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Research on materials at *CeFITec* of the new University of Lisbon: Preparation and characterisation of thin films

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1. INTRODUCTION

The *CeFITec* (Research Centre for Physics and Technological Development) is a research centre of the Department of Physics of the Faculty of Science and Technology of the New University of Lisbon, financed by the FCT (Foundation for the Science and Technology) of the Portuguese Ministery of Science and Higher Education.

The main target of *CeFITec* is to perform R&D activities in Physics and Technology, Surface Science and Technology, Gas Phase Chemical-Physics, Thin Films, Applied Plasma Physics, Vacuum Technology, Biophysics and Biomedical Engineering.

Four main research lines are considered:

- Surface Science and Engineering
- Photoionisation and Mass Spectrometry
- Biomedical Sciences
- Physical Engineering

Surface science and engineering

- Ion-surface interactions: sputtering, scattering and electron transfer mechanisms
- Adsorption, desorption and reactivity with small molecules
- Self-assembled films for molecular electronics and photonics
- Materials analysis
- Instrument development

Photoionisation and mass spectrometry

- Gas-phase studies on thermal decomposition of aliphatic azides by Ultraviolet Photoelectron Spectroscopy
- Mass Spectrometry of aliphatic azides
- Electron Spectroscopy of some atmospheric atoms and molecules using Syncrotron Radiation

- Multi-photoionisation experiments
- Negative Ion Photoelectron Spectroscopy
- Surface adsorption of different molecules

Biomedical sciences

- Magnetic Resonance Imaging
- Electrocardiography and electromyography
- Ophthalmology

Physics engineering

The group strategy has been centred in fundamental research on cold abnormal glow discharges, on magnetron type cathodes and in the development of equipment and processes related with applications to industry. This strategy will remain open, however an inflection is in progress to increase the activity related to the study of discharges, films and optical processes on fundamental grounds and with the perspective of eventual applications.

The activity is grouped in six lines:

- Abnormal glow discharge spectroscopy with spatial resolution.

Researchers: P.R.GORDO, M.B.FERNANDES, M.P.DOS SANTOS and M.J.P.MANEIRA.

- Reactive and non-reactive magnetron discharges in magnetron hollow cathode. Selective and hard coatings.

Researchers: A.WEMANS, A.EVARISTO, P.TEIXEIRA and M.J.P.MANEIRA.

- Abnormal glow magnetron discharges in planar magnetron cathodes.

Researchers: M.L.ESCRIVÃO, P.J.S.PEREIRA, M.H.CABRAL and M.J.P.MANEIRA.

- Binary and ternary alloy thin films with Aluminum. Cathode magnetron sputtering co-deposition.

Researchers: Y.NUNES, M.P.DOS SANTOS, M.J.P.MANEIRA, M.JOÃO CARMESIM and A.SIMÕES.

- Spectroscopic analysis of corona discharges.

Researcher: I.FRANCO.

- A new light-guide pumping scheme for improving the performances of a CW solid-state laser.

Researchers: P.BERNARDES and D.LIANG

2. RECENT RESULTS IN THE PHYSICAL ENGINEERING GROUP (#)

Emission spectroscopy with spacial resolution on abnormal glow discharges assisted by magnetron.

The production of metal thin films, alloys and “Cermets” by magnetron sputtering needs a good control of the plasma parameters, in order to obtain pre-determined stoichyometries and properties. Among the plasma diagnosis methods, optical emission spectroscopy is

particularly interesting for its easiness and possibility of real-time process control. The relative abundance of excited species in different plasma zones is proportional to the concentration of the atomic species relevant for the obtained film composition. As magnetron discharges are not spatially homogeneous, this is an interesting case to determine the space distribution of the relative abundances for the present species. In this work we apply to planar magnetron discharges an Optical Emission Spectroscopy with Spatial Resolution (EOERS) method to obtain a two dimensional spatial distribution of the discharge radiation.

Our aim is the determination of two-dimensional luminous glow map for different magnetic confinements, and correlate all the spectroscopic information with the macroscopic electrical characteristics of the discharges and the properties of the obtained thin films. We prepared a System for the Study of Abnormal Glow Discharges (SEDLA), which is already working, and some preliminary optical spectra, for a discharge of argon on copper were obtained.

