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SOME EXPERIMENTS REGARDING MAGNETRON SPUTTERING DEPOSITION WITH SMALL CAPACITY DEVICES

IoanMoga[1],Remus Ghincu[2],TraianCostea[3],Dan Ţarcă[4]and Moldovan Octavian Alin[5]
[1]University of Oradea,Faculty of Management and Technological Engineering,imoga@uoradea.ro
[2]University of Oradea,Faculty of Management and Technological Engineering,remusghincu@yahoo.com
[3]University of Oradea,Faculty of Management and Technological Engineering,tcostea@uoradea.ro
[4] University of Oradea,Faculty of Management and Technological Engineering,bh90tdi@gmail.com
[5] University of Oradea,Faculty of Management and Technological Engineering,moldovan.o.alin@gmail.com

ABSTRACT: In this paper the authors describe the testing of electric devices and magnetic components which should be used to set up a magnetron sputtering system. The results of tests are presented in the form of micro and nanoscopic analysis made with optical and atomic force microscopy. The experimental installation was realized at the University of Oradea, Faculty of Management and Technological Engineering in the SMARTMAT Laboratory.
KEYWORDS: magnetron sputtering, electronic device testing, atomic force microscopy

1. INTRODUCTION

Depending on the modality to obtain particle vapor depositions there are two categories of methods: Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD). In comparison with CVD, PVD procedures allow obtaining coatings at a smaller temperature and with a larger microstructural and compositional variety. In addition the PVD methods are environmental friendly. The PVD procedures can be classified in: Thermal Evaporation, Reactive ion Plating and Cathode Sputtering. Our study is focusing on a type of cathode sputtering called magnetron sputtering.

Sputtering is the physical phenomenon of breaking atoms from the surface of a solid material as a result of its bombardment with energetic particles. The particles used can be: neutral atoms, high energy electrons, neutrons or ions. Usually inert gas ions mostly argon, are employed, the source of ions being the plasma discharge. The acceleration of the positive ions from the target to the substrate is made by a potential. Detailed description of the sputtering process can be found in [1], [2], [3].

The simplest method of sputtering is the one using DC voltage although it is applied in rather useful researches [4], [5], [6]. Other methods apply impulses like in [7] or radio frequency voltages like in [8].In what regards the DC voltage method in order to increase the effectiveness of the deposition, the sputtering is assisted by a magnetic field.

In preparation of reconditioningof a high capacity magnetron sputtering equipment we tested the magnetic components of the magnetrons and the DC circuit which will be part of the sputtering equipment. In this article we present the considerations and results of these tests.

At the University of Oradea researches regarding magnetron technology have a long tradition and complex researches where undertaken [9],[10],[11],[12],[13],[14],[15].

2. EXPERIMENTAL SYSTEM DESCRIPTION.

The experimental device consists of a glass bell to which the anode and the vacuum outlet are attached. The bell is placed on a copper plate 5 mm thick with a Viton gasket between the plate and the bell, which insulates the vacuum from the atmosphere. Also attached to the upper part of the bell is the support for the glass substrate.

These kind of small sputtering configurations are presented in various forms on the internet and we found it suitable for our experiments as our goal was to test the magnetic components and the DC voltage source.Figure 1 and 2 shows the constructed experimental device.

Figure 1. Sputtering with the experimental device.

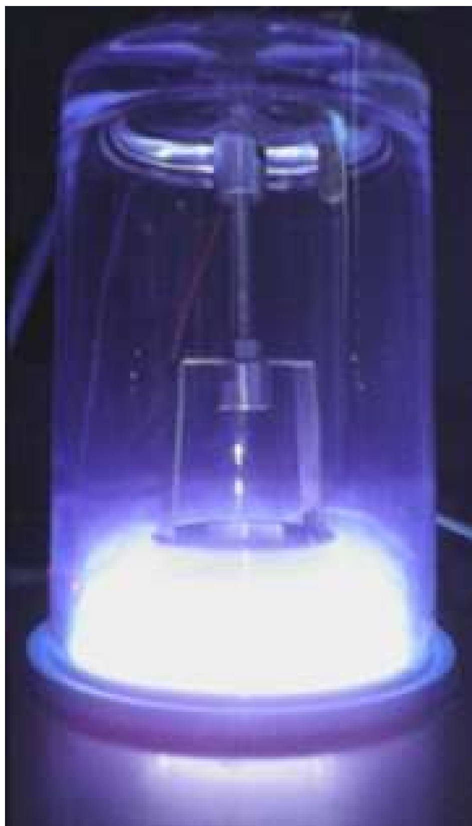

Figure 2. Sputtering with the experimental device.

