ANNALES
UNIVERSITATIS MARIAE CURIE-SKLODOWSKA
LUBLIN — POLONIA
VOL. XLIII/XLIV, 20 SECTIO AAA 1988/1989

Instytut Fizyki UMCS

H. MURLAK-STACHURA, M. PILAT

Determination of the Working Conditions of the System for Ion Extraction from Glow Discharge Plasma

1. INTRODUCTION

Extraction of ions from glow discharge plasma plays a very important role when the processes occuring in plasma are the subject of main interest. In this case of particular importance is the fact that extraction of ions does not disturbe the processes occurring in plasma.

The extraction system consists of a wall probe perforated for ion extraction and electrodes accelerating and forming the ion beam. Further analysis and detection of ions can be made by conventional methods (e.g. mass spectrometer).

The theory of extraction probe results from the theory of plate probe developed by Langmuir [1,2]. According to this theory, a sheath positive space charge is formed in front of the probe, which increased until equilibrium is established i.e., when the current of positive ions is equal the electron current. The probe potential at which the condition is satisfied is called floating potential, whereas the space charge layer is termed the probe sheath. In the theory it is assumed that this sheath formed by particles of one charge is distinctly separated from the remainder plasma, and the total difference of the potentials between the probe and undisturbed plasma comes to this sheath. Outside the sheath boundary the plasma potential and density of ions and electrons are the same as in undisturbed plasma. The sheath thickness near the probe is often identified with Debye´s length. However, these assumptions of Langmuir´s theory are a great simplification.

In the area of the sheath probe there occurs a strong electric field which penetrates deep into plasma outside the sheath boundary [2-4]. A quasineutral area, determined in literature as presheath, is formed between the sheath edge and undisturbed plasma. Here, despite the quasineutrality, the concentration of ions and electrons is different than that in undisturbed plasma, and distribution velocity of positive ions is not isotropic. The presented considerations indicate that the field of the probe placed in plasma extends beyond the boundary of the space charge sheath. In reality the probe disturbs plasma at a distance greater than that of Debye´s length.

In the case when the extraction probe is placed on the tube wall for discharge there appear additional problems. The bore in the probe locally changes the distribution of the electtric field, and the boundary surface of plasma is deformed. Ion concentraction at the wall differs from that in the plasma volume, which is the consequence of ambipolar diffusion into walls and recombination processes. The tube wall on which the probe is placed is at negative potential in relation to plasma. Thus, there arises the problem of determining the working conditions of the probe and the whole extraction system.

2. EXPERIMENTAL SYSTEM

The discharge plasma used in the measurement system (Fig.1) is formed in discharge tube 110 cm long and 5.5 cm in diameter. An extraction probe with a bore 0.2 mm in diameter is on the tube wall about 40 cm from the anode. The probe is made from a platinum foil 0.04 mm in thickness and 1 mm in diameter. Inside the extraction system, at a distance of 7 mm behind the probe, a cone steel electrode E is placed. Behind the electrode there is a collector C in the form of the Faraday can, 1 mm in diameter and 20 mm long.

The electrical system of the tube consists of a current feeder Z_1 and stabilizer on the side of the cathode, and of a regulated feeder Z_2 with a stabilized voltage on the side of the anode.

Two systems of pumps connected separately with the extraction chamber and discharge tube enable obtaing a pressure of the order 10^{-6}Tr. The dosing system 10 l in volume, connected with the tube through a capillary, was pumped empty, and then a definite pressure value was determined so that the gas flowing into the tube compensated its loss due to its out flow through the tube bore.

Probe S_1 and S_2 serve for determination of the longitudinal field intensity in plasma.

The probe extraction characteristic was measured at determined pressure p and intensity of discharge current I (p=const, I=const). The intensity curve of the current probe I_s, as a function of polarization voltage U_s was platted by X-Y recorder. The extraction probe potential was changed by changing the anode potential (Fig.1). At the same time in the X-Y recorder a curve of the current intensity of the ions reaching the collector was obtained versus the extraction probe voltage U_s, and the current intensity of the ions reaching the conic electrode E (I_E) versus the extraction probe voltage. Measurements were made for various potentials of the conic electrode E. The object of the studies was a positive column of glow discharge in argon.

