Microwires-based Metal-Insulator-Metal (MIM) structures produced by hollow cathode magnetron sputtering

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Metal-Insulator-Metal (MIM) devices represent a hot topic for many applications such as mixers, capacitors, detectors, rectifiers and energy conversion devices [1,2]. Also, micro-electro-mechanical systems (MEMS) and microelectronics use MIM devices like integrated sensors, actuators and control circuits in various areas, such as the automotive and microelectronics industries, as well as space exploration, biomedical research and healthcare [3]. One way to obtain the metal-insulator-metal structure on the wires and fibres is to use plasma sputtering technique. However, for thin wires, the deposition temperatures are quite high, leading to degradation and even breaking of the wires during deposition due to thermal damage. Hence, deposition of the metal-insulator-metal structure on thin wires and fibbers at low temperatures has become increasingly important. Hollow cathode magnetron (HCM) sputtering technique is promising under circumstances where low temperature deposition and uniform coatings are needed. The geometry of HCM systems allows decreasing the cathode potential needed to sustain the discharge and lowers the plasma temperature. With HCM system, one can gain independent control over the discharge voltage and current. Also, the system allows the work at very low pressure operation ($< 0.1x10^{-3}$ mbar) but with high discharge currents and dense plasma.

In this work, we introduced a novel and versatile route for the preparation of MIM on micowires, based on the HCM sputtering technique. Because of their enclosed geometry, the hollow cathodes have been used widely since their development to coat wires and fibres [4]. Therefore, we have built a new installation composed of two hollow cathodes, placed in a cylindrical stainless steel vacuum chamber, 100 mm in diameter and 700 mm in length. A diffusion pump of 1500 l/sec backed by a mechanical pump evacuated the chamber into a base pressure of less than 10^{-6} mbar. On the outside of the cathodes, there are placed rare-earth permanent magnets producing parallel magnetic fields of about 0.04 T at the surface of targets. Due to the $\boldsymbol{E}$ x $\boldsymbol{B}$ drift, the electron path forms a circle whose radial dimensions depend on the radial uniformity of the magnetic field and on the discharge current. The water cooled cathode units can accept interchangeable cylindrical hollow targets of Cu, Ag, Al2O3, SiO2, etc., 140 mm long and with the external diameter of 40 mm. For the metallic targets we used a DC power supply which can output up to 400 mA at 3 kV. The power supply was operated in a constant voltage mode.

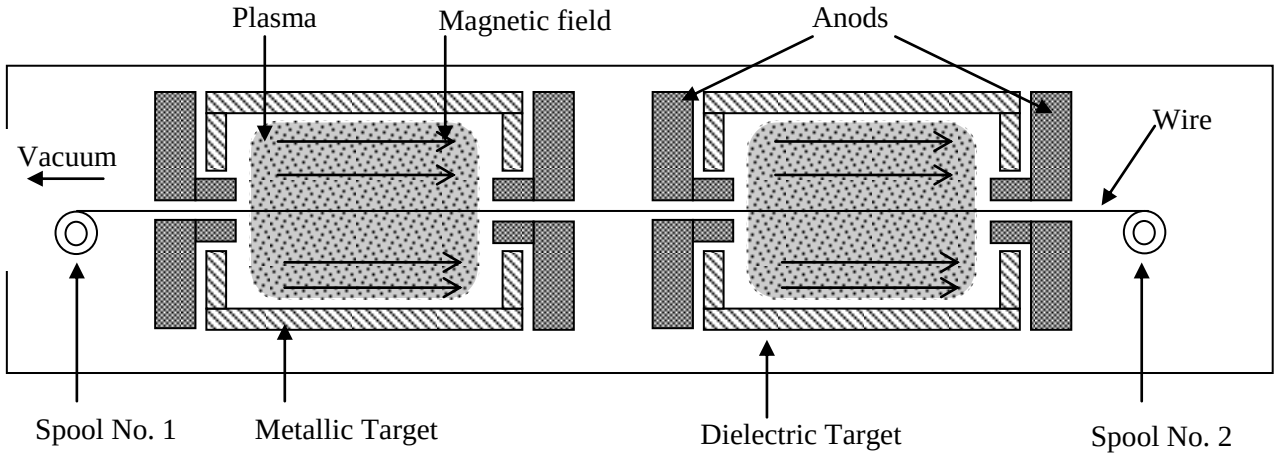

Figure 1. Basic setup of installation (geometrical dimensions are not to scale)

Through adjustment of the output voltage, the discharge current was regulated. The cathode for dielectric targets is connected to a 500 W RF (13.56 MHz) generator via an impedance matching network. The pressure was maintained in the range of (0.3 - 3) x10^{-3} mbar. For most of the experiments, a gate valve between the vacuum chamber and the diffusion pump was not fully open. Through adjustment of the opening of the gate valve, the steady state pressure was regulated. Ar gas with high purity grade was introduced into the chamber from the opposite end of the vacuum chamber as the diffusion pump. Precision needle valve was used to control the flow. The steady state pressure was reached when the pumping rate was balanced by the gas feed rate.

