Nuclear Instruments and Methods in Physics Research A 676 (2012) 18–20

Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

# Measurement of plasma parameters of an ion source for EAST-NBI using water-cooled Langmuir probe

Yahong Xie *, Chundong Hu, Sheng Liu, Jun Li, Caichao Jiang

*Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, PR China*

ARTICLE INFO

*Article history:*
Received 18 January 2012
Received in revised form
8 February 2012
Accepted 12 February 2012
Available online 18 February 2012

*Keywords:*
High current ion source
Langmuir probe
Arc discharge
Electron density

ABSTRACT

As the langmuir probe is a famous diagnosis tool for plasmas, the langmuir probe with cooling water is developed for an EAST-NBI high current ion source. Using the sawtooth wave sweeping power, the electron temperature and density are measured for the first time, and the plasma uniformity is analyzed with three langmuir probes. They are very useful to study the characteristics of high current ion sources.



## 1. Introduction

A High current ion source is one of the most important parts of plasma heating equipment for fusion device. Many researches have been done to achieve a high performance of the ion source[1–3]. In order to develop the 4 MW EAST-NBI project, the high current ion source was developed and tested primarily in ASIPP [4]. In order to further study the characteristics of the high current ion source, the langmuir probe is employed as a diagnosis tool to diagnose the plasma parameters, such as electron temperature and electron density. Since the EAST-NBI ion source is a high current ion source, the langmuir probe is developed with cooling water is required to avoid probe damage during the arc discharge. The development of langmuir probe is introduced and the experimental results of plasma parameters measurement are also analyzed.

## 2. The langmuir probe system

The langmuir probe [5–6] is one of the most famous diagnostic tools to measure the plasma parameters, especially for low temperature plasmas, such as ion source plasma. Considering the high current ion source, the langmuir probe with cooling water is developed, which is shown in Fig. 1. There are two cooling water pipes, to remove the heat from the probe tip and probe body. Between the inner and outer pipes, the ceramic is used as an insulator, and the probe signal can be transmitted through the inner pipe.

The probe tip, which is made of molybdenum has the shape of a cylinder with the diameter of 1 mm, and its surface area is of 10.68 $mm^2$. The langmuir probe is installed near the surface of plasma grid, which is shown in Fig. 2. The dimension of plasma chamber is 650 mm(L) × 260 mm(W) × 300 mm(D), and the extraction area is 120 mm × 480 mm. The sawtooth wave power is applied on the probe tip from 0 V to 160 V in 30 ms and the classical probe current–voltage characteristic curve can be obtained by the slope of sweeping voltage. According to the langmuir probe theory [5], the electron temperature can be calculated by the transition region of current–voltage curve and electron density can be calculated by the ion saturation current or electron saturation current. For the hydrogen plasma, the electron temperature $T_e$ can be solved by

$$Te = \left| \frac{dV}{d\ln(I+I_{i0})} \right| \tag{1}$$

where $T_e$ is electron temperature in eV unit, $V$ is probe voltage, $I$ is probe current and $I_{i0}$ is ion saturation current. The electron density $n_e$ can be calculated when the electron temperature is given as follows:

$$n_e = \frac{I_{i0}}{2.2 \times 10^{-15} S\sqrt{T_e}} \tag{2}$$

where $S$ is the surface of probe tip, $S = 10.68\ mm^2$.

## 3. Plasma parameters measurement on EAST-NBI ion source

In the arc chamber, three langmuir probes are installed in three different directions. The sawtooth wave power is connected in the circuit of probe as reported before [7], and a bias voltage is used to get the ion saturation current. Each probe can measure the plasma

* Corresponding author.
*E-mail address:* xieyh@ipp.ac.cn (Y. Xie).