3. MAGNETICCOMPONENTS

In order to replace some of the magnets of the US Gun II^{TM}magnetrons which have been deteriorated by the cooling water, we measured the magnetic induction for a magnet which is in good condition and two more magnet types: a microwave oven magnetron magnet and a neodymium magnet assembly of the same dimensions and shape as the US Gun II^{TM}. For the measurements we used a Phywe digital Teslameter. The results of the measurements are shown in figure 3. From the diagram in figure 3, it can be seen that the neodymium magnet assembly have the best characteristics (the strongest magnetic flux density) and can be used to replace the US Gun II^{TM}deteriorated magnets.

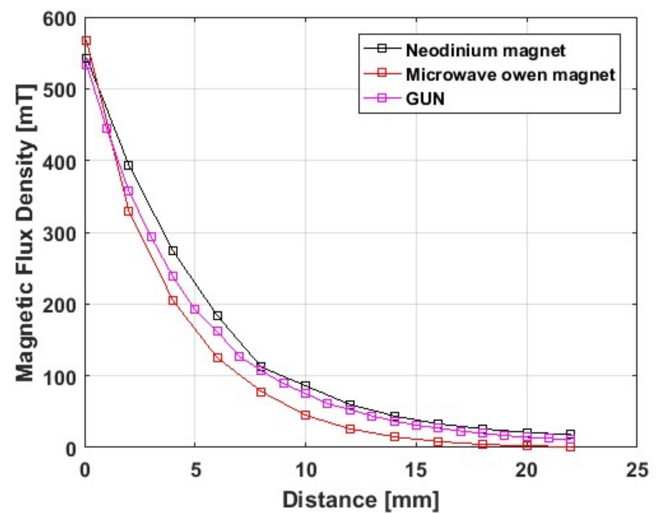

Figure 3. Magnetic induction (magnetic flux density) as a function of distance, for 3 types of magnetic components.

4. ELECTRICCIRCUITS

In order to test the efficiency of the DC voltage sources and particularly the effect of the voltage and current control loop on the obtained deposition, we tested the sputtering of Cu of 99.99% purity on glass substrate with two kinds of DC sources (figure 4 and figure 5).

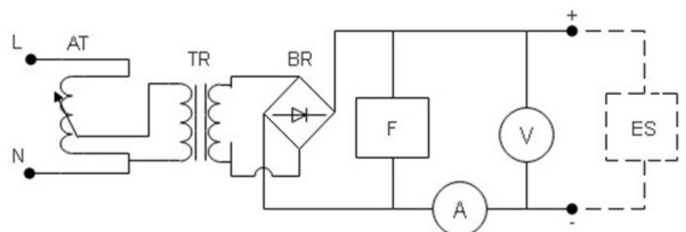

Figure 4. Electric circuit without control loop (ECWCL).

The notations, in figure 4 are as follows: AT-autotransformer 3KVA; TR – step-up transformer 1:10 2kVA; BR - full wave rectifier; F – filtering circuit; V – voltmeter; A –ammeter; ES – sputtering equipment. The high voltage necessary for the plasma generation is obtained from the voltage of the mono-phase grid, which is applied to the AT autotransformer primary circuit; AT isnecessary toadjust the circuit output voltage. The output of the AT unit is applied to the TR primary circuit, whose secondary winding produces a high AC voltage which is rectified and filtered by the BR and F components. The obtained high DC voltage is then applied to the anode of the sputtering device. The voltmeter and ammeter are used to measure the voltage and the current in the sputtering device.This circuit does not have a built in control loop.

