IRSTI 29.27.49 https://doi.org/10.26577/ijmph-2019-i2-8

[1,*]**A.R. Abdirakhmanov**, [1]**Y.A. Ussenov**, [1]**M.K. Dosbolayev**, [1]**S.K. Kodanova**, [1]**T.S. Ramazanov**

[1] Institute of Experimental and Theoretical Physics,
Al-Farabi Kazakh National University, Kazakhstan, Almaty,
*email: abdirakhmanov@physics.kz

Langmuir probe and optical diagnostics of stratified glow discharge in a magnetic field

Abstract. The article presents the preliminary results of an experimental study of the characteristics of a DC stratified glow discharge plasma in an external magnetic field. Single Langmuir probe and emissive spectrometer are used as diagnostic tools for the estimation of various plasma parameters. The main plasma parameters, such as electron temperature, density and floating potential were determined from the voltage- current (VI) characteristics of the probe in the stratified glow discharge plasmas for different magnetic field values. Increasing the value of the magnetic field leads to an increase in the concentration of plasma particles and a decrease in the temperature of electrons. Also by the optical emission spectroscopic (OES) method it was found that the intensity of spectral lines of the stratified glow discharge increases with an increase value of magnetic field. A simple interpretation was made to explain our results according to the work of Bickerton&Engel [21].
Key words: glow discharge, plasma, magnetic field, Langmuir probe, spectrometer.

Introduction

At the moment, it is difficult to overestimate the importance of studying plasma physics. A huge number of scientific groups around the world are engaged in research of plasma processes. In the future, these studiescan be widely used in industry in the form of technical applicationslike light sources, modern plasma nanotechnology; sensitive ion cleaning of the surface of materials and etc. [1-6].

Low-temperature plasma is the subject of numerous studies. Interest in it caused by the possibility of wide application in gas lasers, plasma chemical reactors, energy converters, voltage switches, etc.Successful application of plasma technology is impossible without a deep understanding and quantitative description of the processes occurring in them. The construction of physical models fully reflecting the behavior of plasma systems is based on the knowledge of the corresponding plasma parameters. In this regard, the development of plasma diagnostic methods is of great interest and practically important [7-10].

Of particular interest is the study of plasma behavior in a magnetic field. Since plasma is an ionized gas consisting of charged particles, the presence of a magnetic field has a significant effect on all processes occurring in plasma[11-16].

Important plasma parameters are density of charged particles, electron and ion temperature, and plasma potential. Also, the discharge parameters include its power and magnetic configuration, the pressure of the working gas. To study the dynamics of dust particles depending on all the above parameters, it is necessary to be able to determine them.

The Langmuir probe diagnostic method is a common method for determining the density of charged particles, as well as the energy of electrons in plasma. An electric probe is an electrode of small size placed in plasma and used to determine its local characteristics.Usually,VI characteristic (voltage-current relationship) of the probe must bemeasured. A probe immersed in plasma is surrounded by a double electrical layer (volume charge layer or "sheath") and, in fact, the probe's VAC is the VAC of the layers. The reference electrode can be either one of the electrodes of the gas-discharge system or a metal element of the gas-discharge chamber, or a specially introduced reference probe.The main task of the theory of interpretation is to establish a connection between the probe current and plasma parameters. A rigorous solution to this problem in general is very difficult and has not yet been fully achieved. For the correct interpretation of the results of probe measurements, it is necessary to construct theories corresponding to the given conditions of application of the method[17-26].

In this work, probe and optical diagnostics of a glow discharge in a magnetic field was carried out.

Description of Experimental setup& Results

The experiment was conducted in the the laboratory of Dusty plasma and Plasma technology at the IETP. The general scheme of the experimental setup is shown in Figure 1. The gas pressure was 0.23Torr. The operating discharge current was 1.3 mA. This condition was chosen to determine the parameters of the glow discharge plasma, which manifested an interesting behavior of dust structures and not observed in other similar experimental works [27]. The magnetic field is created by a Helmholtz coil. The magnetic field strength depends on the current flowing in the solenoid. When the current is set to the 1.9 A the maximum magnetic field in the center of the solenoid is equal to B=28 mT. Probe and optical diagnostics were performed in the center of the solenoid (see Figure 1).

