structure of the stand

The PVD stand is composed of typical functional elements (Fig. 1) used in materials engineering technologies. The main element of the PVD is a specialised vacuum chamber, where the architecture and the types of materials used to a great extent determine the technological capabilities of the device.

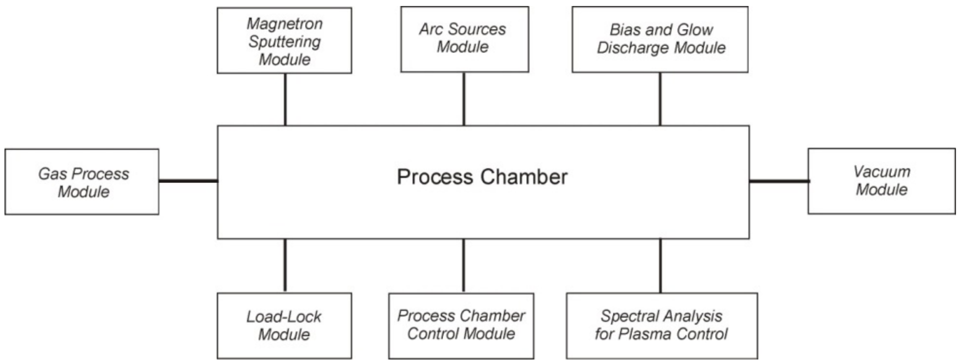


Fig. 1. Structure of the modular PVD stand

The basic element of the PVD stand is the *Module for creating technological vacuum* and the *Module for creating working atmosphere* that ensure that each technological process is performed in proper environment. The *Module for chamber supervision* enables control over the cooling system and ensures the proper system for the placement and shift of details during the process conducted and the appropriate operation of shutters and blinds. To this base other specialised modules can be added. Their type and number depends on the planned technology and the structural possibilities of a working chamber.

The basic modules are plasma creation modules, which are based on arc plasma sources (*module of arc plasma source*) or magnetron sputtering sources (*module of magnetron source*). It is also worth mentioning that these types of sources can also have a technologically varied structure [2, 3, 4]. The majority of PVD technologies require proper polarisation of a substrate, for which a part of the *module of bias and glow discharge* is used. This module concurrently forms the basis of *the module of glow discharge*. It is extremely convenient to have these two modules connected together with an additional unit *(pulsed power supply)*, which changes DC into pulsed DC with adjustable frequency of impulses, so that they form a single system constituting the *module of bias and glow discharge,* and thus create an integrated system adjusted to plasma processes [5].

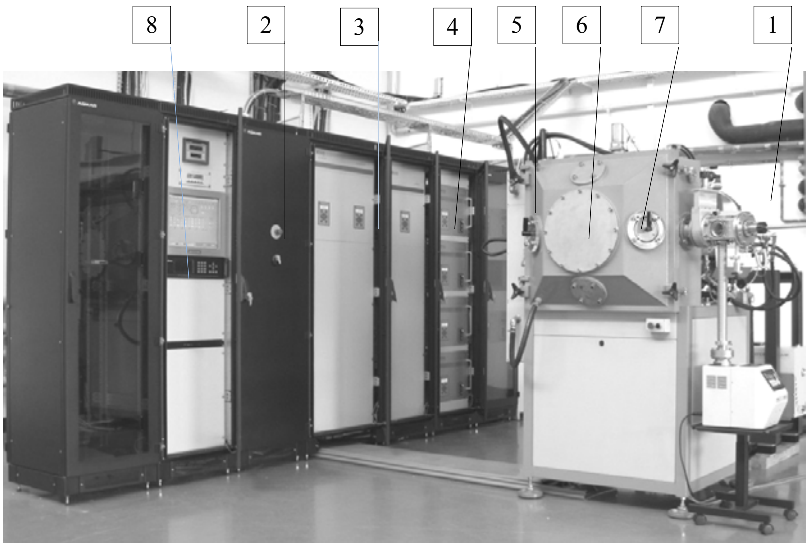


Fig. 2. Specialised test stand: 1 – vacuum chamber with, 2 – control cabinet with a PC and control apparatus, 3 – electrical switchgear module, 4 – bias power supply, 5 – resistance heater power supply, 6 – arc source power supplies, 7 – magnetron source power supplies, 8 – cabinet for additional equipment (instrumentation)

