PROBE DIAGNOSTICS IN CHEMICALLY ACTIVE PLASMA[1)]

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The influence of various phenomena and processes in chemically active plasma on the probe current was studied by means of computer experiment. There are two models proposed. One of them has served for testing the influence of arising polymer film parameters (the thickness, the resistivity) as well as physical interactions of particles (drift velocity, secondary emission and reflection). The other provides information about the interactions only of positive ions with the polymer film. The influence of both plasma parameters and the arising thin films is discussed.

I. INTRODUCTION

The basic diagnostic method in plasma physics is the probe diagnostics. It is widely used for the characterization of plasma parameters in both dc glow and other types of discharges. The theory of Langmuir probes is built up for plasma under different conditions, e.g. [1].

Recently the preparation of thin films by polymerization of organic vapours in dc, ac or rf glow discharge has received increasing attention. The probe diagnostics can again bring information on plasma parameters. The analysis of probe characteristics is more complicated because of polymer films covering the metal probe surfaces. On the contrary, from the change of probe characteristics due to the polymer films some information on film parameters can also be derived [2]. The study of probe characteristics in chemically active plasma is a difficult problem which can be simplified with the help of computational physics.

II. MONTE CARLO METHOD

At present the Monte Carlo method is widely used for the study of transport processes. About ten years ago it was very time consuming to model the transport of electrons in electrical discharges by dividing their trajectories into a large amount of linear parts.

In the last ten years several improved algorithms (all based on the Monte Carlo method) have been proposed (e.g. [3–6]), which reduce the necessary computer time. Now we can use such computer models to study various problems in plasma physics and suppose more realistic conditions in the models.

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III. PROPOSED MODELS

In our models we are trying to study one probe characteristic both in the inert and the chemically active plasma for probes of an arbitrary form and orientation. Both models are based on the Monte Carlo method with some modifications. The first results were published in [7–8] and can be used now in the modelling of an electron source for the study of probe characteristics.

The current flowing to the probes of an arbitrary form can be obtained by the weighted summation of contributions from elementary plane areas [7]. Therefore, the models of the sheath region can be two-dimensional only (Fig. 1).

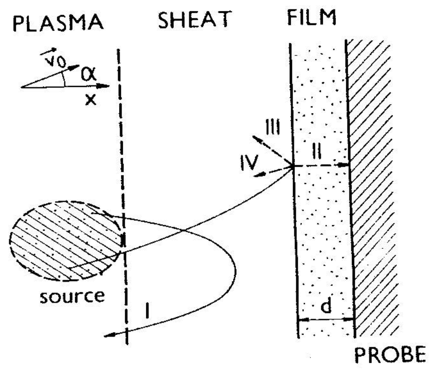

Fig. 1. Model region schematic diagram with illustrated trajectories of particles: PLASMA — undisturbed plasma (source of particles); SHEATH — region of the sheath with electric field which returns a part of particles into the undisturbed plasma (I); FILM, PROBE — metallic probe covered with a thin polymer film. Processes of interaction between the particle and the film are demonstrated

Our models were proposed under the following simplifying assumptions:

- The increase in the number of electrons due to ionization is compensated by the ambipolar diffusion.
- The constant electric field in the plasma region.
- The isotropic scattering of electrons.
- Possible interactions are elastic collision, ionization and excitation, the Coulomb interaction between electrons.
- The collisionless transport of particles through the sheath — i.e., the total gas pressure being less than about 100 Pa.

All potentials used in the models refer to the plasma potential.

III.1. Model A

In the chemically active plasma a thin polymer film can be deposited onto exposed surfaces and, consequently, on the probe surface, too. For the elementary area of the film on the probe we suppose:
— A planar film surface.
— Both the film thickness and resistance are homogeneous.
— The particles on the polymer surface can be reflected (III) or attached and then contribute to the probe current by the sequential pass through the film (II) or can induce the secondary emission (SE) of electrons (IV) — see Fig. 1.

Additionally we simply suppose that the coefficients of SE depend on the primary energy E_p for small values of energy (less than 10 eV) according to

$$\sigma = kE_p + q, \quad (1)$$
$$\gamma = \text{const}, \quad (2)$$

where k, q are constants, σ is the coefficient of the electron–electron SE and γ is the coefficient of the electron–ion SE. The method of the calculation is described in [9] and in the Appendix.

III.2. Model B

In the model we have studied only the interactions of positive ions with the polymer film surface. For the elementary area of the film we suppose the following:
— The planar film surface.
— The ion at the film can be attached or reflected or it can induce SE of electrons. The coefficient of the reflection δ and the coefficient of SE γ equal

$$\delta = kE_p + l\alpha + m, \quad (3)$$
$$\gamma = pE_p + q, \quad (4)$$

where α is the angle of incidence of the ion with primary energy E_p and k, l, m, p, q are constants.

IV.1. Results from model A

The simulation in both models has been performed for Ar plasma (pressure 100 Pa). The first results were published in [9]. It has been found, see Fig. 2, that both the thickness d and the resistivity ρ of the polymer film influence the probe characteristic. Here is also shown the probe characteristic for inert plasma ($\rho d = 0$).