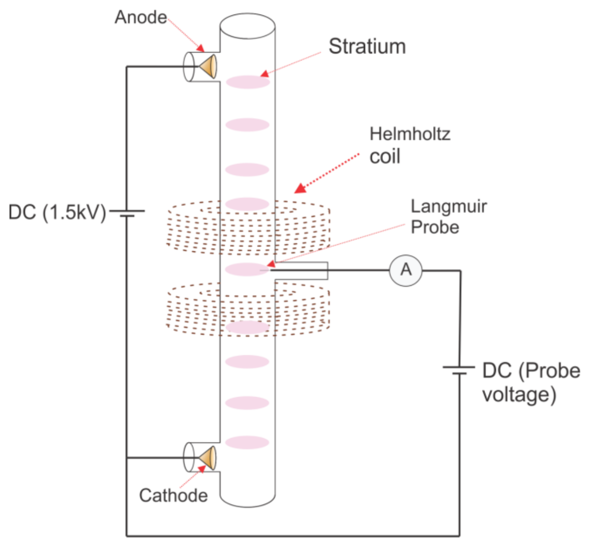

Figure 1– Experimental setup for probe diagnostics

The probe is made of tungstenire with a diameter of 100 microns. To determine the electron temperature and concentration, as well as other plasma parameters, the VI characteristic of the probe was obtained at different values of the magnetic field (Figure 2).Detailed information of the probe and the method for determining the plasma parameters are described in [28].

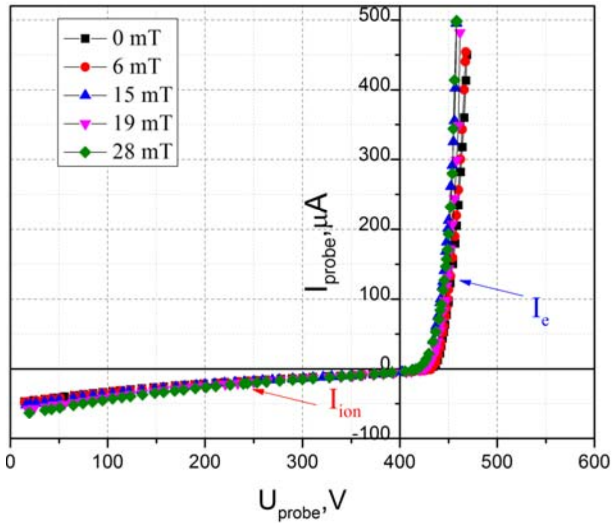

Figure 2– VI characteristic of the probe under different magnetic field conditions.(Experiment parameters: Argon, P=0.23torr, I=1.3 mA)

As can be seen from the graph, a significant difference in probe VI characteristic does not appear at different magnetic fields. This suggests that the plasma parameters do not change at weak magnetic field values. A table of plasma parameters was constructed for different magnetic field strength, which is shown in Table 1.As can be seen from the table, the measurement was carried out at five points of magnetic field values (0;6;15;19;28 mT).As the magnetic field increases, we can see that the plasma concentration increases and the electron temperature drops.When the magnetic field increases, the ambipolar diffusion decreases in the direction perpendicular to the magnetic field. The probability of collision between electrons and atoms increases; therefore, ionization also increases.As a result, electrons lose their energy more due to ionizing collisions during their drift due to the E×Beffect.This leads to a decrease in the value of the electron temperature from 4.1 to 3.45 eV.With increasing magnetic field floating potential takes less negative values.At relatively high magnetic fields, electrons become more and more restricted, and therefore the plasma potential becomes more negative to compensate the ion loss rate and maintain plasma quasi-neutrality.

