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Transitional Phenomena in Magnetron Discharge

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Magnetron sputtering is widely used as for deposition of thin films in micro- and nanoelectronics as for creating rather thick protective and hardening coatings.

In our previous works we produced thin film Cu mirrors for plasma diagnostics in nuclear fusion devices. During the magnetron sputtering of Cu the originating and subsequent breaking of conelike formations on the cathode surface were observed [1-3]. This phenomenon causes defects in the deposited films in the form of micro drops with size about 20…60 *mcm*. In this case an integral reflectance of the mirror and its stability under deuterium ion sputtering are significantly decreased.

The aim of this paper is to clarify the influence of physical processes which take place on the cathode surface and in the working gas during the transitional period of magnetron sputtering on the current-voltage (*I-V*) characteristics of the discharge.

Details of the experimental setup were described elsewhere [4]. It represents standard planar magnetron sputter with Cu target of 190 *mm* diameter.

The forming of conelike microasperities on the cathode surface may significantly change its emissive characteristics. In this connection we have studied time evolution of *I-V* characteristics of the discharge for two pressures $3{\cdot}10^{-3}$ and $6{\cdot}10^{-3}$ *Torr* and also for targets with different microtopography and different erosions.

We observed classic shift of *I-V* characteristics towards lower values of discharge voltage with changing the Ar pressure to the higher one (Fig.1a), and also with deepening the erosion profile (Fig. 1b).

Discharge characteristics may be similarly influenced when the conelike microasperities

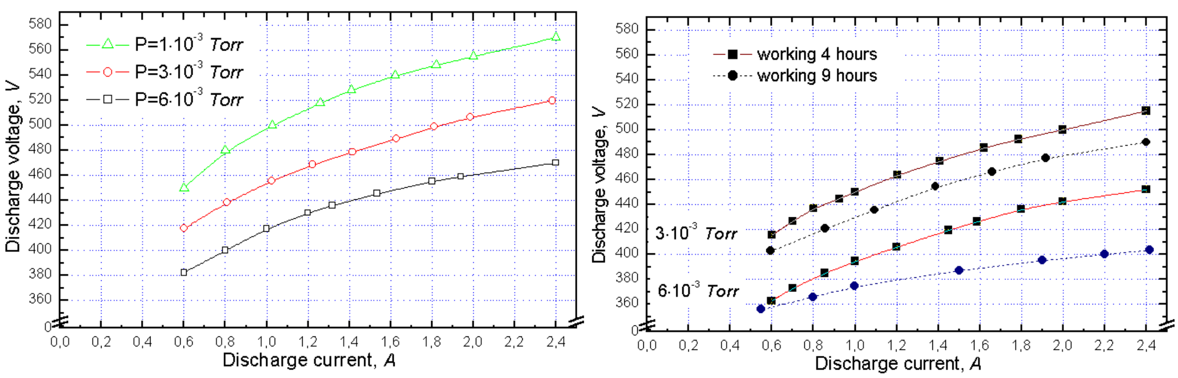

Fig. 1. Dependence of current-voltage characteristics on Ar pressure (a) and erosion depth (b).

appear and further grow on the cathode surface. We obtained such microasperities in [2] with very similar magnetron parameters. The main reason for shifting the discharge characteristics we believe the emission characteristics of the cathode should be considerably changed in that case.

After sputtering of the cathode in magnetron discharge within 1 hour it was found a great number of conelike formations on its surface. The height of cones were 10-300 *mcm* and base diameter 10-200 *mcm.* They occupied the area of about 50% from the whole area of the erosion zone. The number of asperities not depended on discharge pressure.

Two series of experiments for $3\cdot10^{-3}$ и $6\cdot10^{-3}$ *Torr* were carried out to justify our assumption about the possible influence of cathode microtopography on discharge characteristics. Features of cathode microrelief were removed by mechanical polishing in every series of experiments.

In the first series cathode was sputtered within 1 h under conditions P_{Ar}=$3\cdot10^{-3}$ *Torr*, I_{DC}=1,4 *A*, U_{DC}=480 *V*. This time allow the copper surface to go to the dynamical balance when overall state of cathode microrelief remains constant. Than current-voltage characteristic was measured (curve 1 in Fig.2a). After that microasperities which appeared on the cathode during this cycle were mechanically removed and *I-V* characteristic was measured every 3 minutes after discharge initiation (curves 2-4 in Fig. 2a).