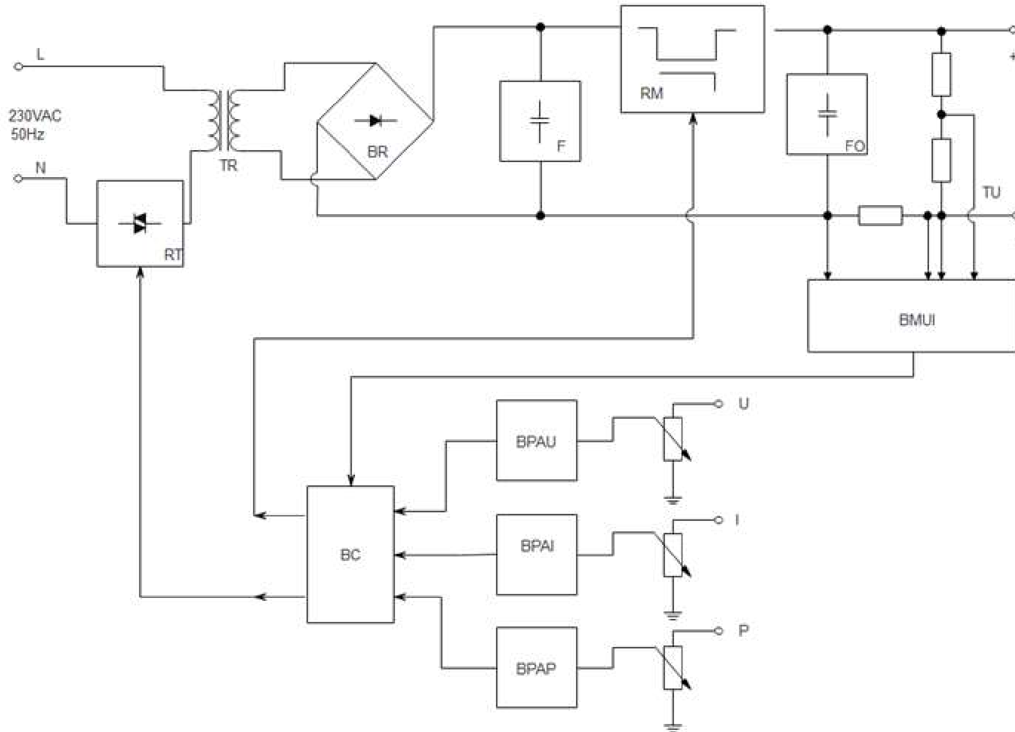

Figure 5. Electric circuit with control loop (ECCL).

The notations, in figure 5 are as follows: RT – TRIAC controller; TR - step-up transformer; BR - full wave rectifier; F – preliminary filtering circuit; FO – final filtering circuit; TI - current transducer; TU - voltage transducer; RM - MOSFET control circuit; BMUI –voltage and current measurement block; BPAU - voltage programming and display block; BPAI - current programming and display block; BPAP - power programming and display block; BC - control block.

The voltage regulated with the RT controller is applied to the primary of the TR. The secondary voltage of TR is rectified by BR, filtered by F and finally is applied to the load by the means of a MOSFET control block, RM, and a final filtering circuit FO.

The load's (sputtering equipment) voltage and current are measured by the transducers TU and TI, and the measured signals are passed to the BMUI block. Voltage, current and power applied to the load are set by the user and are displayed by the blocks BPAU, BPAI, BPAP and are also transmitted to the control block BC.

In the same time the BC block receives the signals generated by the BMUI block. The BC block by means of three negative feedback loops, generates the control signals for the MOSFET circuit RM, and for the TRIAC control circuit RT. In this way the voltage, current and power with values preset by the user are generated and applied to the load.

5. MICRO AND NANOSTRUCTURE OF THE DEPOSITIONS

Using the experimental sputtering device presented in paragraph 1, we made tests with both DC voltage supply circuits, with and without control loop. The substrate was placed 15 mm from the target, and the current was set to 400 mA.

The sputtering process in both cases lasted about 60 seconds.

A typical topography of the surface of the deposition using ECWCL circuit is presented in figure 5 and a typical deposition using ECCL is presented in figure 6 (the left bottom corner was

scratched on purpose for the CSAFM testing). Figure 7 shows the 9x9 µm area scan with the Agilent 5500 AFM, and figure 8 shows a 1x1 µm area.

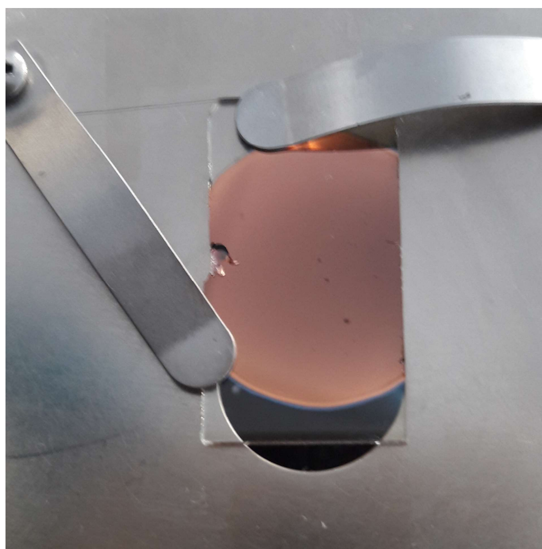

Figure 6. Surface of the deposition

We also analyzed the surface with the Current Sensing Atomic Force Microscopy (CSAFM) mode to visualize the conductivity of the surface (figure 9). In this case a part of the copper was removed by scratching in order to contrast the conductivity of the glass (left) with the conductivity of the copper (right). The middle zone of uniform conductivity is the zone of the scratching.