Table 1 – The parameters of the stratified glow discharge for different values of the magnetic field. The results were obtained using Langmuir probe diagnostics method. (Experiment parameters: Argon, P=0.23torr, I=1.3 mA)

Induction of magnetic field	n_i, m^3	T_e, eV	V_f, V	$I_{saturation}$, mkA
0 mT	$1.41*10^{15}$	4.1	-17.8	2.35
6 mT	$1.48*10^{15}$	4.07	-17.6	2.37
15 mT	$1.49*10^{15}$	3.57	-15.6	2.59
19 mT	$1.58*10^{15}$	3.58	-15.5	2.89
28 mT	$1.74*10^{15}$	3.45	-14.9	3.16

In [21] the density of the ion current in the wall also was measured. As the field increases, the ratio of the density on the wall to the density on axis decreases with the growth of the magnetic field.For the number of electrons per unit length of the discharge to remain constant, the concentration must increase. It should be mentioned that we use a constant current (DC discharge) discharge.

Also, optical emission spectrawas obtained in stratified glow discharge at different magnetic fields (Figure 3).

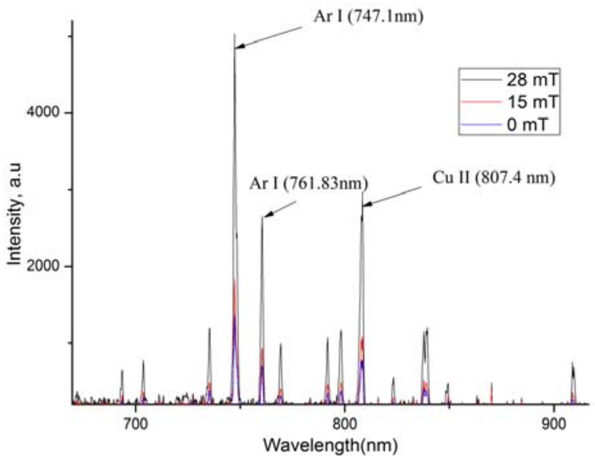

Figure 3– Optical emission spectra of stratified glow discharge at different magnetic fields

As can be seen from the graph, with increasing magnetic field the intensity of the spectral linealso increases. As mentioned above with increasing magnetic field due to diffusion the probability of collision increases, which in turn leads to enhance of ionization.Perhaps the number of excited atoms increases, leading to an increase in the intensity of the discharge.

Conclusion

In order to obtain the information about the plasma of stratified glow discharge, probe and optical diagnostics were carried out.During the experiments it was found that with increasing magnetic field plasma parameterscan be also changed.The change of these parameters is related to the processes of diffusion and collision of charged particles in ExB fields.Of course, the work requires further research in different conditions of the glow discharge.

The work was done with the support of the Ministry Education and Science of Republic Kazakhstan in the framework of the grant AP05133536.

References

1. G. Bonizzoni, E.Vassallo. "Plasma physics and technology; Industrial applications. "*Vacuum* 64(2002): 327-336/

2. RoshanShishoo. "Plasma Treatment– Industrial Applications and Its Impact on the C&L Industry."*Journal of Industrial Textiles* 26, (1996): 0026-10.

3. Bogaerts, A."The glow discharge: an exciting plasma!."*Journal of Analytical Atomic Spectrometry* 14 (1999): 1375-1384.

4. V N Tsytovich."Elementary Excitation and the Physics of Stochastic Processes in a Plasma", *Sov.Phys.Uspekhi*13(1970): 413–414.

5. Francis F. Chen. "Industrial applications of low-temperature plasma physics."*Physics of Plasmas* 2,(1998): 2164.

6. . Golant V.E., Zhilinsky A.P., Sakharov I.E."Fundamentals of Plasma Physics", NewYork: Wiley (1980).

7. W.L.Wiese. "Spectroscopic diagnostics of low temperature plasmas: techniques and required

8. data”. *SpectrochimicaActa Part B: Atomic Spectroscopy* 46 (1991): 831-841.

9. Francis F Chen. “Langmuir probe analysis for high density plasmas.”*Physics of Plasmas* 8, (2001): 3029-3041.

10. I.H. Hutchinson. “Principles of Plasma Diagnostics.”Cambridge University Press, New York (1987).

11. G. S. Selwyn. “In situ laser diagnostic studies of plasma-generated particulate contamination.” *Journal of Vacuum Science & Technology A* 7 (1989): 2758.