In the second series microrelief features were removed again. Than the cathode was sputtered within 1 h. under conditions P_{Ar}=$6\cdot10^{-3}$ *Torr*, I_{DC}=1,4 *A*, U_{DC}=420 *B* and further the *I-V* characteristic were measured (curve 1 in Fig. 2b). After subsequent polishing *I-V* characteristic for P_{Ar}=$6\cdot10^{-3}$ *Torr* were measured (curves 2-4 in Fig. 2b) similar to our previous series for lower Ar pressure.

Simultaneously with studies of discharge characteristics the operational mass spectrometry of gas composition in the discharge chamber was carried out.

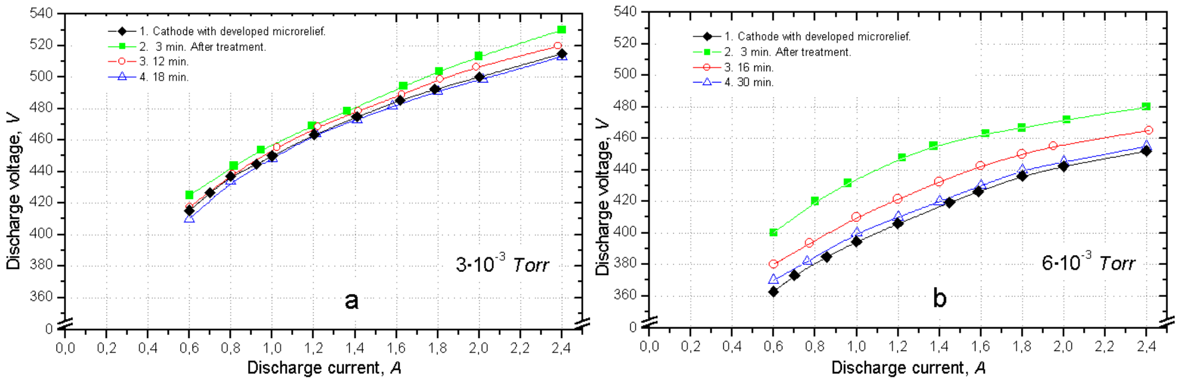

Fig. 2. Dependence of current-voltage characteristics on the cathode microrelief.

Time-domain measurements of ion currents intensities of gas components were conducted for targets with initial average height of microrelief asperities <10 *mcm*. Time dependence of ion currents for 28 (N_2^+, CO^+), 14 (N^+), 44 (CO_2^+) и 32 (O_2^+) a.m.u. is presented in Fig. 3-6. The data were measured for Ar pressure $3{\cdot}10^{-3}$ and $6{\cdot}10^{-3}$ *Torr* under constant discharge current I_{DC}=1,4 *A*.

From the experimental result we can make certain conclusions about the influence of cathode surface conditions and gas composition on behavior of transitional processes in magnetron sputtering system from the discharge initiation up to steady-state mode. Under work parameters used in our experiments the time which necessary for magnetron to reach the steady-state mode gives ~20 *min*. for P_{Ar}=$3{\cdot}10^{-3}$*Torr* and increases up to ~30 *min*. when

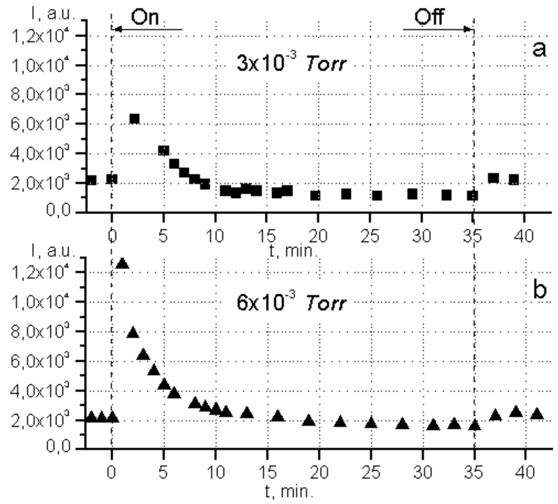

Fig. 3.

