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In the reactor that is used in this work the three most important functions (dissociation and ionization, transport and deposition) are spatially separated, and each of them is optimized separately[1]. A cascaded arc plasma in argon is used to dissociate and ionize the injected methane and acetylene molecules. The produced reactive particles are transported efficiently towards the substrate by means of a supersonic expansion into vacuum and a subsonic plasma beam. On the substrate an amorphous carbon film is growing.

The flowing plasma in the cascaded arc is analyzed with diagnostics and models. The electron density and the electron temperature are measured as a function of position in the arc by means of Stark broadening of the hydrogen H_β–line (486.1 nm) and the ratio of continuum– and line emission respectively. Together with the measured axial pressure profiles these measurements have been used to calculate the profiles of the gas temperature from a best fit of the quasi one–dimensional model to the experimental profiles. Then the overpopulation of the neutral argon ground level has been calculated. In the beginning of the arc channel this overpopulation amounts to a factor 40, independent of the gas flow. Energy considerations have shown that a large amount of the dissipated electrical energy (about 60%) is used to heat the originally cold argon gas. The ionization of argon atoms takes the other 40%.

The pressure drop over the arc channel is associated with viscous friction between the arc wall and the plasma. The flow has been analyzed numerically using the conservation laws for mass, momentum and energy. The obtained relation between the friction factor and the Reynolds number has a strong resemblance to the theoretical curve for laminar flow through a perfectly smooth duct.

The dissociation of the injected methane is analyzed using the conservation laws for mass and energy. The calculations indicate that an arc length of 2 cm after injection of the methane is sufficient to establish complete dissociation and ionization. The carbon atoms are ionized mainly by charge transfer from argon ions.

In the supersonic expansion the gas velocity, the gas temperature and the

electron density are measured by means of Doppler shift, Doppler broadening and Stark broadening of the hydrogen β–line respectively. The gas velocity increases from 1700 m/s in the anode nozzle to about 4000 m/s after 50 mm. Meanwhile the temperature drops from 12000 K to less than 2000 K. Therefore the plasma composition is frozen: the ratios of the densities of the several species present in the plasma hardly change. Three particle recombination of argon ions causes the electron temperature to remain higher than the gas temperature. Again the conservation laws for mass, momentum and energy are used to describe the supersonically expanding plasma. The agreement between model and measurements is good.

A shock wave occurs at an axial position of about 50 mm. The kinetic energy of the highly directed motion is now converted partially into thermal energy. The velocity decreases to 2000 m/s, and the temperature increases (to 6000K). After the shock wave has been crossed, a subsonic, but fastly flowing (1000 m/s) plasma beam is created. The argon ions are eliminated by charge transfer to carbon atoms. Then the created carbon ions recombine fast. In this way the carbon ion density remains constant until all argon ions have been eliminated. Then also the carbon ion density decreases. Lowering the background pressure causes this process to slow down.

The growth of the amorphous carbon coatings is studied by means of *in situ* He–Ne ellipsometry. This technique, that uses the changes in polarizing properties of a growing film, provides the growth rate, but also the real and imaginary parts of the refractive index of the deposited material. The implementation that has been used for the experiments described in this thesis has an accuracy that allows the detection of a film thickness of 10 pm. Spectroscopic ellipsometry has been used to analyze the optical properties of the films over a large spectral range. Finally the hardness of the films is estimated by means of scratch tests.

The deposition rates obtained (up to 200 nm/s) exceed the highest values (for amorphous carbon coatings) reported in the literature so far by a factor of 30. One can conclude that the chosen, unconventional approach to plasma deposition, as it is illustrated in this paper, offers a drastic increase of the deposition rate while the quality of the deposited films is at least as good as the ones obtained by more conventional processes.

References

1) G.M.W. Kroesen: Plasma deposition: investigations on a new approach, Ph. D. Thesis, University of Technology, Eindhoven, the Netherlands