*34th EPS Conference on Plasma Phys. Warsaw, 2 - 6 July 2007 ECA Vol.**31F**, P-5.072 (2007)*

DIAGNOSTIC OF PULSED PLASMA USING PIEZODETECTORS

O.V. Byrka[1], A.N. Bandura[1], I.E. Garkusha[1], V.I. Tereshin[1]

L. Karpiński[2], R. Miklaszewski[2], M. Scholz[2], B. Ulejczyk[2]

[1]*Institute of Plasma Physics of the NSC KIPT, Kharkov, Ukraine*

[2]*Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland*

Abstract

It seems a diagnostic of plasma is significant problem in plasma technology. In this paper a feasibility of a piezo-detector to determine of some plasma parameters is presented. The piezo-detector was used to measurement of a plasma pressure in Pulsed Plasma Accelerator (PPA) PROSVET and in Plasma Focus (PF). Based on results of plasma pressure measurements another parameters of plasma, like a plasma stream velocity and an average ions energy, were calculated.

Introduction

To well understanding the interaction between the plasma and the material it is necessary to well determine of plasma parameters, like the pressure, the energy, plasma density and others. The aim of this work is an examination of feasibility of apply the piezo-detector to analysis the parameters of plasmas. The plasmas were generated in two in two, differ devices: in Plasma Focus (PF) and in Pulsed Plasma Accelerator (PPA) PROSVET. Both devices operate in pulsed regime and both can be used in material engineering.

Experimental set-up

PPA consists of two coaxial copper electrodes installed into a vacuum chamber. The centre electrode (a cathode) was 50 mm of a diameter. The outer electrode (an anode) was 140 mm of a diameter. The power is supplied by a condenser bank with a maximum stored energy of up to 68 kJ. PF consists of two coaxial electrodes isolated by alumina insulator sleeve. The outer electrode (a cathode) was constructed from twelve stainless steel bars (with a bar diameter 12 mm). The centre electrode (an anode) was made of copper and it diameter was 25 mm. The power is supplied by a condenser bank with the maximum stored energy of up to 19 kJ. Constructions of these device was detailed described and shoved in earlier paper [1,2].

Plasmas were characterized by using the piezo-detector (Fig. 1). The detector measured the plasma pressure in definite zone of a reactor chamber. The velocity of plasma stream was

carried out by time of flight method. The average ions energy was calculated from the velocity and an atomic mass of ions.

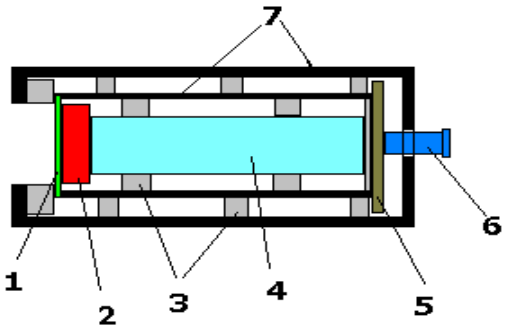

Fig. 1. Schema of piezodetector: 1 - protective insulator, 2 - piezo-ceramic pill, 3 and 5 - elastic gaskets, 4 - lead rod, 6 - hold-down screw, 7 - metal case (screen)

In this experiment PPA used krypton as working gas. Discharge voltages ranged from 15 to 22 kV. PF operated in argon atmosphere at 0.6, 1 and 1.5 Tr of the pressure. Discharge voltage was keep at 10 kV.

Results

On the beginning the results obtained by using PPA will be shown. Basing on information about the plasma pressure in various place of the reactor chamber and velocity of plasma stream there were calculate the plasma density and the average ions energy. The results are shown in Fig. 2. The duration, measured by the piezo-detector, of a plasma flow was equaled 5-6 μs. The measured plasma pressure in the compression zone is $P=nk(T_e+T_i)$, and dynamical pressure of the plasma stream outside of compression region is determined as $P=nmv^2/2$. The plasma density in the compression zone estimated from the pressure measurements achieves $n\sim(2.5\text{-}7)\times10^{14}cm^{-3}$. This value is in reasonable agreement with electron density measurements by Stark broadening of spectral lines ($n\sim4\times10^{14}cm^{-3}$). The plasma stream velocity strongly depended on the discharge voltage. The velocity increased with the voltage increasing. The average ions energy is proportional to the velocity and an atomic mass of ions. The atomic mass of krypton ions is constant, so only the velocity influents on the ions energy. The energy which can be stored in energy bank increases proportionally to the square of the voltage. A part of this energy is transferred to ions during the discharge. And, if the energy in condenser bank is increased then more energy can be transferred to ions. Consequently, the velocity and the ions energy increased.