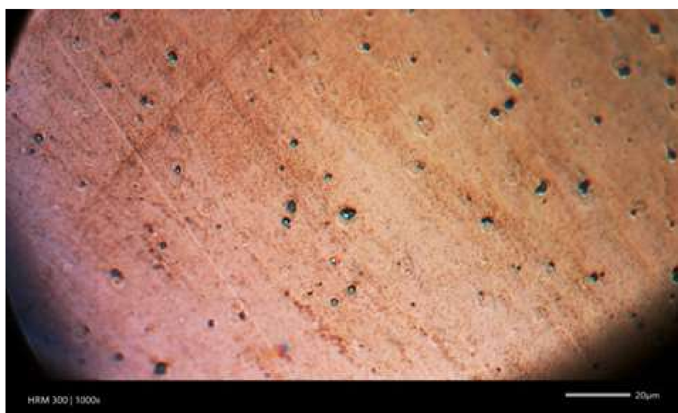

Figure 7. Deposition with ECWCL, optical microscopy, 1000x.

Figure 8. Deposition with ECCL, optical microscopy, 1000x.

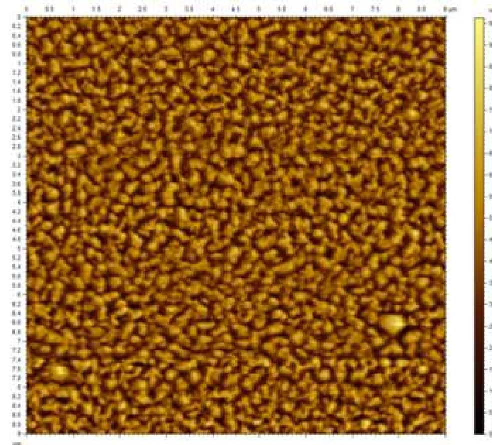

Figure 9. Deposition with ECCL, AFM, 9x9µm.

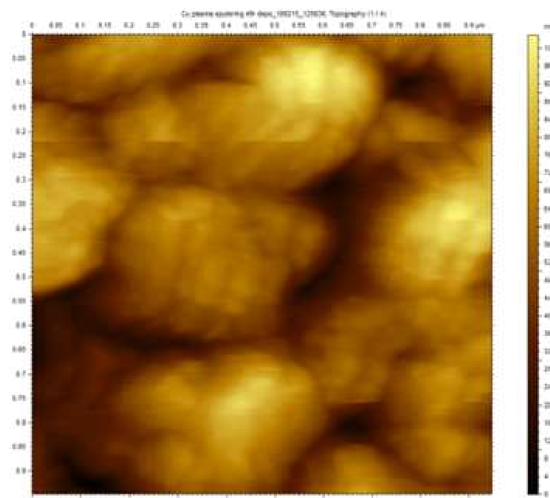

Figure 10. Deposition with ECCL, AFM, 1x1 µm.

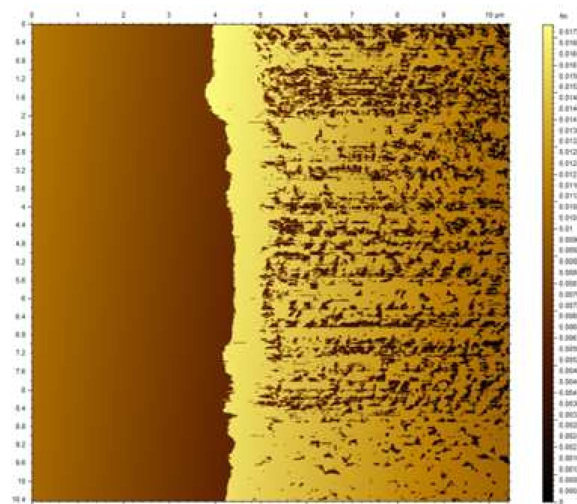

Figure 11. Deposition with ECCL, CSAFM, 9x9 µm.

6. CONCLUSIONS

Examining the results of the experiments we can assess that we can replace the damaged magnets of the magnetrons with neodymium magnets of the same shape and size. Another option would be to use samarium – cobalt magnets which are weaker but have a much higher resistance to corrosion and heat. This option will be tested in the near future.

Regarding the DC voltage supply circuits, results of the tests show that the circuit with control loop is performing much better than the one without control loop. The first observation is that in both cases the deposited layer of copper has a very good adherence to the surface of the substrate. The differencesbetween the two cases can be seen comparing the surfaces of the deposited layer of copper shown in figures 5 and 6. The deposition obtained with the ECWCL circuit has numerous large protuberances which are absent on the surface obtained with the ECCL circuit. We assume that these protuberances are the result of uncontrolled electric discharges, as the process in this case lack the control loop capability.

Examining the AFM images of the results in the case we used the ECCL circuit, we can observe that the surface of the deposited layer has a granular structure with the medium size of the granules of about 400 nm. The magnitude of the granularity will be controlled in future experiments by controlling the temperature of the substrate and the parameters of the process gas. As a conclusion we can assume that the ECCL circuit is working well and will be used in the assembly of the high capacity magnetron sputtering equipment.

7. ACKNOWLEDGEMENTS

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