Transilvania
University
of Brasov

HABILITATION THESIS
SUMMARY

GENERAL AND PARTICULAR ASPECTS IN ELECTRONIC MEASUREMENTS
IN THE FIELD OF NANOMATERIALS

Domain: Electronic engineering, telecommunication and information technologies

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This habilitation thesis is a synthesis of my research activities since supporting the doctoral thesis (2010) to the present and the way in which personal scientific development influenced the didactic component. There are synthesized activities based on innovative ideas launched from the beginning of my Ph.D. in the Faculty of Electronics and Telecommunications, "The Politehnica" University of Bucharest, and later developed in my scientific evolution.

In all these years I have had important collaborations with prestigious researchers from research laboratories in the country and abroad, without whom I certainly would not have achieved the results obtained. I can mention here:

- I.N. Mihailescu, C. Ristoscu, and their colleagues, on advanced methods for thin film deposition, Laser-Surface-Plasma Interactions Laboratory, National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania,
- G. Stanciu, B. Savu, R. Hristu, on high-resolution optical methods for surface characterization, Center for Microscopy, Microanalysis and Information Processing, "Politehnica" University of Bucharest, Romania,
- V. Lazăr, on microbial biofilms, Department of Botany - Microbiological Physics, University of Bucharest, Romania,
- M. Badea, M. Moga, on biosensors, biochemistry and medicine, Department of Fundamental Disciplines and Clinical Prevention, Faculty of Medicine, Transilvania University of Brașov, Romania,
- D. Cotfas, P. Cotfas, on studies on solar cells in concentrated light, Department of Electronics, Transilvania University of Brașov, Romania
- C. Samoilă, D. Ursuțiu, on the topic of surface functionalization for applications in electronics and medicine, Department of Electronics, Transilvania University of Brașov, Romania,
- M. Galca, L. Găman, Faculty of General Medicine, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania,
- C. Wieckert, Y. Baeuerle, D. Wuillemin Solar Technology Laboratory of the Paul Scherrer Institute, Villigen, Switzerland,
- D. Lieberman, R. Rubin, on the topic of concentrated solar energy, Solar Research Unit, Weizmann Institute of Science, Rehovot, Israel,
- R. Chiesa, G. Candiani, N. Pastori, M. Moscatelli, Department of Chemistry, Materials and Chemical Engineering "Giulio Natta", Politehnica of Milan, Via Mancinelli 7, 20131, Milan, Italy.

In recent years, the need to produce state-of-the-art electronic devices, in line with the growing demands of society, has imposed a rapid pace in the development of new, chemically complex, or nanostructured materials with multifunctional properties. In many areas of science and technology, there is a trend towards nanoscale or even atomic levels, and electronics is now experiencing a transition from microelectronics to nanoelectronics. This continued downward trend of scale is currently being achieved by large-scale nanomaterial thin films with multiple applications in electronics, medicine, telecommunications, transport, and so on.

Following this trend, my research has been partly in the field of electronics measurements on thin layers built for electronics and medical applications, dealing both with advanced nanotechnologies of thin films and high-resolution methods for their characterization.

These nanostructured thin film coatings may be required, for example, to protect biocompatible devices such as sensors, pacemakers, electrodes, conductors, probes, stents, bone or dental implants, etc. They are important because they can stop the release of metal and metal oxides in biological fluids and move them to internal organs and can protect against corrosion, accelerate bio-integration (by using bioactive materials), can exert antimicrobial effects (through the use of antimicrobial agents), while offering the possibility of lowering the price of devices (by using cheap materials but without special properties).

The field of electronic measurements has focused on advanced nanotechnologies for thin layers obtained using a pulsed laser, namely pulsed laser deposition (PLD), matrix-assisted pulsed laser evaporation (MAPLE-Matrix Assisted Pulsed Laser Evaporation), and Combinatorial Pulsed Laser Deposition (C-PLD).

We have applied and perfected these processes to obtain:

- TiN, ZrC, ZrN thin films for electronics;

- Nanostructured thin films for coating biocompatible devices.