Current-pressure-voltage characteristics in a planar magnetron discharge

The experimental study of the variation of the current, I, with the pressure, p, (3.3 *Pa* ≤ p ≤ 66.7 *Pa*) in a planar magnetron discharge Ar-Cu, with constant cathodic voltage, V ≤ 450 *V*, showed that the I-p-V characteristics present a maxwellian variation for V ≤ 360 *V*, the maximum current occurring for p ≈ 12 *Pa*. For intermediate values of voltage, the I-p-V characteristic has a maximum for p ≈ 12 *Pa,* and a minimum for p ≈ 25 *Pa.* After this minimum, the current changes linearly with pressure. For higher values of the cathodic voltage the current has a monotonous groth with pressure.

We present a two terms empirical model and discuss it comparing with a theoretical model from literature for the interpretation of I-p-V characteristics on diode and magnetron discharges. This analysis suggests that the first term of this model represents the electronic current resulting from the ionization inside the cathodic sheath and the second terms is related to the current from ions and secondary electrons near the target.

This discussion, together with some other results, suggest that, for lower pressures (p < 33 *Pa*), the cathodic sheath is relatively large, and argon ionization occurs in its interior by electronic scattering. Above this pressure, ionization seems to occur outside the cathode dark space.

Based on these experimental results and on the above theoretical model, we estimate the thickness, d, of the cathode dark space, for values of the pressure and current, respectively, p ≥ 33 *Pa* and V ≥ 370 *V.*

The calculated values of d, compared to the mean free path values for the argon ions, show that most of the argon ions that reach the target had collisions inside the cathodic sheath, and then hit the target with energies lower than the corresponding potential difference of the sheath.

Reactive discharges in a hollow magnetron cathode.

An experimental study of the dependence of current intensity with pressure, at different constant voltages, V_a ≤ 450 *V*, in the pressure range between 3.3 and 66.7 *Pa* is made for an argon-copper planar magnetron discharge. At V_a ≤ 360 *V*, the current increases with pressure,

till approximately 12 *Pa,* where a maximum is observed and then decreases leading the discharge almost to extinction. At intermediate voltages the relative current maximum, at approximately the same pressure, is followed by a local minimum after which a linear increase is observed. At higher voltages the structure of maxima and minima tends to fade out.

An empirical relation with two terms is proposed for the current intensity dependence on pressure and voltage. The first term suggests an electron scattering effect. The second term is linearly dependent on pressure.

The empirical model is discussed and compared with a theoretical model from literature. From this analysis the first term is interpreted as the contribution of electrons generated inside the cathode dark space, while the second term represents the contributions to the current of ions striking the target and of secondary electrons. Results indicate the occurrence of significant ionization in the cathode dark space for the pressure range from 3 to 30 *Pa*. For higher pressure values and $V_a > 360$ *V* the cathode sheath is relatively thin and most ionization takes place outside it. Using both models, theoretical calculations and experimental parameters, the thickness of the dark space as a function of pressure, at several discharge voltages, is obtained.

Influence of the magnetic field in abnormal glow discharges.

The objective of this work is to study the influence of the geometry and of the magnetic field in the current-voltage characteristics on abnormal glow discharges produced on planar magnetron cathodes with a copper target. We explored experimentally the effects of the variation of the magnetic field from the almost absence of it up to situations with a strong magnetic configuration.

The obtained results show that, in the "weak" magnetic configuration, Thornton law is not valid, because we do not get a straight line in a logarithmic scale. In an "intermediate" magnetic configuration, Thornton law seems to be valid in some different parts, which implies that processes of charge multiplication are effective, and we also obtain a significant discontinuity in current at about 320 *V*. For the "strong" magnetic field configurations, Thornton law is observed in a single form in almost all the range of measures we covered. The modeling of these phenomena can lead to a more complete understanding of this kind of discharges.

(#) These results were presented at « FÍSICA 2002 - 13th Conference of the Portuguese Physical Society », Évora-Portugal, September 2002.

REFERENCES

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2. M.L. Escrivão, P.J.S. Pereira, M. RIBAU Teixeira, J.L. Ferreira, M.J.P. Maneira, "The discharge gas density near a planar magnetron" (in print).