GRID FORM EFFECT ON THE SENSITIVITY OF A FAST IONIZATION GAUGE

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Abstract

It is indispensable to measure the pressure inside the vacuum vessel of magnetic confinement fusion devices to understand the plasma confinement and divertor characteristics. For this purpose, we made a fast ionization gauge and examined the performance. With the fast ionization gauge, sensitivity could be restrained to less than 100 $Torr^{-1}$ by changing the grid form, the applied voltage and the control plate to measure even in a high pressure range, such as in the divertor region. The relative sensitivities to nitrogen were estimated for various gases using a B-A gauge. They gave values of 0.45 and 0.19 for hydrogen and helium, respectively.

1. Introduction

It is important to measure the neutral gas pressure around the plasma in magnetic confinement fusion devices to understand the plasma confinement characteristics. The pressure inside the device equipped with a divertor is also important to understand the divertor characteristics such as particle exhaust and removal of impurities. The requirements for the vacuum gauge are as follows: good applicability in the magnetic field, fast response and low sensitivity to noises. The fast ionization gauge developed by the ASDEX team [1] meets these three requirements. However, its characteristics have not been sufficiently reported. We made a fast ionization gauge and investigated its sensitivity performance. Experiments on the effect of the grid and control plate forms and the magnetic field direction on the sensitivity were carried out for this purpose.

2. Grid form effect

A schematic description of the fast ionization gauge [2] used in our experiment is given in Fig. 1. Most of the electrons emitted from the filament go through the grid and oscillate be-

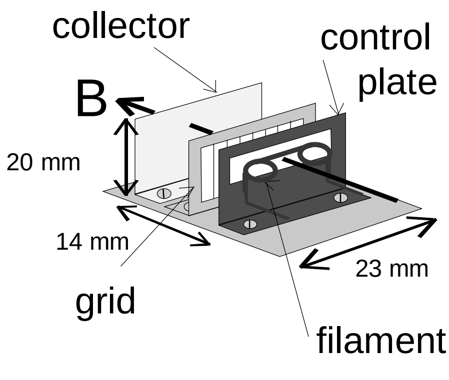

Fig. 1. Schematic view of fast ionization gauge

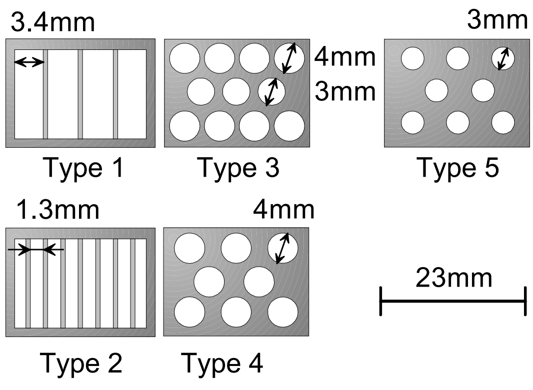

Fig. 2. Schematics of various grids

tween the filament and collector. The ions produced by electron bombardment are captured by the collector. The control plate adjusts the emission of thermal electrons.

Several grid types are illustrated in Fig. 2. Type 1, 2 grids have slits and Type 1 has wider spacing. Type 3-5 grids have circular holes and the transparency rate are 29%, 22% and 17%, respectively. The sensitivity of each gauge was evaluated under a nitrogen gas pressure of 3×10^{-5} Torr by using a cold cathode gauge that utilized the Penning discharge (IKR250, Balzers Ltd.). The experimental results are shown in Fig. 3. As the transparency rate of the grid increases, the higher sensitivity is obtained. When the transparency increases, the total distance traveled by an electron becomes longer, and the number of ions produced by electron impacts increases. As a result, the sensitivity rises as the transparency rate increases.

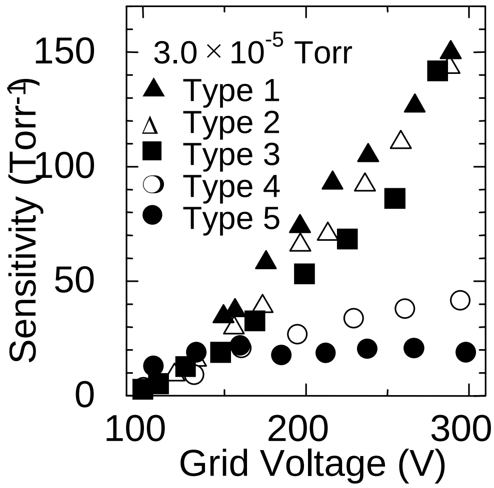

Fig. 3. Gauge sensitivity vs. grid voltage for different grid types.