3. MEASUREMENT RESULTS

The extraction probe characteristic $I_s=f(U_s)$ and the typical dependence of current intensity of I_c ions reaching the collector versus the probe voltage U_s, at the cone electrode potential $V_E=0$ are presented in Fig.2. The potential of probe s was referred to floatation potential. $U_s=0$ corresponds to the situation when current intensity of ions is equal that of electrons in $I_e=I_i$, i.e. that total current flowing to probe $I_s=0$. In Fig.2 the authors have also shown the current intensity of ions reaching the conic electrodes versus the probe voltage, measured at the same parameters of plasma. The potential of the conic electrode $V_E=0$.

Fig.3 show current intensity curves of collector I_c and of the current reaching conic electrode I_E versus probe voltage U_s for various potentials of conic electrode V_E. The presented diagrams were obtained for the positive column of glow discharge in argon for pressure $p=5.10^{-2}$ Tr and discharge current intensity I=40 mA. Fig. 3- also show the plotted summary of intensity curves of the current reaching the collector and the conic electrode versus the voltage of probe U_s. $(I_c+I_E)= = f(U_s)$.

4. CONCLUSIONS

From the presented relationships (Fig.2-3) it appears that a maximum occurs on the intensity current curve of ions extracted from plasma versus probe voltage $I_c=f(U_s)$ which confirms the results of papers [3, 5-8] . As the earher measurements showed 8 the position of this maximum versus the floating potential for $V_E=0$, does not depend on the value of discharge current intensity, but on the pressure.

Negative potential V_E applied to the cone electrode increases the current intensity of the collector, and the shape of curve $I_c=f(U_s)$ is simultaneously changed.

The results obtained indicate that the current intensity recorded on the collector constitutes only a part of the current of ions passing through the bore in the extraction probe. An increase of negative potential of the cone electrode leads to extraction of ions already at positive probe voltages (counted versus the floating potential).

The measurements of the cone current intensity $I_E=f(U_s)$ indicate that the change of this potential V_E affects focusing of the ion beam. At high negative potentials V_E (Fig.3), almost a double increase of current intensity I_E occurs in relation to $V_E=0$ (Fig.3) thus the ion beam becomes divergent.

From the presented results it appears that the electric field from the conic electrode has no significant influence on the character of changes of curve $I_c=f(U_s)$. Therefore, it can be supposed that the sheath probe layer and the processes occurring in it are responsible for the changes of current intensity of ions reaching the collector. This point of view is confirmed to some extent by the determined ion distrubution curves versus the energy. At high probe voltages the distribution functions are strongly distorted (in comparison with Maxwell´s distribution). It seems that the most optimal working conditions of the probe is the interval of positive polarization potentials and the floating potential.

Ackowledgement

Supported in part by the Polish Academy of Science under contract CPBP 02.02.t.2.1.

References.

1. Brömer H., Hesse J.; Z. Naturforsch. 1968, 23a, 1960
2. Lergon H.G., Möller K.G.; Z. Naturforsch. 1977,32a,1093
3. Pahl M.; Z. Naturforsch. 1957, 12, 632
4. Pahl M., Weimar U.; Z. Naturforsch. 1958, 13a, 745.
5. Knewstubb P.F., Tickner A.W.; J. Chem.Phys. 1962, 36, 674-684
6. Henrick K., Möller K.G.; Z. Naturforsch. 1974,29,1276.
7. Nowak M., Waidmann G.; Z. angew.Physik, 1971,31,300.
8. Murlak-Stachura H., Stachórska D., Wroński Z.; Annales UMCS, 1984.

