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Low-Pressure Plane Plasma Discharge Sputtering System

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Ultra-thin semiconductors and metal films have gained high technological importance in recent years. Sputtering is considered to be the preferable way for industrial thin semiconductor systems preparation. The main goal of our work was to develop a sputtering based method suitable for fine electronic and opto-electronic applications. The basic idea behind the developed method was to create a plane of gas discharge placed between the sputtering target and the growing film in order to enable the sputtered atoms to reach the substrate without collisions. Thus, the shape of the created plasma is viewed as a thin wall.

The work was devoted to the modeling and practical implementation of the novel sputtering method. The mean free path of the gas molecules in the vacuum chamber is chosen as the critical parameter that defines the type of the sputtered particle transport and the level of the gas pressure used in the vacuum chamber. The properties and behavior of the plane plasma are considered under the conditions of ballistics (collisionless) and boundary transfer of the sputtered atoms (taking into account the diffusion part as well).

The basic properties of the plane plasma were experimentally studied with the Langmuir probe introduced in plasma. The evaluation of electron temperature and ion concentrations was done using the Bohm approximation for collisionless conditions, which were created in the designed system. The measurements were taken in a gas pressure range from 0.2 mTorr up to 5 mTorr in various points of the vacuum chamber: along the plasma plane and in its vicinity. It was found that the electrons with the maximum temperature of about 7-7.5 eV occur along the plasma plane. Positive argon ion concentration was found to vary in the range from 3.5×10^{11} cm^{-3} to 6×10^{11} cm^{-3} on the plasma axis, depending on the gas pressure.

The substrate in the novel system is completely protected from the plasma and the electron irradiation. The substrate temperature does not exceed 60 °C during 1 hour of operation. Titanium and silicon were tested as sputtering targets. The deposition rates for these materials were 60 A°/min and 100 A°/min, respectively, with the applied power not exceeding 50 W. All of the electrical supplies were isolated from ground, to protect against parasitic discharges in the vacuum chamber.

This novel sputtering method enables one to independently vary the sputtering voltage and the ion current while sputtering. This is of course impossible in a conventional sputtering system such as magnetron sputtering systems. The following table shows the position of the proposed sputtering method in comparison with the other known methods:

Process Type	**Typical Particle Energy**	**Vacuum (Pa)**
Evaporation	< 1 eV	0.001
Triode (tetrode) Sputtering	**500 ... 3000**	**0.05**
Magnetron Sputtering	10 ... 100	0.5
Diode Sputtering	1000	10