In figure 1 is shown a schematic representation of the newly developed set-up. The microwires are transported with constant velocity along the axis of cathodes, first passing through the metal target, then through the target ceramic, being wound on the spool No. 2, obtaining the metal / insulator deposition. In the next step, the microwire is returned on the same way, being wound on the spool No. 1, but in this case only the metallic target is pulverized, obtaining the structure metal / insulator / metal. The working parameters of the hollow cathodes, the current-voltage (I-V) curves for fixed discharge pressure and voltage–pressure (V-P) curves for fixed cathode current are measured.

Voltage as a function of pressure (V– p) for two metal targets Cu and Ag at fixed total cathode current of 150 mA are presented in figure 2. For HCM system, working regime was found to be suitable at substantially lower pressures. In particular, for Ar discharge with Cu cathode, a 0.3 x10^{-3} mbar stable operation was possible at a cathode current of up to 150 mA. This pressure value can be compared with the usual planar magnetron lowest pressure of about 1–2 x10^{-3} mbar. Operation at lower gas pressures is desirable for thin film deposition due to less scattering of sputtered particles and less collisions for energetic particles. Therefore, the deposition particle and energy flux can be increased. Gas incorporation into the film can also be reduced, and the thin film quality can be modified. For a target, the deposit rate depends on the gas species, working pressure magnetic field strength and power applied. In order to obtain the structure metal / insulator with thickness desired, all this operating parameters should be correlated.

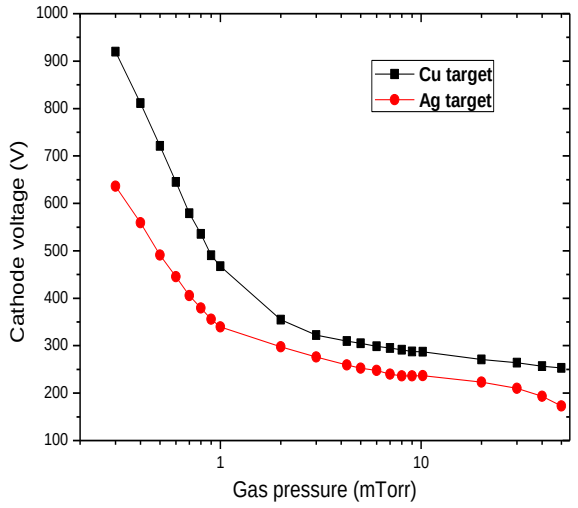

Figure 2. *V– p* characteristics for Cu and Ag targets.

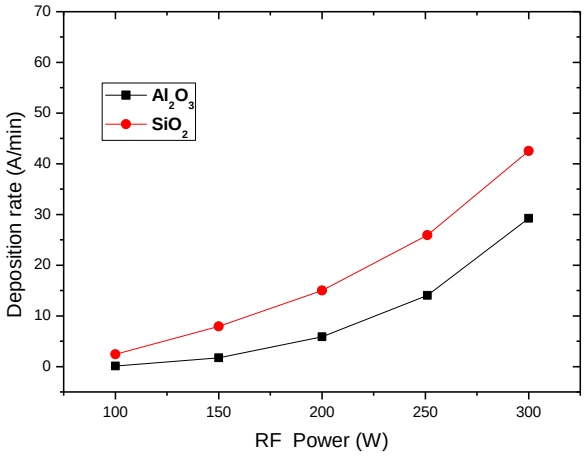

Figure 3. Dependence of Al_2O_3 and SiO_2 deposition rates on RF power, for 2x10^{-3} mbar pressure.

The deposition rate as a function of the RF power for Al_2O_3 and SiO_2 depositions can be seen in figure 3. At high powers, the rate reached 43 Å /min for SiO_2 and 30 Å/min for Al_2O_3 film deposition, respectively. Both these values exceeded substantially the growth rates reported in the literature.

Acknowledgements

Work supported by the Romanian NUCLEU Programme, project No. PN 09-43 01 02.

References

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