0168-9002/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2012.02.018

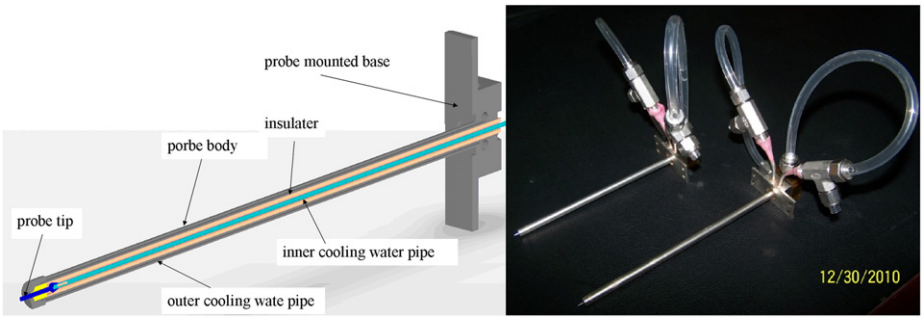


**Fig. 1.** Structure and picture of langmuir probe with cooling water.

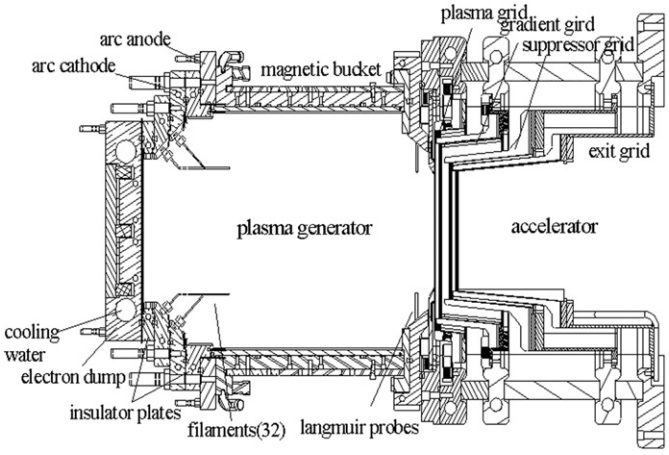


**Fig. 2.** Schematic of megawatt high current ion source. The dimension of plasma chamber is 650 mm(L) × 260 mm(W) × 300 mm(D).

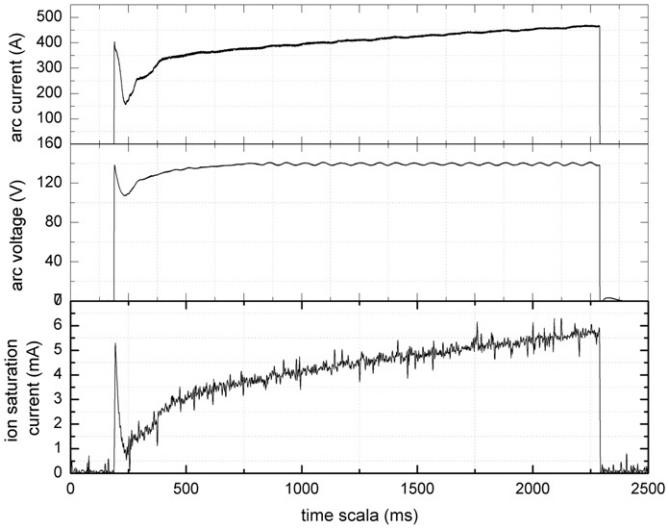


**Fig. 3.** Experimental waveform of arc discharge (Shot no: 20110991). Arc voltage is 140 V, arc current is 450 A, and probe ion saturation current is 5.5 mA.

parameters, and all of them can be used to analyse the plasma uniformity.

The ion source discharge parameters in the experiment are listed as follows: arc voltage is 140 V; arc current is 450 A; arc pulse length is 2000 ms; ion source background pressure is $5.0 \times 10^{-4}$ Pa; and discharge pressure is approximately $10^{-1}$ Pa with hydrogen gas. The experimental waveform is shown in Fig. 3. The arc voltage is 140 V, and the arc current increases from 100 A to 450 A. The probe ion saturation current has the same trend of arc current, an increase from 1 mA to 5.5 mA. This attributed to the self-heating of filaments, which because of the filament power supply and arc power supply share the same negative port. The probe current–voltage characteristic curve obtained using the sawtooth wave sweep power in 30 ms. The current–voltage characteristic curve is analyzed and $T_e$ and $n_e$ is calculated in each 250 ms. The $T_e$ and $n_e$ are listed as a function of time, as shown in Fig. 4.