The developed test stand is also equipped with additional modules increasing its functionalities and technological capabilities, including *the load-lock module* enabling a continuous execution of the test without the need to stop the technological process. This module also makes the exchange of substrates at different stages of the technological process possible, and it facilitates the analysis and measurement of the selected parameters. Technological capabilities of the stand were extended by an additional feeder for substrate resistance heating *(Module of resistance heaters).*

Technological capabilities of the stand were also extended by the application of *the plasma spectral analysis and control module* enabling advanced supervision over the plasma production process. Figure 2 presents the view of the stand and its modular structure described above.

2. Control system

To ensure flexible expansion and reconfiguration, a researcher needs to make sure that the addition of other elements is possible. There is a great variety of control systems in which centralised or distributed systems are used for the development of the stands of technological devices [6]. This problem was solved by means of the application of local communication networks, which called for the inclusion of a PLC that can be extended with typical input/output elements and, most importantly, with additional communication networks. In the stand, an internal industrial network based on Modbus RTU protocol was used for the acquisition of data and the control over selected subunits of the stand (i.e. a system of specialised high power supply adapters).

Control over specialised vacuum control and measurement instruments and technological gas dosage elements are executed through a RS232 port. The structure of the control system in depicted in Figure 3.

The remaining elements and components of the stand are directly controlled through digital and analogue input and output modules. The number and type of these modules both have to be closely correlated with the hardware configuration of the stand. The main element of the control system is the modular M340 controller by Schneider-Electric [7, 8], which enables a flexible configuration of the system, and it helps to select specialised modules available for a given stand.

The system can be configured in the two following ways:

– Manually, changing the configuration of the controller and its software as well as by changes in the main software; and,
– Automatically, through the configuration of the programmed controller and main software.

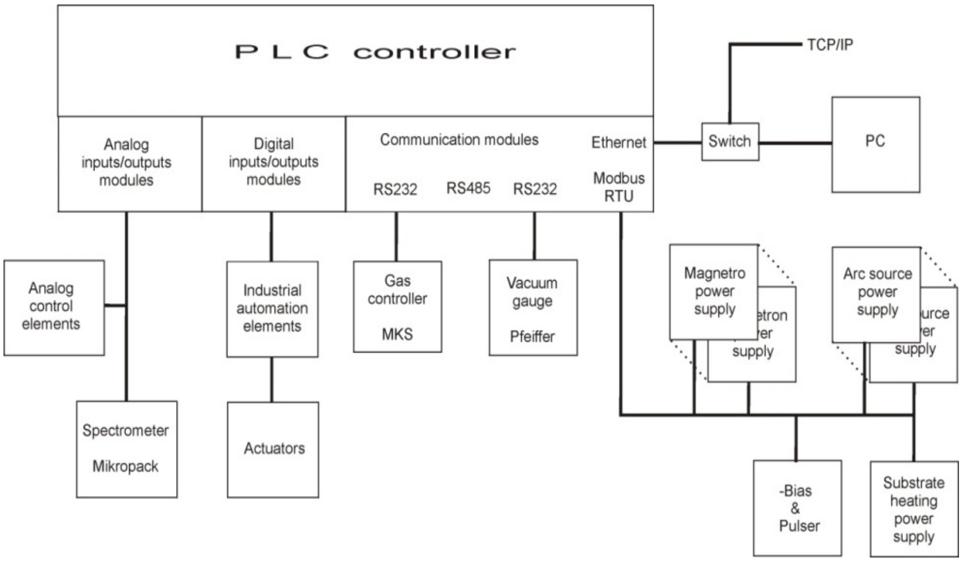


Fig. 3. The organisation of the control system for the developed test stand

Manual configuration needs to be applied in the case when the range of necessary changes exceeds the possibilities of automatic configuration. This is particularly important with reference to a test stand intended for the development of novel technologies, for which it is difficult to predict the final composition of the final set of hardware units.