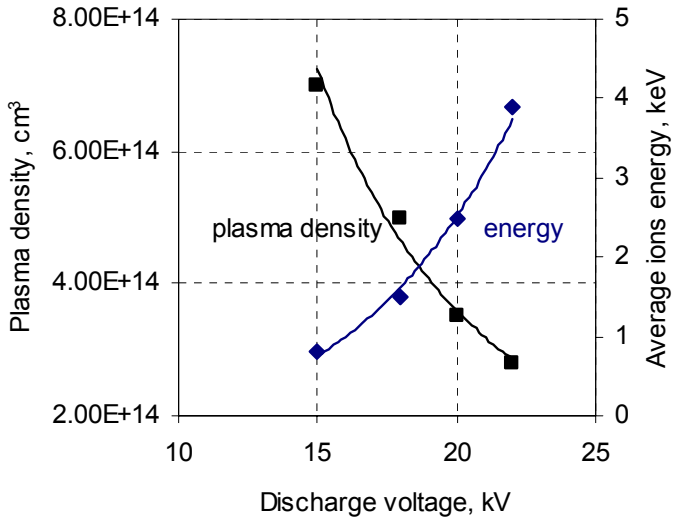

Fig. 2. Influence of the discharge voltage on the plasma density and the average ions energy

Now, the results obtained using PF will be shown. During the experiments the plasma pressure was measured at the distance 4 and 9 cm from electrodes. The duration, measured by the piezo-detector, of a plasma flow was equaled 1-2 μs. Next, the plasma density and the average ions energy were calculated. The plasma density and average ions energy is shown on fig. 3 for various argon pressures. The plasma density is not very changed at variation of argon pressure in chamber from 0.6 to 1 Tr. Its value is equal to $2.5 \times 10^{14} cm^{-3}$. When the argon pressure increased to 1.5 Tr, then the plasma density decreased to $2.3 \times 10^{14} cm^{-3}$. The ions energy also decreased with the argon pressure increasing (Fig. 3) because, as it is mentioned earlier, it is proportional to the velocity. Why the velocity decreased? It can be explained as follows: the energy which was stored in energy bank was constant in all experiments because the voltage was constant. Consequently, the part of the energy from the condenser bank, which can be transferred into gas particles during the discharge, was also constant. However, the number of particles increased with the argon pressure increasing. So, if the energy from the condenser bank was transferred to larger number of particles, then each particle take over lower energy. Finally, the average ions energy decreased.

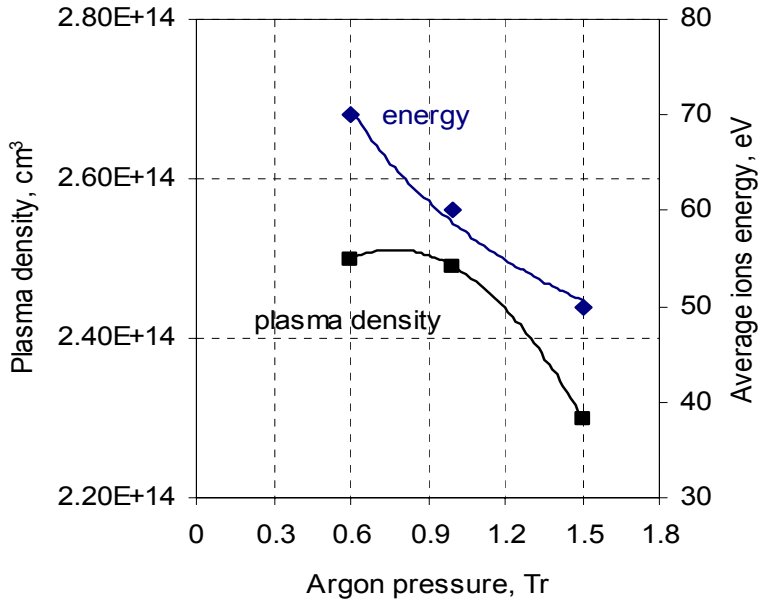

Fig. 3. Influence of the argon pressure on the plasma density and the average ions energy

Conclusions

Measurements of the plasma pressure with high spatial and temporal resolutions are of importance for the investigation of the plasma dynamics in such plasma sources, of compression effects and of plasma stream interaction with different materials. The results show that the piezo-detector can be applied to the plasma diagnostic. Detectors provide us about many plasma characteristics – plasma density, duration, directed ion energy, velocity with high temporal resolution. It works well in various devices, where it can be used to the plasma generation. The piezo-detector gives information about the plasma pressure in various places of plasma generators. Basing on these information, the plasma density and the average ions energy can be calculated.

Acknowledgements

We acknowledge the support of the International Atomic Energy Agency (project code POL/1/013)

References

[1] V.Tereshin, A.Bandura, O.Byrka, V.Chebotarev, I.Garkusha, O.Shvets and V.Taran, Vacuum **73**, 555 (2004)

[2] M.Chernyshova, I.Ivanova-Stanik L.Karpiński, M.Scholz, B.Ulejczyk, I.N.Demchenko and J.K. Lee, Czechoslovak Journal of Physics **B 56,** 237 (2006)