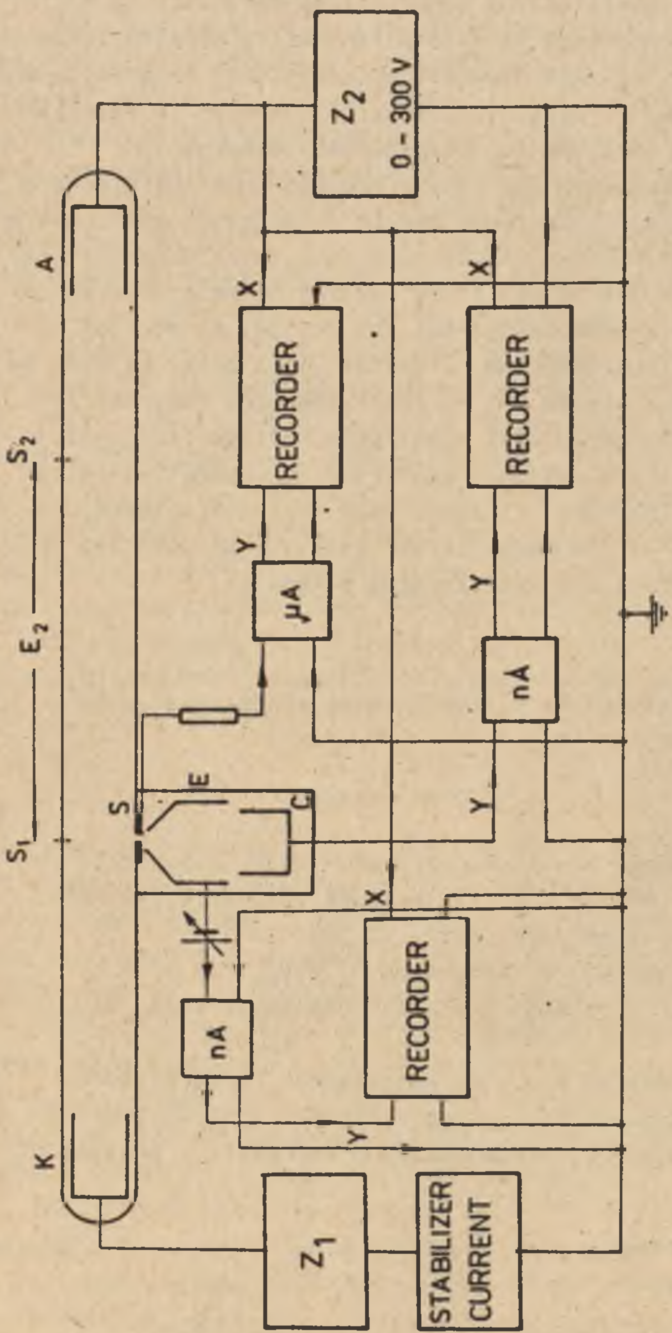

Fig. 1. The simplified diagram of the experimental apparatus.