We have thoroughly analyzed the structures obtained to validate the use of laser technologies for their realization, find optimal deposition conditions, and evaluate their properties. In this way, they were completely physically, chemically, and biochemically characterized with advanced electronic measurement methods, using a number of independent and complementary high-resolution techniques:

- Scanning Electron Microscopy;
- Confocal Laser Scanning Microscopy;
- energy dispersion spectroscopy;

- X-ray diffraction;
- electrochemical impedance spectroscopy;
- Infrared Fourier Transform spectrophotometry;
- scratch test;
- cell viability, proliferation, and cell adhesion assays;
- bioactivity tests;
- methods for determining electrical properties.

The investigated properties were: chemical composition and stoichiometry, crystallographic structure and crystallinity, surface morphology, mechanical properties (adhesion, roughness), biological properties, electrochemical properties, electrical properties.
We have also emphasized the evaluation of the corrosion resistance of materials, an important parameter in electronics, for example in the case of electrical contacts, but also in the event of materials being used in the development of biocompatible devices.

On the other hand, my research turned to green energy systems.

In this context, my research is focused on the characterization of thin semiconductor films with specific electrical and optical properties and on cell design technologies that lead to optoelectronic devices with high performance, in the photocell regime, and with the lowest possible cost. Thus, I studied solar cells with thin layers of inorganic (CdTe și CdS), and organic (ITO and ZnO, ZnPc, Alq3 and PTCDA) semiconductor materials, with high stability of properties over time, with the lowest possible mass and the lowest possible cost. With the decrease in the manufacturing cost of photovoltaic cells, the cost of solar panels would also decrease and implicitly that of the electrical energy produced.

I started with the study of improving the quality and performance of existing photovoltaic structures by increasing the efficiency of converting solar radiation into electrical energy using innovative concepts for capturing and coupling light. These research directions were based on the use of nanostructured surfaces with the help of laser, from materials with potential for the photovoltaic industry.

It is also very important to study the "aging" of structures over time, concentrating light by allowing the study of cell aging and lifetime calculation in experiments over several days (instead of around 25 years as a cell works) and on the other hand study of the operation in extreme conditions, knowing that solar cells can be used both in terrestrial applications to supply different systems as well as in space applications for the supply of satellites, spacecraft, etc.

Characteristics of the studied cells were obtained using a program developed in the LabVIEW graphic programming environment, following research applied on different types of solar cells, when it became necessary to develop a robot arm for measuring the current characteristic - light voltage concentrated solar power, a necessity dictated by the development of very high temperatures in the illuminated area, which requires the exposure to be controlled for an extremely short duration. The entire system, which is a combination of digital electronics, analog electronics, and data acquisition, has been successfully tested to achieve the current-voltage characteristic even in environments with high electromagnetic disturbance.

We did the following:

- I-V characteristics for different types of solar cells at different levels of solar illumination (1-1000 suns) at different temperatures and different wavelengths (VIS-IR);

- Determination of the correlation between the deposition parameters using pulsed laser nanotechnologies and the optical and electrical properties of the layers;

- Determination of solar cell properties and parameters in concentrated solar energy: short circuit current, cell efficiency, open circuit potential, fill factor, maximum power, series resistance, and shunt;

- Study of aging of photovoltaic cells using concentrated solar light.

Another direction in which I have directed my research in recent years is related to the development of detection and control systems with applications in electronics and medicine, namely:

- Fractional adaptive control for a fractional – order insulin – glucose dynamic model;

- Innovative detection systems in life sciences with sensors and biosensors;

- Telemedicine and telemonitoring systems.

And because this is the era of **Artificial Intelligence**, we have managed to take a different approach to the problem of autonomous navigation: we have used a recurrent neural network to model the dynamics of the environment in which a robot is located. Environmental dynamics, in the context of this study, refers to the dynamic obstacles present in the scene. Recurrent neural networks are a type of model capable of capturing temporal dependencies and processing sequential data (for example, objects moving in the scene). By incorporating historical data in the form of previous observations of mobile sensors, a recurrent network can improve the accuracy and robustness of a collision prediction algorithm, especially in complex and unstructured environments.

From the spring of 2018, I became the coordinator of the Systems for Process Control research center within the Research - Development Institute of the Transilvania University in Brașov. In this context, I coordinate (and I work with) a team made up of 23 teaching staff and 31 full-time PhD students, who are currently developing research in various thematic areas associated with the fields of Systems Engineering, Electronic Engineering, Telecommunications and Information Technologies, Computers and Information Technology, Mechatronics and Robotics.