12. U.Konopka, D.Samsonov, A.V. Ivlev, J.Goree, V.Steinberg, and G.Morfill. “Rigid and differential plasma crystal rotation induced by magnetic fields.”*Phys. Rev. E* 61,(2000): 1890.

13. P. K. Kaw, K. Nishikawa, and N. Sato. “Rotation in collisional stronglycoupled dusty plasmas in a magnetic field.”*Phys. Plasmas* 9, (2002):387.

14. V.Y. Karasev, A.I. Eikhvald, E.S. Dzlieva, and A. Y. Ivanov. “Rotational motion of dusty structures in glow discharge in longitudinal magnetic field.”*Phys. Rev* 74,(2006): 066403.

15. M. M. Vasiliev, L. G. D’yachkov, S. N. Antipov, R. Huijink, O. F. Petrov, V. E. Fortov. “Dynamics of dust structures in a DC discharge under action of axial magnetic field.” *EPL*93,(2011): 15001.

16. E. Jr. Thomas, B. Lynch, U. Konopka, R. L. Merlino, and M. Rosenberg. “Observations of imposed ordered structures in a dusty plasma at high magnetic field.”*Phys. Plasmas* 122, (2015): 030701.

17. V. Y. Karasev, E. S. Dzlieva, S. I. Pavlov, L. Novikov, S. Maiorov. “The rotation of complex plasmas in a stratified glow discharge in the strong magnetic field.”*IEEE Transactions on Plasma Science*46, (2018): 727-730.

18. I. Langmuir, C. G. Found, A. F. Dittmer. “A new type of electric discharge: the streamer discharge.”*Science*31, (1924): 392-394.

19. F.F. Chen, in Plasma Diagnostic Techniques, R. H. Huddleston, and S. L. Leonard, eds., Academic Press, New York (1964), Chapter 4.

20. F.F. Chen,Introduction to Plasma Physics and Controlled Fusion, Plenum Press, New York (1984).

21. J.W. Swift and M. J. R. Schwar,Electrical Probes for Plasma Diagnostics, Iliffe Book Ltd., London (1970).

22. R. J. Bickerton and A. von Engel.“The Positive Column in a Longitudinal Magnetic Field.”*Proceedings of the Physical Society* 69, (1956): 468.

23. Juan R. Sanmartin. “Theory of a Probe in a Strong Magnetic Field.”*The Physics of Fluids* 13 (1970): 103.

24. D. Bohm,“The Characteristics of Electrical Dischargesin Magnetic Fields.” A. Guthrie and R. K. Wakerling, Eds.McGraw-Hill Book Company, New York, (1949).

25. Juan Sanmartin“Theory of a Probe in a Strong Magnetic Field.”*Physics of Fluids* 13, (1970): 22-41.

26. Chung, P. M., L. Talbot, K. J. Touryan, Electrical probes in stationray and flowing plasmas, Theory and Application, Springer-Verlag, New York, (1975).

27. Demidov, V. I., S. V. Ratynskaia, and K. Rypdal, “Electric probes for plasmas: The link between theory and instrument.” *Rev. Sci. Instrum*.,73,(2002) 3409–3438.

28. A.R. Abdirakhmanov, Zh.A. Moldabekov, S. K. Kodanova , M. K. Dosbolayev , and T. S. Ramazanov. “Rotation of Dust Structures in a Magnetic Field in a DC Glow Discharge.” *IEEE Transaction on Plasma Science* (2019), doi 10.1109/TPS.2019.2906051.

29. T. S. Ramazanov, N. K. Bastykova, Y. A. Ussenov, S. K. Kodanova,K. N. Dzhumagulova, and M. K. Dosbolayev. “The behavior of dustparticles near Langmuir probe.” *Contrib. Plasma Phys*. 52,(2012): 110.

30. A.R. Abdirakhmanov, M. K. Dosbolayev, and T. S. Ramazanov. “The gas discharge dusty plasma in a uniformmagnetic field”*AIP Conference Proceedings* 1925 (2018): 020007.

31. Abdirakhmanov A.R., Dosbolayev M.K., Ramazanov T.S.*Journal of the problems of the evolution of open systems.* 18, (2016): 34–39.