In automatic configuration, the existing modules enable the optimum adjustment of the control system to the requirements of the user. In the control system, at the time of system configuration, the type and number of the planned modules are selected for the needs of the given technological process. The use of local industrial networks to control individual modules allows their number to be easily and conveniently increased.

3. Application of the stand in the development of technological devices

The stand described in this paper is used for the development of new technological devices. It was used, *inter alia,* for the modernisation of a PVT-550 stand utilised at the Silesian University of Technology, which focused mainly on the system for plasma creation using two arc sources and a substrate feeder together with a dedicated control system (Fig. 4).

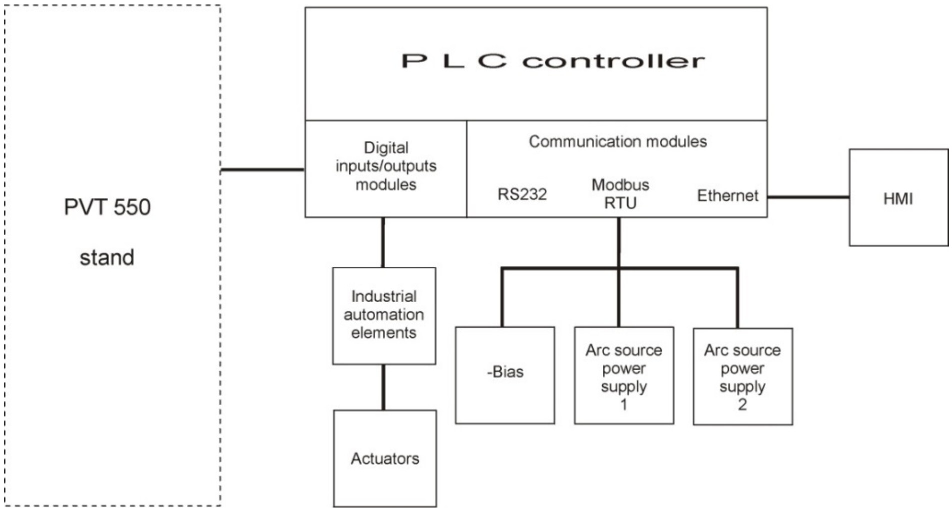


Fig. 4. Draft of the control system for the modernisation of the PVT 550 stand

In the stand in question, a dedicated control system and arc source and substrate feeders were installed. Modernisation of the stand was based on modified arc source feeders, which were verified using the modular PVD stand. The scope of work concerned the introduction of changes necessary to ensure proper cooperation between the feeders and arc sources of the PVT 550. Arc source feeders required modification due to the different structure of the arc source. This task was performed on the developed stand; however, prior to its execution, the arc sources were temporarily installed in the working chamber. Figure 5 presents a new control system, including dedicated power supply adaptors.

Fig. 5. Modernisation of the PVT-550

Apart from arc sources, the modernisation of the PVT-550 stand concerned the implementation of a new module of bias by means of the adaptation of the module developed for the needs of the PVD stand. The changes introduced to the PVT-550 stand called for the installation of a control system tailored to the requirements stemming from the modernisation of the stand and the existing environment.

Another example of the application of the developed stand is the execution of the ion nitriding module at the "Motor" company in Tarnow (Figs. 6 and 7). The above module was built based on two specialised power supply adaptors – a DC adaptor (1200V and 40A) and a pulsed power supply changing DC into pulsed DC. The two modules can be controlled via Modbus RTU. They are also equipped with local panels enabling direct setting of module work parameters.