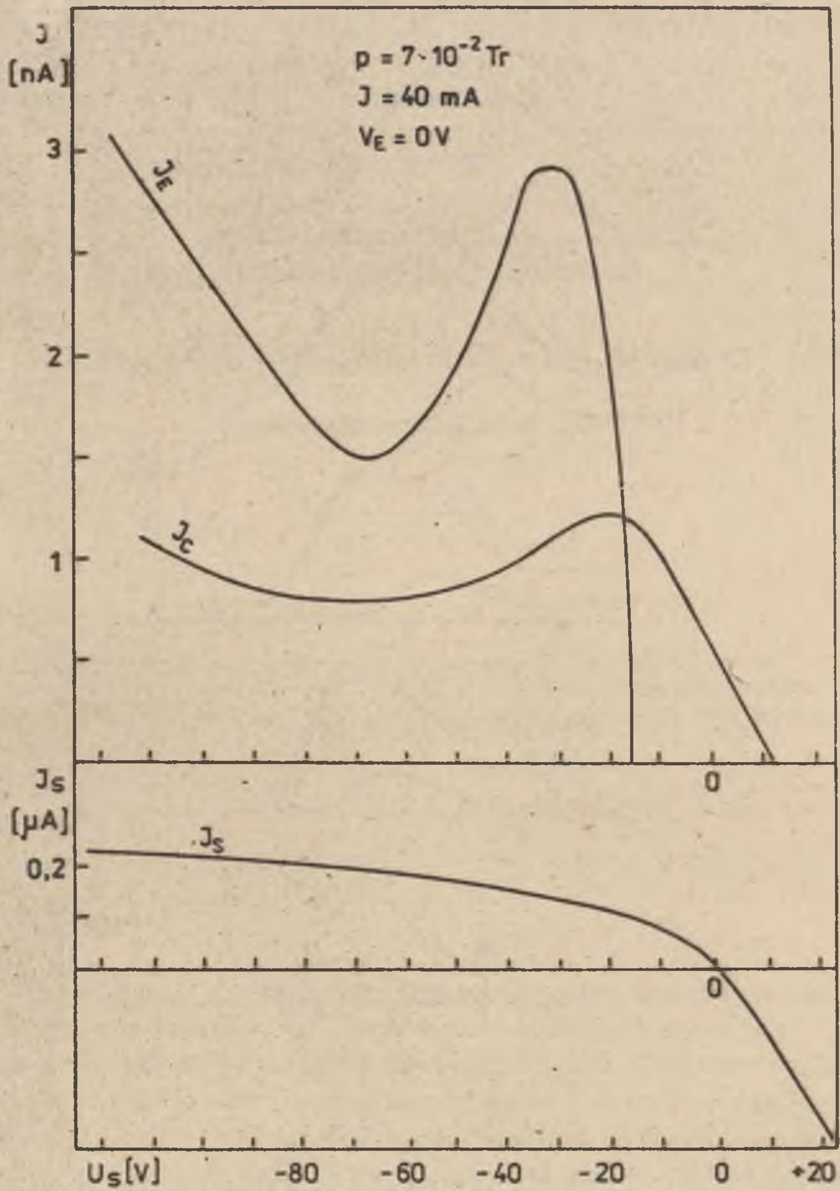

Fig. 2. Typical extraction probe characteristic $I_S=f(U_S)$ and dependence current intensity of the collector I_C and cone electrode I_E versus the probe voltage U_S.

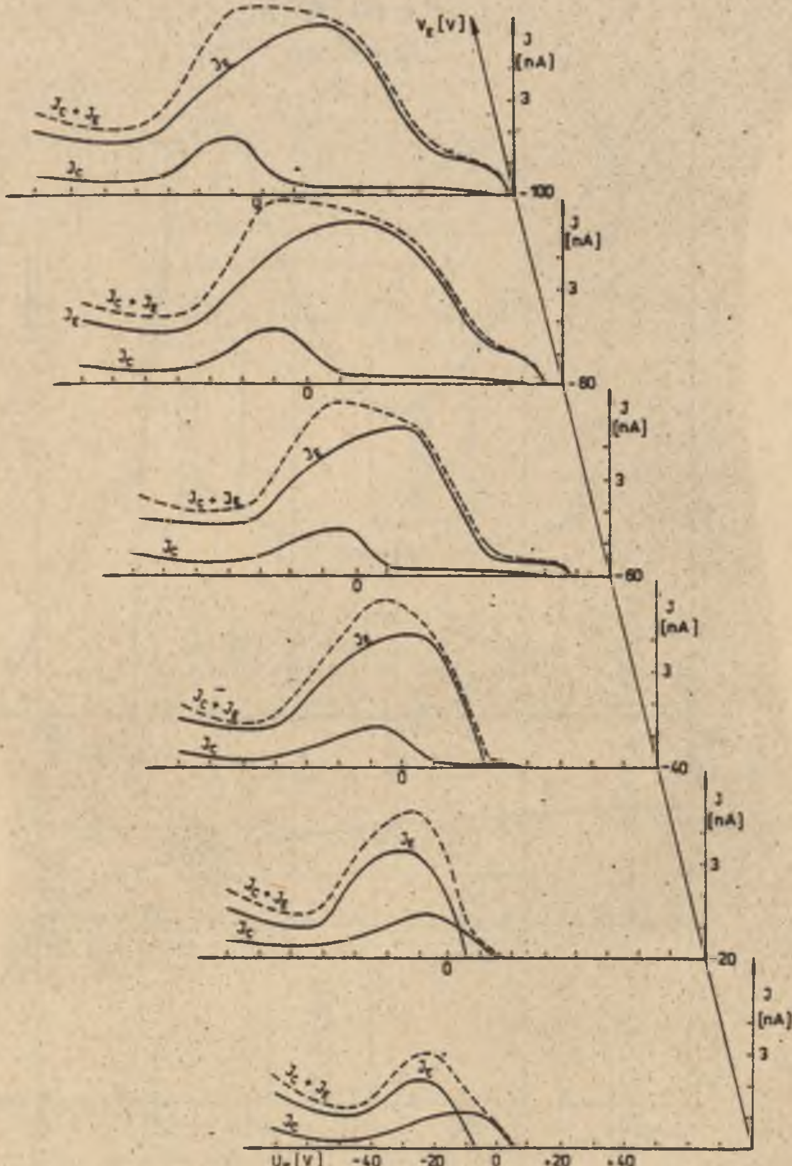

Fig. 3. The dependence current intensity of the collector I_C and cone electrode I_E versus the probe voltage U_S at the various potential V_E.