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STUDY OF THE RADIAL DISTRIBUTION FUNCTION OF CHARGED PARTICLES IN THE OXYGEN-NEON MIXTURE GLOW DISCHARGE[1)]

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By means of probe methods the radial distribution of charged particles in positive column of glow discharge is studied. This radial distribution is measured in the dependence on the ratio of neon and oxygen in the mixture and on the discharge current. The great influence of even the small amount of oxygen is found.

I. INTRODUCTION

Oxygen glow discharge is a very frequently studied medium due to its application in technological processes and also in laser physics. Very often in these applications the oxygen exists in mixtures with both rare and other kinds of gases. Here we continue our previous studies of mixtures of oxygen with rare gases (e.g.[1], [2]), now from the point of view of the charged particles radial distribution.

In pure oxygen this radial distribution was often studied both theoretically and experimentally. As an example of the theoretical approach can be mentioned the paper of Sabadil [3], who solved numerically the balance equations in order to find the radial distribution of charged particles and found the enlargement of radial distribution with increasing ratio of a negative atomic oxygen ion in comparison with the Bessel distribution. Mašek and Láska [4] studied the influence of wall on the oxygen positive column and derived correction factors for radial distribution. A complex theoretical and experimental analysis was made in [13, 14], where the radial profile of the electrons and of the negative atomic ions was studied. In experimental studies the dependence of the existence of a more uniform distribution on increasing negative ion density was found [5], [6], [7], too. These changes are

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studied in these papers in dependence on discharge currents and oxygen pressures. It was found that in pure oxygen there exist the radial distributions of electrons both more uniform in comparison with the Bessel distribution and steeper. It depends on the density ratios of negative ions and electrons and there exists the critical limit [6] of this ratio ($n_-/n_0 = 3 - 4$). Above this limit the electron radial distribution is more uniform.

II. METHOD

Similarly as the authors of papers [5] and [6], we used probe methods for radial distribution measurements. In [5] electron densities measured both by the microwave method and the double probe method were analysed. The same electron densities in oxygen were found by means of the resonator method and from the double probes saturated ion current; the radial distribution was determined from the relative values of this current. We derived the same dependences of electron densities also from these two methods in mixtures with oxygen [1], [2].

In the present paper, our measurements were performed for two pressures of mixtures 133 and 266 Pa for discharge currents 10, 20 and 30 mA, such conditions, for which in pure oxygen there exists the H-form of the positive column only. From the brief survey above, it is clear that the existence and the density of negative ions in the discharge is the dominating influence on the oxygen radial changes. From the detailed analysis in [8] we found that for our condition (by E/N), the negative dominant particle is the electron (the number of negative ions O^- is less than 10% and the number of ions O_2^- even by one order of magnitude lower), so that we can expect a distribution similar to the Bessel one. We tried to measure not only the relative saturated ion double probe current as in [5] and [6], but also the relative saturated one probe ion current (about 100 V from floating potential). The type of distribution was practically the same (difference in the amplitude was 1 - 2%, only for 133 Pa and 10 mA for pure oxygen it was about 8%).

All our measurements were performed in the discharge tube, the shape and dimensions of which are seen in the Fig. 1. The radial moving cylindrical probe was 100 μm of diameter and 3 mm of length, parallel to the discharge tube axis. The positive column was homogeneous from the point of view of moving striations for all measured mixtures and for pure oxygen. In the pure neon for the pressure of 266 Pa there was the limit of moving striations about 12 mA, so that for 20 and 30 mA we have mean values of probe currents only.

III. RESULTS OF MEASUREMENTS AND DISCUSSION

In the Fig. 2 the courses of the axial electric field are shown (in the upper part for the pressure 266 Pa and in the lower part for 133 Pa). This field has the usual

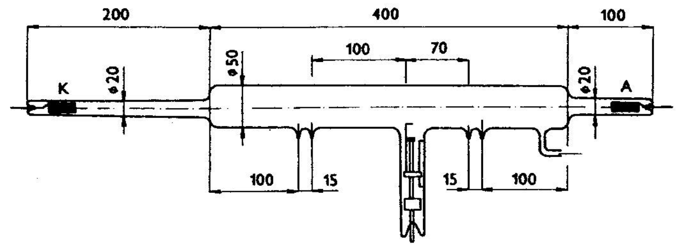

Fig. 1. Discharge tube. Both the electrodes and the probes are made of platinum.