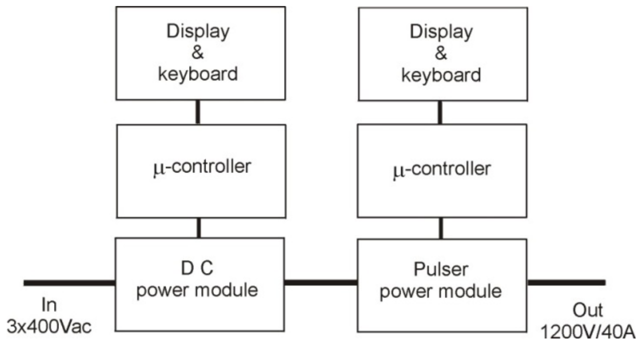
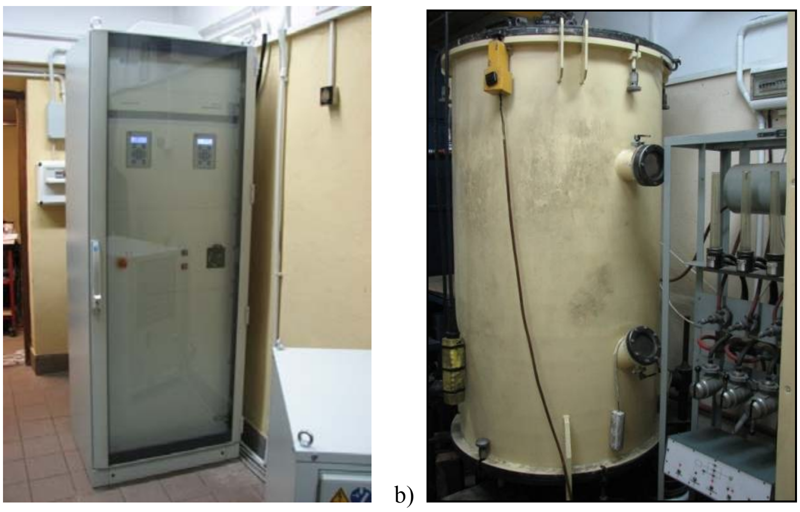


Fig. 6. Structure of ion nitriding module control



a) b)

Fig. 7. Modernisation of a production line in "Motor" company (a – ion nitriding module, b – technological stand)

The module installed enables the execution of ion nitriding processes with parameters set in the DC module and the possibility of pulsating work up to 10 kHz and the repletion of the chamber between 0-100%. This module was developed and verified on the test stand and then used for the modernisation of the existing production line.

The developed modules were also used for the development of a device enabling the execution of Duplex processes (Plasma Technology Centre – ITeE – PIB) (Fig. 8) [9]. The device is equipped with a vacuum chamber with a technological vacuum creation module and a working atmosphere creation module. The structure of the chamber also enabled the installation of five arc source modules and an additional specialised Arc Enhanced Glow Discharge (AEGD) module. The stand is also equipped with a substrate-heating module containing resistance heaters, as well as a module of bias and glow discharge.

Fig. 8. Technological device for the execution of Duplex processes

Summary

The modular structure of the stand together with control using local industrial networks allows flexible configuration of new technological devices. The modular structure of the control software used in the stand implemented in the PLC helps to increase the possibilities of the adjustment of the stand to the needs of novel technologies. The solution enables flexible and easy creation of new solutions tailored to the individual requirements of potential clients, e.g. those described in this article. These solutions can also be applied for the development of test and technological stands for plasma processes.

The device presented by the authors enables the development of simple as well as complex technological devices. The flexibility and modularity of its structure is also useful when modernisation of existing devices and production lines is taken into account. The possibility of experimental verification of design solutions enabled by the stand significantly speeds up the transfer of plasma technologies of materials engineering processes.

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Struktura i zastosowania sterowania stanowiskiem badawczym technologii PVD

Słowa kluczowe

Technologie PVD, stanowisko badawcze, modułowy system sterowania.

Streszczenie

Budowa technologicznych stanowisk badawczych przeznaczonych do prac rozwijających nowe technologie wiąże się z problemem określenia właściwej struktury stanowiska, umożliwiającej realizację procesu z odpowiednim oprzyrządowaniem lub realizację różnych procesów z wybranymi zestawami oprzyrządowania. W artykule przedstawiono stanowisko do badań procesów technologii Physical Vapour Deposition (PVD). Możliwość rekonfiguracji stanowiska uzyskano poprzez zastosowanie modułowej struktury stanowiska oraz odpowiednich rozwiązań systemu sterowania odnoszących się do warstwy sprzętowej i programowej. Przedstawiono przykłady wykorzystania struktury stanowiska do modernizacji istniejących i budowy nowych urządzeń technologicznych.