It has been found that the influence of the real drift velocity of electrons and ions is very small. For the real drift velocities the changes of the probe current are very

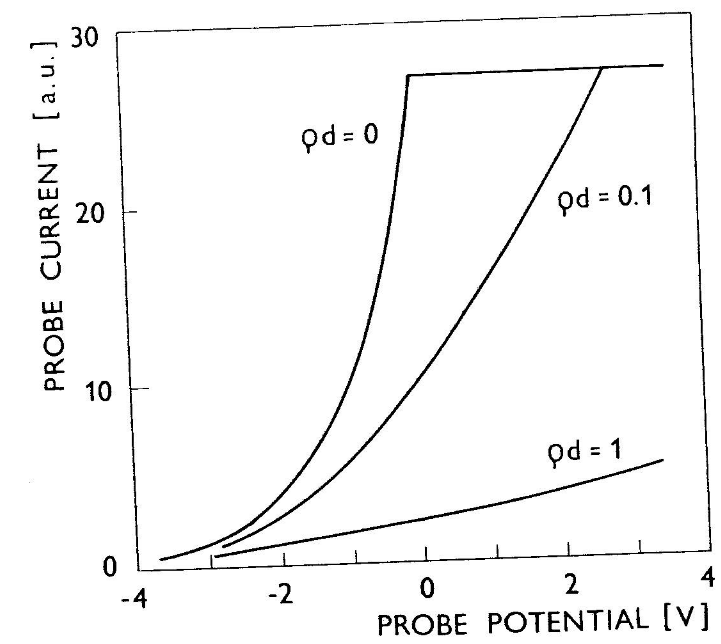

Fig. 2. Probe characteristics for various polymer films (d — thickness in m, ρ — resistivity in Ωm)

small and we can say that the influence of the drift in real cases is compensated on the opposite sides of the probe.

The influence of SE on the probe characteristic is shown in Fig. 3. It seems that the form of the curves is smooth and thus more real. The change of the coefficient γ is negligible for the I–V characteristic.

IV.2. Results from model B

One of the first results is shown in Fig. 4. We can see the influence of the reflection of ions, mainly the influence of the first term in Eq. (3) on the ion current. The dependence of the characteristics on the constant term m in Eq. (3) is simple. The ion current decreases with the increasing absolute term but the form of the curves is similar to the previous case.

At present we compute other results in the model and they will be published in the near future.

V. CONCLUSIONS

In this paper we have analysed the surface processes on the probe covered with a polymer film and their influence on both the probe characteristic and the ion current only. We can say that the probe current essentially depends on the polymer

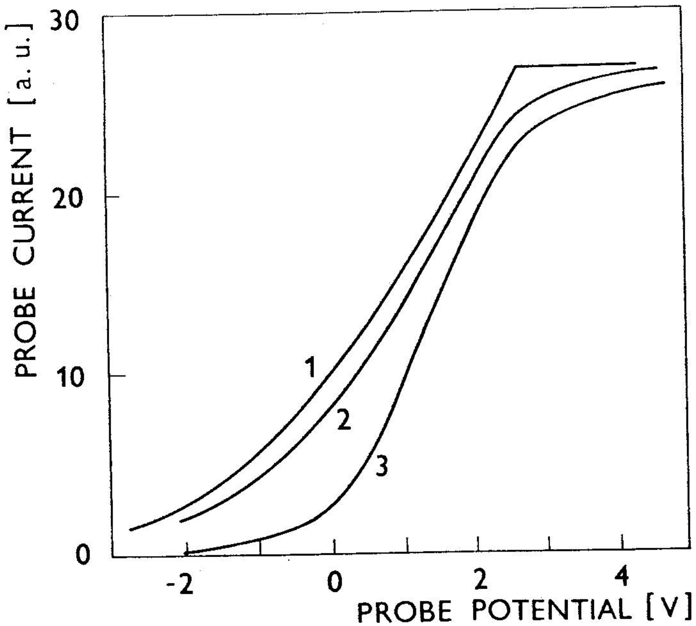

Fig. 3. The influence of probe surface processes on the probe characteristic: 1 — without secondary emission; 2 — coefficient of electron-electron SE $\sigma = 0.3$; 3 — $\sigma = 0.9$. Coefficient of electron-ion SE in both cases $\gamma = 0.1$. Parameters $pd = 0.1$

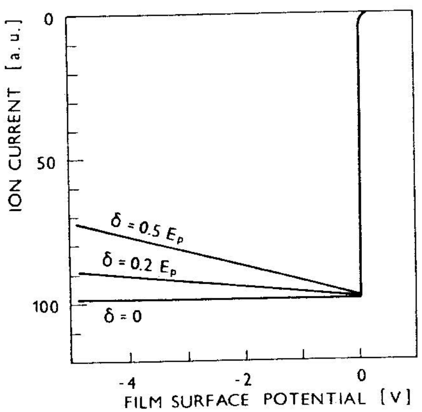

Fig. 4. The influence of the reflection of ions on the ion current when the coefficient of reflection depends on the primary energy

film thickness and on the particle interactions on the film surface. The ion current essentially depends on the reflection.

We try to manage a set of measurements and then during the confrontation with our results we will be able to decide whether our assumptions have been realistic or not.

APPENDIX

The model was based on the method of macroparticles. Their interactions were studied statistically by the Monte Carlo method.

It should be noted that we have used the model described in [8] as the particle source. The particle velocity $\boldsymbol{v}$ is determined by and added with the appropriate drift velocity $\boldsymbol{v}_D$. It has been found that the probe current density j appertaining to a particle with velocity v, mass m and charge e may be written as

$$j = \frac{en}{4v}\left[(v + v_{Dx})^2 - \frac{2eU_F}{m}\right], \qquad \text{(A1)}$$

where n is the concentration of particles, v_{Dx} is the x-component of the drift velocity, U_F the polymer film potential. We had computed the current according to Eq. (A1) for every particle and in the end we determined the averaged probe current.

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ЗОНДОВАЯ ДИАГНОСТИКА В ХИМИЧЕСКИ АКТИВНОЙ ПЛАЗМЕ

Влияние различных явлений и процессов в химически активной плазме на ток зонда изучается при помощи ЭВМ. Обсуждается влияние параметров плазмы, в том числе и возникающих тонких плёнок.