MAGNETRON WITH A CONCAVE HEMISPHERICAL CATHODE

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A magnetron set up with a hemispherical concave cathode has been worked out for the first time. The cathode center of curvature was registered with the sputtered surface. An aluminum nitride film was sputtered by this magnetron in the pulse regime. The pulse duration was about 2 ms. The film thickness was between 10 to 12 nm. The sputtering rate was about 50 nm/s. The magnetron characteristics agree with a qualitative model of the magnetron.
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In magnetron sputtering systems (MSS), flat or convex (e.g., cylinder) cathodes are usually used [1–3]. But such cathodes provide rather non-uniform density of sputtered atoms in the plane of a substrate, and the flux value is 10 to 100 times less than that near the cathode surface. If the cathode surface is concave from the side of the covered surface, then the density of the atomic flux directed on it can be considerably increased due to increase of the spatial angle providing observation of the cathode from the points of a covered object. Besides, uniformity of the flux can be considerably increased.

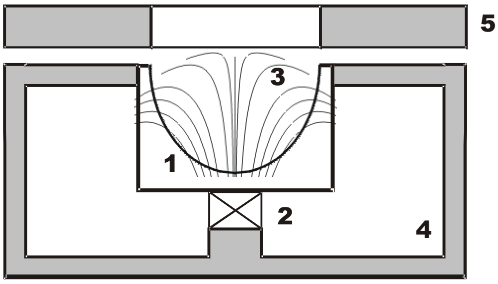

Fig. 1. The scheme of the magnetron with a hemispherical cathode: 1 – cathode, 2 – constant magnet, 3 – system of magnetic field lines,
4 – magnetic core, 5 – anode

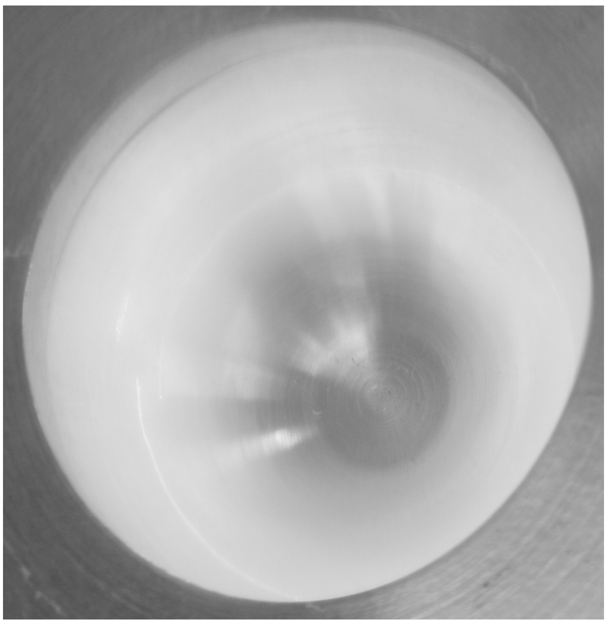

Fig. 2. Photo of the magnetron discharge

We have investigated some characteristics of the magnetron with a hemispherical cathode presented in Fig. 1. When evenly sputtering all the surface of this cathode in accord with the Lambert law [4], the density of flux in the meridional plane is even, and its value is equal to π for the unit "brightness" [5, 6]. The same figure illustrates lines of magnetic field, which are built using the data of measuring its radial component. With this configuration and value of magnetic field, when the pressure reaches 10^{-2} Torr the discharge arises at the voltage 700 V and is quenched at 270…290 V. Fig. 2 shows the discharge view. It can be seen that the discharge ignites almost evenly over the cathode area except the segment of 7-mm diameter near the axis.

When sputtering, the substrate was practically located in the cathode meridional plane. Using the total time of sputtering 0.2 s, we obtained the aluminum nitride films, transmission spectra of which are shown in Fig. 3. The measured spectra have been presented with dots. The transmission spectrum for normal incidence of radiation that was calculated for the case of a dielectric film with weak absorption [6] has been pictured there, too.

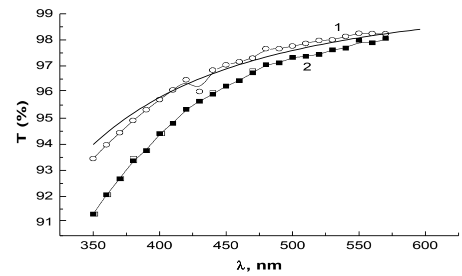

Fig. 3. Transmission coefficients for the AlN film sputtered on a glass substrate: in the center (1) and near the cathode edge (2).
The solid line is an approximation of the curve 1

Choosing the refraction index and absorption coefficient, we reached a satisfactory coincidence between the experimental and calculated spectra for the film geometric thickness 10 nm. It corresponds to the estimated sputtering rate 50 nm/s. This value is more than one order higher than that in magnetrons with flat cathodes. A narrow dispersion of thicknesses testifies a satisfactory uniformity of the film growth over the covered area.

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Beside continuous discharge, there is a small glowing spot in its center. The glowing region is located inside the cathode cup at the distance of 6 mm from the meridional plane along the axis. Its diameter is no longer than 3 to 5 mm. It is fully probable that this cloud is related with plasma radiation in caustics that arise due to presence of a "mirror" component in angular distribution of sputtered atoms [7,8]. To obtain a caustic in optics presents no difficulties even for a small value of the mirror component. The density of atoms in caustics can be estimated by the following way. Let the characteristic dimension of the cathode be L, and the caustic looks like a filament with the diameter d_1 and a dot with the size d_2. Then, in the filament and dot caustics the density of atoms will be L/d_1 and $(L/d_2)^2$ times higher than that at the cathode surface. Beside caustics, the origin of this spot can be related with intersection of electron trajectories near the cathode center. But respective estimations give values considerably smaller than the cathode radius.

As a result of these preliminary experiments, we ascertained that magnetrons with concave cathodes can be used to obtain even thickness over the area of sputtered films in the reactive method.

Thus, using the magnetron with a concave hemispherical cathode one can obtain a high rate of sputtering the films of aluminum nitride, which more than one order exceeds that in magnetrons with flat cathodes. These sputtered films are even in their thickness over all the covered surface. The obtained data give a basis to construct an experimental model of the magnetron with a concave hemispherical cathode to prepare films for optical and semiconductor facilities. These results can be used to efficiently sputter the film coatings in various technologies. Perhaps, using these magnetrons one will be able to obtain plasma clouds of a high density.

Further experiments will give an answer to the question of advantages and lacks in the offered construction of the magnetron with the hemispherical cathode.

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МАГНЕТРОН С ВОГНУТЫМ ПОЛУСФЕРИЧЕСКИМ КАТОДОМ

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Впервые создана модель магнетрона с полусферическим катодом, вогнутым в сторону напыляемой поверхности. В импульсном режиме напылена плёнка нитрида алюминия, толщина которой в центре запыленной площадки равна 10 нм, а вблизи края катода – 12 нм. Скорость напыления – 50 нм/с. Характеристики магнетрона качественно соответствуют модельным расчётам.

МАГНЕТРОН З УВІГНУТИМ НАПІВСФЕРИЧНИМ КАТОДОМ

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Вперше створено модель магнетрону з напівсферичним катодом, що увігнутий у бік поверхні, на яку проводиться напорошення. В імпульсному режимі напорошена плівка нітриду алюминию, товщина якої в центрі запорошеної області дорівнює 10 нм, а поблизу края катоду – 12 нм. Швидкість запорошення – 50 нм/с. Характеристики магнетрону якісно відповідають модельним розрахункам.