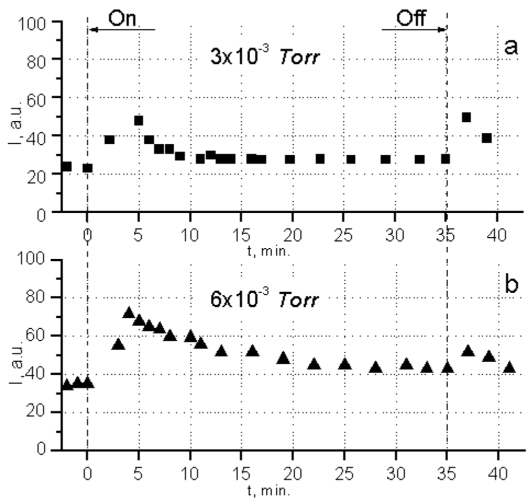

Fig. 4.

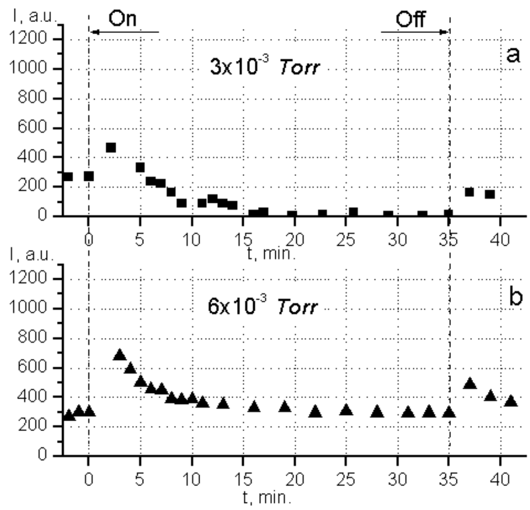

Fig. 5.

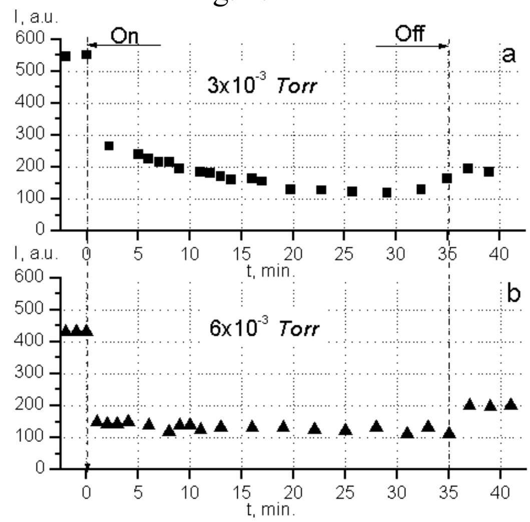

Fig. 6.

Fig. 3 – Fig.6. Consequent dependences of ion intensities of 28 a.m.u. (N_2^+, CO^+), 14 a.m.u. (N^+), 44 a.m.u. (CO_2^+), 32 a.m.u. (O_2^+) on time in magnetron discharge for two Ar pressure $3{\cdot}10^{-3}$ (a) and $6{\cdot}10^{-3}$ *Torr* (b).

raising the Ar pressure up to P_{Ar}=6·10^{-3}*Torr*.

During the interoperational period when magnetron is exposed to the atmosphere and especially during the target mechanical processing cathode emissive characteristics are deteriorated. Owing to this fact discharge voltage are higher within the initial period of magnetron functioning. After the near surface layer with thickness ~1-2 *mcm* was sputtered the voltage on discharge gap becomes some lower. Under conditions of rather low power used for sputtering in the work this phenomenon takes place within first minutes (1-2 *min.*) of unsteady magnetron functioning. Further with target sputtering surface microrelief is developed and as a result secondary electron yield is increased. Hence the current-voltage characteristic is shifted towards lower discharge voltage.

In the commercial "oil" vacuum an essential contribution into the discharge steady state forming give sputtered atoms and also gas contaminants actively liberated from the near surface region of the cathode and other parts of vacuum vessel. These factors have also influence on duration of transitional period of magnetron sputtering systems.

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