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A STUDY OF THE GAS FLOW IN THE LOW PRESSURE PLASMA JET SPUTTERING SYSTEM

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The low pressure plasma jet sputtering system has already become well known as an important tool for the thin film deposition of various materials [1, 2, 3]. It is based on the low pressure hollow cathode discharge which is generated in the nozzle of the plasma jet system [4]. A systematic study of this kind of discharge is our long-term goal. In past we were interested mainly in electrostatic Langmuir probe diagnostic measurements [5]. Here we present results obtained from experimental measurements of the working gas flow inside the system too.

For the experimental study of the gas flow the pulsed excitation mode of the discharge was used. A negatively biased probe was inserted into the reactor chamber at the nozzle axis and the time dependence of the positive ion current to the probe was recorded synchronously with the negative voltage pulses on the cathode. The distance between the nozzle outlet and the probe could be changed since the whole jet is moveable in vertical direction via motion feedthrough. Typical result of such measurement is depicted in the left panel of Fig. 1. From the earlier experiments performed by electrostatic Langmuir probe it was found that the cathode potential is in its nearest vicinity very well shielded and so the electric field inside the reactor is weak. It allowed us to consider the ion current as unaffected by the electric field. The time when the most of the ions generated during pulse-on phase reached the probe was located for each probe to cathode distance and the distance-time relation was constructed – see the right panel of Fig. 1. The duration of the voltage pulse on the cathode and the repetition frequency had to be chosen in such way to attain sufficient time resolution of the maximum of the ion current. Practically it means to decrease the duration of the voltage pulse as much as possible while keeping the discharge stable. We managed to operate the discharge under these parameters: voltage on the cathode $U = 500$ V, repetition frequency $f = 400$ Hz and duration of the voltage pulse $T_p = 25$ µs. The dependences of the ion translation on the time of flight were fitted by a polynomial because parabolic dependence is expected in the case of uniform deceleration caused by collisions between ions and neutral gas. By differentiation we then obtained the ion velocity which we depicted in the dependence on the distance between the probe and the nozzle outlet. The measurements were realized for various pressures and flow rates of the working gas. An example the ion velocity for the flow rate of the working gas $\Phi = 30$ sccm and different pressure as parameter is shown in Fig. 2.

We observed that with increasing flow rate and decreasing pressure in the reactor the gas flow near the nozzle transforms from the subsonic to the supersonic one. This behaviour closely relates with formation of the plasma channel which is of a big importance for the deposition of the thin films. At some conditions the course of the ion current to the probe did not reach one maximum as in the case in Fig. 1 but there appeared two well distinguishable maxima. Such effect could show to several different groups of ions in the plasma which are being created in the nozzle. It will be object of further research. Currently we have constructed a computer model which simulates the flow of the working gas according to the Navier-Stokes equations for various pressures and flow rates at a definite temperature. The results given by this model will be compared with the presented measurements.

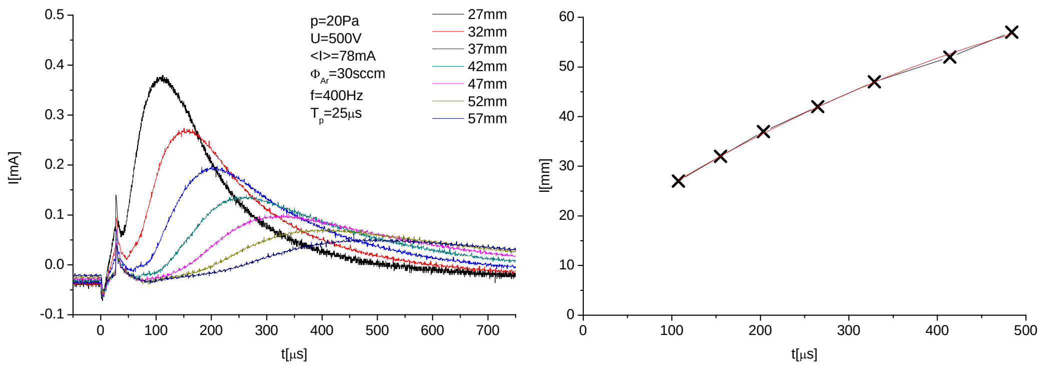

Fig. 1: The typical course of the ion current to the negatively biased probe for different distances between the probe and the nozzle outlet in the left graph and the dependence of the distance traveled by ions on time in the right.

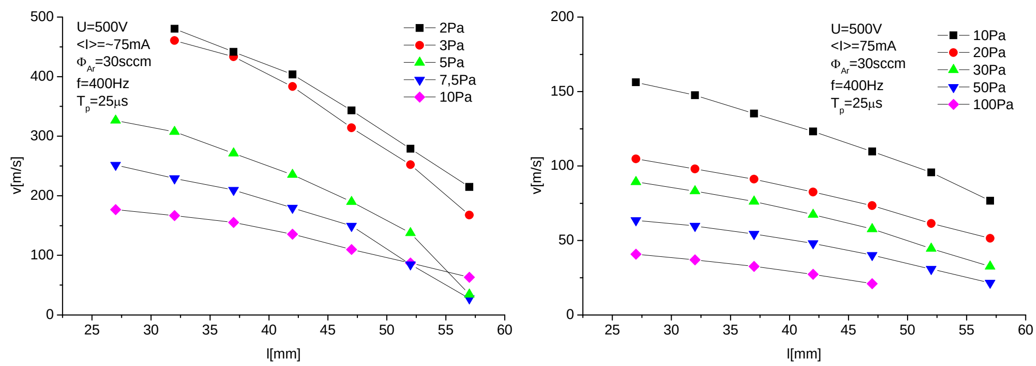

Fig. 2: The decrease of the ion velocities with the increasing distance between the probe and the nozzle outlet. The indicated pressures cover approximately the whole range of working pressures of the used low pressure hollow cathode plasma jet system.

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