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APPLICATION OF INDUCTIVELY COUPLED AND MICROWAVE DISCHARGES[1)]

A. BRABLEC[2)], V. KAPIČKA[2)], Z. ONDRÁČEK[2)], Brno

The present investigations into inductively coupled and microvawe plasma are oriented toward pratical application to spectroscopy and related disciplines, such as plasma chemistry. This article attempts to show various aspects of application of these plasmas and some methods of their diagnostics as well.

ПРИМЕНЕНИЕ ИНДУКТИВНО СВЯЗАННЫХ И МИКРОВОЛНОВЫХ РАЗРЯДОВ

В настоящее исследования индуктивно связанной и микроволновой плазмы ориентируются на практические применения в спектроскопии и смежных дисциплинах, таких как плазменная химия. В данной статье сделана попытка показать разные аспекты применения этих видов плазм, а также некоторые методы их диагностики.

I. INTRODUCTION

High frequency discharges have been widely studied since 1920 [1]. However, their importance has not increased until the last decades. Formely, in conventional applications as well as in industry there used to be applied arcs, sparks and d. c. discharges burning under reduced pressures. In the first investigations of high frequency discharges interest centred upon elementary processes associated with the discharge and determination of electrical parameters. The viewpoints put forward in the present studies concern both the processes taking place in plasma and plasma diagnostics of the inductively coupled (ICP) and microwave (MIP) plasma discharges.

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[2)] Katedra fyzikální elektroniky, PF UJEP, Kotlářská 2, 611 37 BRNO, Czechoslovakia.

Table 1

λ [nm]	0.64 l/min $N \times 10^{-13}$ [m^{-3}]		1.24 l/min $N \times 10^{-13}$ [m]		2.05 l/min $N \times 10^{-13}$ [m^{-3}]	
696.5	4.9	5.1	9.3	8.7	7.2	6.7
706.7	6.3	7.2	12.6	11.6	8.7	8.7
727.3	0.0	6.0	10.9	10.9	8.4	7.3
738.4	6.5	6.2	10.9	10.5	8.7	8.1
750.4	0.9	0.9	1.9	1.7	1.5	1.3
751.5	1.1	1.2	2.2	2.1	1.8	1.5
763.5	5.2	6.1	11.4	12.2	10.6	8.6
772.4	6.4	6.1	13.1	12.2	10.8	10.2
794.8	3.2	3.4	7.0	7.0	6.1	4.9
800.6	9.3	8.0	18.5	17.2	15.8	13.2
801.5	7.2	15.1	14.4	13.1	10.5	
810.4	3.9	4.2	7.8	7.8	6.8	6.8
811.5	7.8	8.2	16.2	15.8	15.7	11.2
826.5	3.5	3.5	8.1	8.1	7.5	5.8
840.8	3.9	3.9	7.8	7.8	6.6	5.5
842.5	4.9	4.9	11.0	11.0	9.8	7.9
P [W]	46	65	46	65	46	65

II. APPLICATION OF ICP AND MIP DISCHARGES

The ICP and MIP are complementary to each other in application and practice. Whereas, the discharges generating the ICP are used as precise and stable spectral sources enabling the use of computer technique and spectroscopic methods (using, e. g., instruments by the ARL, Perkin Elmer, Phillips, Bausch and Lomb) and only in some cases are of practical interest; they can be advantageously applied to plasmachemical processes (like, e. g., deposition of thin films). For the application of the MIP discharge the reverse is true. The discharges generating the MIP are employed at reduced pressures to plasmachemical reactions [2] and in a small measure only as special spectral sources at normal pressure.

Taking advantage of the ICP in spectroscopy appears very effective. First of all, it makes possible to construct complete modern spectral devices maximally adjustable for specified methods and processes in spectral analyses [2]. In the socialist countries such devices are not commercially produced.

From the standpoint of further development these discharges become important through the use of the ICP and MIP in unconventional applications; the ICP, e. g., is used in spectroscopy to analyse unusual chemical compounds and materials, and/or in analyses employing other so far less studied carrier gases, or in new methods of carrying materials in plasma, etc. The above mentioned aspects reveal

the study of an entire new problem arising in the chemical reactions of different parts of plasma and hence in the determination of physical parameters, too.

