CHARACTERIZATION OF MAGNETRON PLASMA USING OPTICAL SPECTROSCOPY AND COLLISIONAL-RADIATIVE MODEL OF NITROGEN *

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Collision-radiative models (CRM) are widely used to determine the parameters of low-temperature plasma using optical spectroscopy [1]. Most of these models are global, i.e. describe the kinetics of spatially averaged quantities. In the case of discharges in nitrogen and nitrogen-containing gas mixtures, these models can be both relatively simple [2] and very complex, including hundreds of different reactions [3], depending on pressure, ionization degree and other conditions.

The magnetron discharge is characterized by low pressure and a relatively high ionization degree. In this case, the processes involving electron impact play the major role and some of the other processes may be neglected thus simplifying the model. On the other hand, the magnetron discharge has a spatial non-uniformity, which may question on the applicability of the global model.

In this work, we propose a method for determining plasma parameters of a magnetron discharge in nitrogen, based on global-local CRM and direct fit of synthetic emission spectrum to the experimental one. The global part of the model describes the kinetics of states with a longer lifetime, which can emerge in regions with a denser and hot plasma, and is transferred to the observation region. The local part of the model describes the states making the main contribution to radiation. The model takes into account the following processes: 1) excitation / quenching of N_2 states by electron impact; 2) excitation / quenching of metastable states by electron impact; 3) dissociation of N_2 due to electron impact; 4) optical transitions between the N_2 states; 5) vibration-vibrational and vibration-translational energy exchange processes for the ground $N_2(X)$ and metastable $N_2(A)$ states; 6) excitation of the N_2 states due to the collision of molecules in the metastable state $N_2(A)$; 7) quenching due to collisions with heavy particles; 8) quenching due to diffusion and collisions with the walls of the vacuum chamber; 9) sputtering of target atoms and compound molecules; 10) chemisorption of atoms and gas molecules on the walls of the chamber and the target of the magnetron; 11) recombination of gas atoms with chemisorbed atoms on the surface covered by the compound.

Using this technique, we investigated the plasma in a laboratory installation for reactive sputter deposition of titanium oxynitrides at several pressures and powers. The rise of the discharge power leads to the increase of rotational temperature determined by contours of the first positive (FPS), second positive (SPS) and first negative (FNS) emission band systems. The temperatures determined by FPS and SPS are noticeably higher than the temperature for FNS. This may be due to the large contribution of collisions of heavy particles to the formation of the corresponding excited states. With increasing pressure, the global and local concentrations decrease, as well as the global electron temperature. A similar dependence of electron temperature and density on pressure was also observed in [4] and may be associated with an increase in diffusion flux across the magnetic field. With increasing power, an increase in electron concentration and a drop in global temperature are observed. A similar result was obtained in [5] and our previous works. Such dependence can be related to the ohmic heating mode [6].

The results are generally consistent with our previous studies of the magnetron discharge in this setup, and with the results of other authors. In addition, we evaluated the degree of dissociation of nitrogen molecules in two ways: theoretical and experimental. These estimates are in good agreement, especially at high discharge power.

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