When the sensitivity is very high, the measurable upper pressure becomes low. The sensitivity should be maintained less than 100 $Torr^{-1}$ to measure the pressure around the divertor region. Therefore, it is necessary to limit the grid voltage to the value of less than 200 V.

3. The effect of magnetic field direction

The direction of the magnetic field in tokamaks changes during operation. If the change of the magnetic field direction greatly affects the sensitivity of the fast ionization gauge, this gauge could not be used as vacuum gauge [3,4]. For this reason, we conducted experiments on the effect of the magnetic field direction on the gauge sensitivity. The experimental result is shown in Fig. 4. The sensitivity is kept nearly constant within the error bars even when the direction of the magnetic field varied in the range of ±8°.

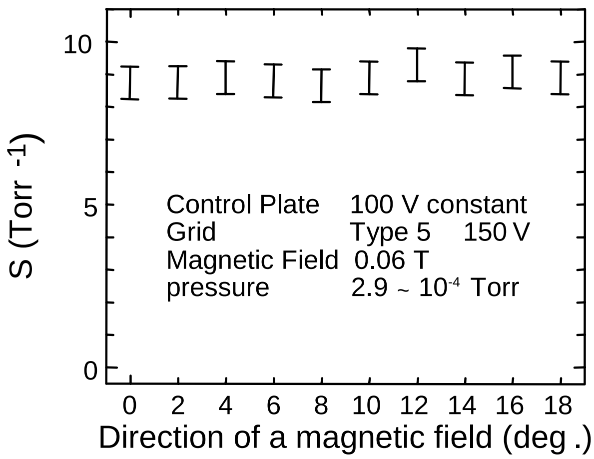

Fig. 4. Gauge sensitivity against the direction of the magnetic field

4. Control plate effect

The control plate is used to adjust the emission of thermal electrons. The voltage applied to the control plate is 1-kHz square-waves. It is positively (emission on mode) and negatively (emission off mode) biased against the filament. By subtracting the data of the emission off mode from that of the emission on mode, it is possible to reduce plasma-induced noises. We also investigated the size effect of the control plate window on the sensitivity. The forms of the control plate are shown in Fig. 5.

Table I Experimental conditions

Filament Bias Voltage	60 V
Control Plate Bias Voltage	±93 V, 1-kHz
Grid Type	Type 4
Grid Bias Voltage	125 V
Magnetic Field	0.09 T
Pressure	1.5×10^{-3} Torr

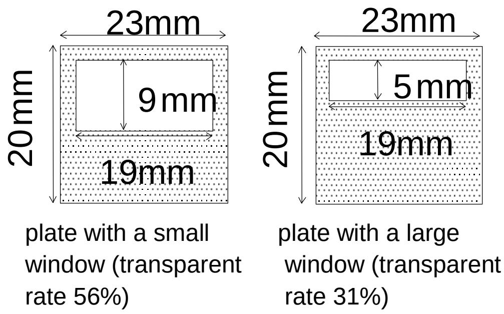

Fig. 5. Schematic of the control plate

Experimental conditions are given in Table I. The experimental results shown in Fig. 6 reveal the following facts: the sensitivity with the small window is higher than that with large one, while the number of electrons which pass through the small window is reduced compared with that of the large window. In spite of the increase in the electron current, the ion current decreases in the case of large window plate.

The following can be considered as the reasons. Many electrons which are not absorbed by the control plate are accumulated around the grid. Accordingly, the grid periphery is electrically charged and the space potential decreases [5]. The applied voltage between the grid and the collector decreases as the result of the decreased space potential around the grid periphery. If electrons are not sufficiently accelerated, atoms are hardly ionized by inelastic collisions with electrons.