III. DIAGNOSTICS OF ICP AND MIP SPECTROSCOPY

The diagnostics of the ICP used in spectroscopy is given, e. g., in [5] and that of the MIP in plasmachemistry in [3].

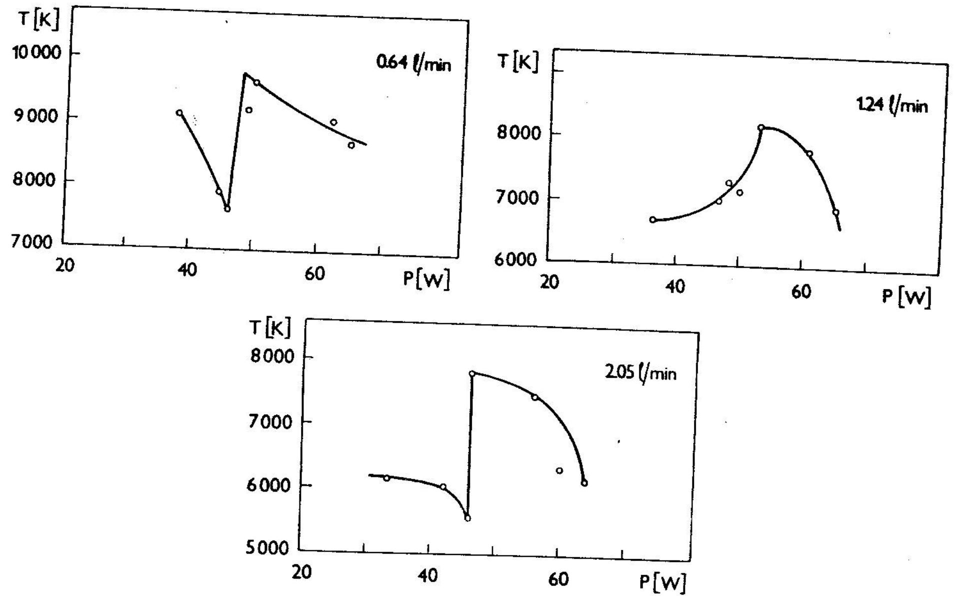

Fig. 1. Temperature in the MIP.

In our case the temperature for the discharge of 2450 MHz has been determined from spectral lines. The Ar flow through the discharge tube was 0.64—1.24—2.05 and 2.8—1/sec. The discharge corresponds to the conditions required in spectroscopy. The concentration of Ar atoms on generated levels was defined in the discharge simultaneously — see Table 1. Measurements were performed for different powers absorbed in the discharge. The error of measurement was about 10 %. The measurement was made by means of the RCA typ 4550 picture image tube. The picture from the image tube screen was scanned by a television camera and the line intensity measured with the help of an oscilloscope [4].

The results obtained from the experiment and the analysis carried out in [5] show the excitation temperature measured to lie between the temperature of neutral gas and that of electrons. (Fig. 1.) In our measurements it rather approximates the temperature of neutral gas. Different experimental arrangements affect the burning of the discharge. There appear, e. g., more discharge channels of various shapes, closing of channels on the wall, etc. [6].

Measurements with ICP discharges have been referred to in many works, e. g., [6—10].

In our work the ARL 35 000 C measuring apparatus with the generator frequency 27.12 MHz and power in the discharge 1.3 kW was applied. With the aid of the line broadening of the Ar 549.5 nm spectral lines the concentration of the charged particles and temperature of the neutral gas was determined. Calculations for two Ar lines measured at same conditions were performed using the HP 9825 A computer in the same way as in [3, 10]. The values obtained for the concentration of the charged particles are $n = [(2.15 \pm 0.07)$ and $(2.05 \pm 0.4)] \times 10^{21}\,m^{-3}$ and $T = [(5.73 \pm 0.43)$ and $(6.77 \pm 0.61)] \times 10^3$ K and agree well with both the data given for the measuring apparatus by the producer and the results reported in literature [7].

IV. CONCLUSION

Considering the above contribution it may be concluded, as regards the conditions and reactions taking place in the ICP and MIP discharges, that they are affected by the application of different carrier gases, pressures and power outputs. Therefore, it appears relevant to control the stability of burning for the spectroscopic purposes and the determination of physical parameters.

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