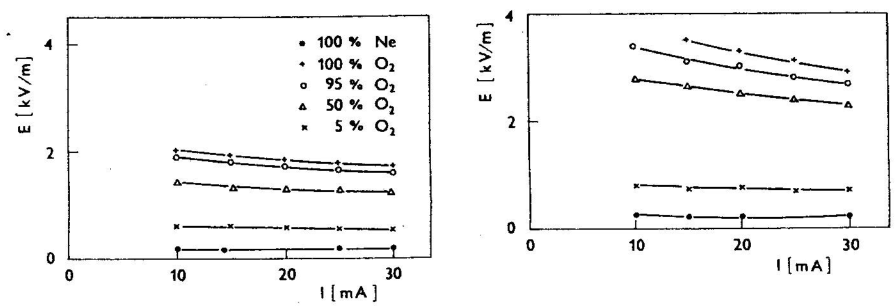

Fig. 2. Dependence of axial electric field on the discharge current for various oxygen-neon mixtures.

character (e.g. [1]) for all measured mixtures. It decreases with decreasing pressure, with decreasing oxygen portion in the mixture and with increasing discharge current.

In further figures the studied radial changes are presented (with the help of relative saturated ion currents). First we shall analyse the situation in the pure gases. In the neon (sign • in all figures) the Bessel distribution exists (it is the direct distribution of electrons, because the quasineutrality condition is $n_e \sim Ne^+$) for all measured currents of both pressures.

In the pure oxygen (sign + in all figures) we found a very good agreement with the results presented in [5] and [6]. It means that the radial distribution of density (practically electron density) is steeper for higher discharge currents at the same pressure (see Figs. 3 and 5 for 133 Pa and Figs. 4 and 6 for 266 Pa) and

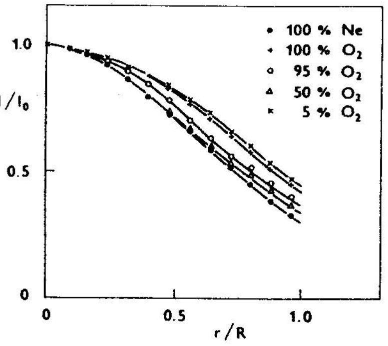

Fig. 3. Radial change of the relative ions saturated current for 133 Pa and 20 mA (I_0 is the saturated ion current on the axis of discharge tube)

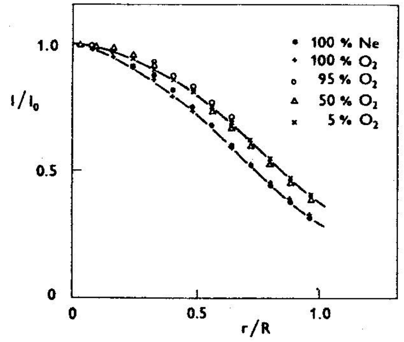

Fig. 4. Radial change of the relative ion saturated current for 266 Pa and 20 mA.

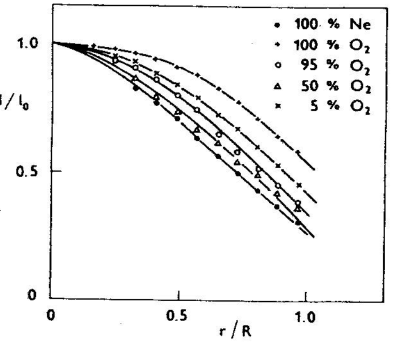

Fig. 5. Radial change of the relative ion saturated current for 133 Pa and 10 mA.