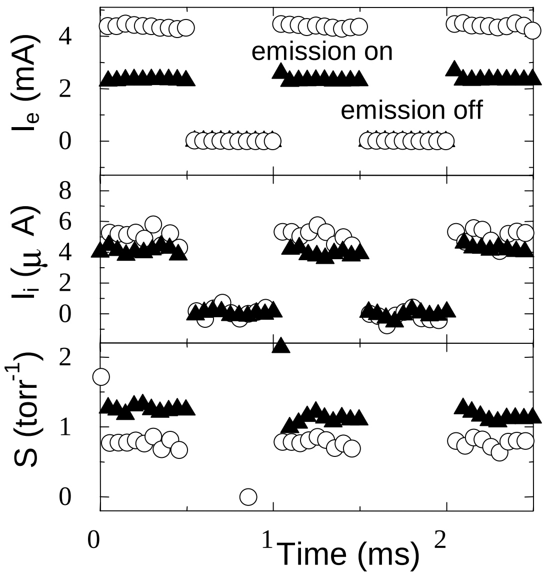

Fig. 6. Modulation traces of the gauge sensitivity, electron current and ion current with different control plate windows.

The applied voltage effect on the sensitivity was also investigated. The experimental result is shown in Fig. 7. Experimental conditions are given in Table II. From the experiment, it was confirmed that the electron current increases and ion current decreases with increasing applied voltage to the control plate. Therefore, the sensitivity is reduced when the voltage is applied.

Table II Experimental conditions

Filament Bias Voltage	60 V
Control Plate	1-kHz
Grid Type	Type 4
Grid Bias Voltage	125 V
Magnetic Field	0.10 T
Pressure	1.6×10^{-3} Torr

5. The relative sensitivity

Relative sensitivities of various gases to nitrogen gas were investigated for the fast ionization gauge because the ionization gauge sensitivity varies with the kind of measured gas. A Bayard-Alpert (B-A) gauge (DIAVAC Ltd.) was used for the calibration. The experimental results are summarized in Table III. The results of this calibration are in good agreement with the relative sensitivities of the B-A gauge [6]. Therefore, the relative sensitivity is expected to be determined by ionization cross sections of the gas.

Table III. Relative sensitivities among three gases of the fast ionization gauge and B-A gauge

	N_2	He	H_2
Fast Ionization	1.00	0.45	0.19
B-A Gauge	1.00	0.44	0.19

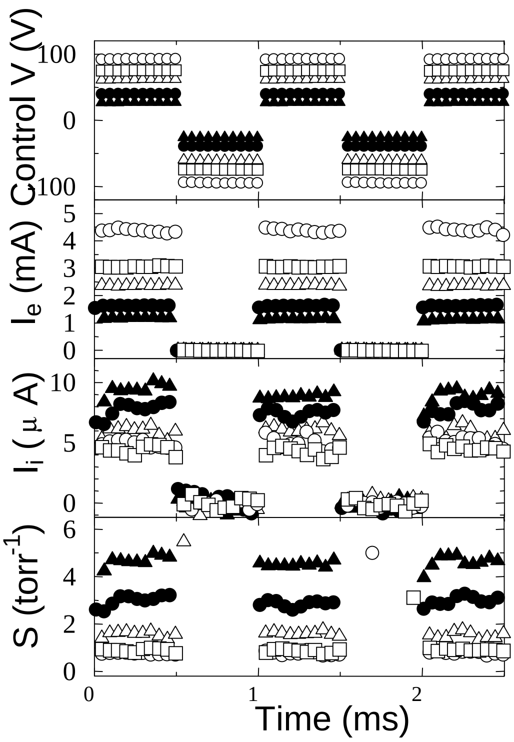

Fig. 7. Traces of the gauge sensitivity, electron current and ion current. Different symbols stand for different control plate voltages.

6. Conclusions

An experimental study on fast ionization gauge which can be used in higher upper limit of the neutral gas pressure has been conducted. The following two points were emphasized to optimize the ionization gauge sensitivity.

- The forms and bias voltages of the grid
- The size and applied voltage of the control plate window

Through these procedures, the basic data on the fast ionization gauge sensitivity were obtained. And the sensitivity was confirmed to be nearly constant against up to ±8° changes of the magnetic field direction.

Fast ionization gauge proved itself to be capable of measuring the pressure even in the case of modulating the control plate bias voltage to a frequency of 1-kHz to subtract plasma-induced noises. The relative sensitivities to nitrogen gas were estimated for two gases using a B-A gauge. They gave values of 0.45 and 0.19 for hydrogen and helium, respectively.

References

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