From Fig. 4 we can see that, the electron temperature has decreased and electron density is increased. The electron temperature decrease is caused by more primary electrons emitted from the filaments into the plasma while the plasma energy does not increase so fast. The electron density increase is attributed to the increase of electron density and better confinement of plasma.

Furthermore, the plasma uniformity was studied using the ion saturation current measured by three langmuir probes. The plasma density uniformity is better than 87% near the extraction grids.

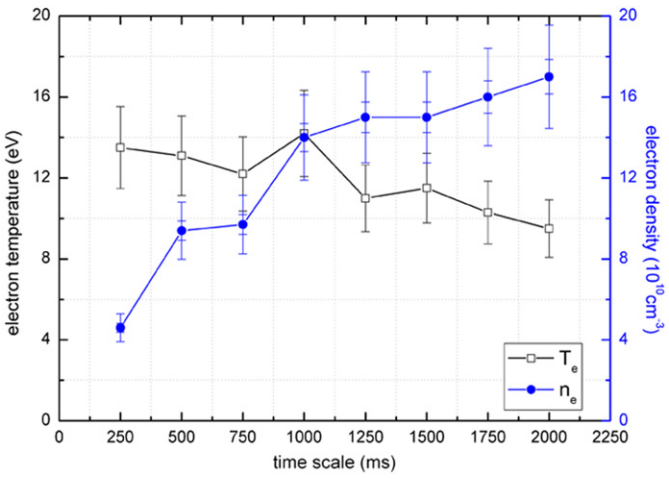


**Fig. 4.** Electron temperature and density vary as a function of time. The mean electron temperature is 12 eV and the mean plasma density is $1.4 \times 10^{11}$ cm$^{-3}$.

## 4. Conclusions and discussions

The langmuir probe with cooling water has been developed in ASIPP successfully. Using the sawtooth wave sweeping power supply, one obtains the probe current–voltage characteristic curve in every 30 ms. The plasma parameters of EAST-NBI high current ion source are measured during the arc discharge, and gets the information of electron temperature and density as a function of discharge pulse are obtained. Three langmuir probes are employed to measure the ion saturation current to analyze the plasma uniformity in the plasma chamber before the extraction grids.

During a round experiment, the probes work with the long pulse length of 12 s and high current of 850 A without damage. It shows that, the langmuir probe with cooling water can work well as a diagnostic tool for high current ion sources.

With the help of langmuir probe, the parameters of EAST–NBI high current ion sources were diagnosed for the first time. It is useful in studying the characteristics of ion source. More useful and interesting works and results will be reported in the future.

## Acknowledgment

This work was supported by the National Natural Science Foundation of China (Contract no. 11075183) and the Knowledge Innovation Program of the Chinese Academy of Sciences (Study of the physical characteristics of arc power feedback control for the high current ion source).

## References

[1] C.C. Tsai, W.L. Stirling, H.H. Haselton, R.C. Davis D.E. Schechter, in Proceedings of the 7th International Symposium on Engineering problems of Fusion Research, New york, 1977, pp. 278–283.
[2] K.N. Leung, Review of Scientific Instruments 65 (1994) 1165.
[3] M.R. Jana, S.K. Mattoo, A.K. Chakraborty, U.K. Baruah, G.B. Patel, P.K. Jayakumar, Fusion Engineering and Design 83 (2008) 729–735.
[4] C.D. Hu, Y.H. Xie, S. Liu, Y.L. Xie, C.C. Jiang, S.H. Song, J. Li, Z.M. Liu, Review of Scientific Instruments 82 (2011) 023303.
[5] I.H. Hutchinson, Principles of Plasma Diagnostics, 2nd ed., Cambridge University Press, Cambridge; New York, 2002.
[6] Z.L. Xiang, High Temperature Plasma Diagnostic Technology, 2nd ed., Shanghai Scientific and Technical Press, Shanghai; China, 1982 [in Chinese].
[7] Y.H. Xie, C.D. Hu, S. Liu, S.H. Shong, C.C. Jiang, Z.M. Liu, Fusion Engineering and Design 85 (2010) 64.