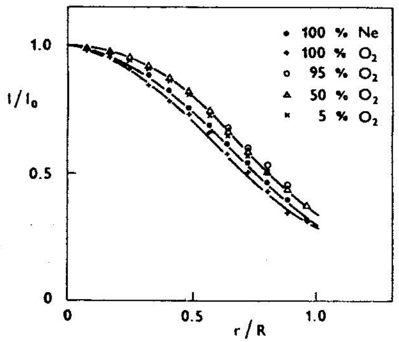

Fig. 6. Radial change of the relative ion saturated current for 266 Pa and 30 mA.

at higher pressures for the same discharge current, too (see Figs. 3 and 4). For the pressure 266 Pa and the discharge current 30 mA, i.e. the case of the highest electron densities in our measurements, the radial distribution in the pure oxygen is steeper than in pure neon. According to analyses in [7], [8] it is possible to assume that the attachment of electrons is compensated.

Let us now pay attention to the studied mixtures. From our figures the difference between both measured pressures is evident. For the pressure 266 Pa (see Figs. 4 and 6) the distribution for all mixtures is practically the same (including 10 mA), for 133 Pa it is different - for 5% oxygen in the mixture it is most uniform (including 30 mA).

We can explain these facts by a further hypothesis. For lower electron density (pressure 133 Pa), the presence of neon can cause the creation of negative ions both atomic and molecular in two ways. Firstly, by supplying energy arising from transitions between neon excited states for the dissociative attachment [15]:

$$O_2 + e \longrightarrow O^- + O.$$

Excited states of neon have also their radial distribution, which is more uniform for lower pressures [9]. Secondly, the neon atom can have the catalytic role in the ternary attachment process [10], [11]:

$$O_2 + e + Ne \longrightarrow O_2^- + Ne.$$

With a further increase of the oxygen portion in the mixture, similarly to the increase of the pressure, the attachment is compesated, because the density of the excited oxygen molecules O_2^* (namely metastable $O_2(a^1\Delta g)$) increases too, which causes a great detachement in reactions [12]:

$$O^- + O_2^* \longrightarrow O_3 + e.$$

$$O_2^- + O_2^* \longrightarrow 2O_2 + e.$$

In future, in order to explain more exactly our measured effects, both the measurements with other rare gases and measurements with the spherical probe (to remove the influence of striation around the parallel probe) will be prepared.

REFERENCES

[1] Hrachová, V.: *Proc. XVII ICPIG*, Budapest 1985, p. 688.
[2] Hrachová, V., Langr, A.: *Proc. XVIII ICPIG*, Swansea 1987, p. 776
[3] Sabadil, H.: Beiträge a.d. Plasmaphys. *13* (1973), 235.
[4] Mašek, K., Láska, L.: Czech. J. Phys. B *30* (1980), 805.
[5] Aruturyan, G. G. et al.: Beiträge a.d. Plasmaphys. *23* (1983), 271.
[6] Amirian, A. A. et al.: Beiträge a.d. Plasmaphys. *25* (1985), 289.
[7] Vicharev, A. L. et al.: Fizika plazmy *15* (1989), 838.
[8] *Research report*, Université de Paris-Sud, Orsay, 1986.
[9] Valignat, S. et al.: Journal de Physique *40* (1979), C7-7.
[10] Massey, H. S. W.: *Negative Ions*, Cambrigge University Press, 1976.
[11] Christophorou, L. G.: *Atomic and Molecular Radiation Physics*, Wiley- Interscience 1971.
[12] Yukimi,Ichikawaet al. : J. Appl. Phys. *67* (1990), 108.

[13] Ferreira, C. M. et al.: J. Phys. D.: Appl. Phys. *21* (1988), 1403.
[14] Gousset, G. et al.: *Proc. ISP 6-9*, Pugnochiuso, Italy 1989, 223.
[15] Eliasson, B.: *Electrical Discharge in Oxygen*, Brown Boveri Forschungszentrum, Baden 1985.

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ИЗУЧЕНИЕ РАДИАЛЬНОГО РАСПРЕДЕЛЕНИЯ НОСИТЕЛЕЙ ЗАРЯДА В ТЛЕЮЩЕМ РАЗРЯДЕ СМЕСИ КИСЛОРОД-НЕОН

В работе исследовано радиальное распределение заряженых частиц методом зондирования в положительном стольбе тлеющего разряда. Распределение измерено в зависимости от состава смеси (неон, кислород) и величины тока разряда. Найдена сильная зависимость влияния примеси кислорода.