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Neutral pressure measured by fast ionization gauge in HL-2A

M.X. Wang *, L.W. Yan, W.Y. Hong, Z.Y. Cui, Y.D. Pan, L.H. Yao, Z. Cao, Q.W. Yang, Y. Liu

Southwestern Institute of Physics, P.O. Box 432, No. 3, South Section 3, Ring Road 2, Chengdu, Sichuan 610041, China

Abstract

A fast ionization gauge capable of working in a strong magnetic field and noisy environment is developed for the pressure measurement in the main chamber and the divertor chamber of the HL-2A tokamak. The neutral pressure in the main chamber evidently decreases after in-situ siliconization. Improvement of boundary plasma confinement is observed with SMBI or PI fueling after siliconization. The neutral pressure in the main chamber for divertor configuration is 50% lower than that for limiter one. The pressure in the divertor chamber rises when the strike point moves toward the bottom of the vertical target plates. The maximum pressure compression of is 24. The relative high pressure in the main chamber is contributed primarily by plasma limiter interaction due to the short distance from separatrix to limiter and secondly by neutral flux from the divertor chamber to the main chamber by leaks in HL-2A.

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Keywords: Neutrals; Particle balance; Fast ionization gauge; Divertor

1. Introduction

Neutral flux from the wall and its gas pressure has crucial influence on the core and divertor plasmas, which can determine the plasma operation region. Both low pressure in the main chamber and high pressure in the divertor chamber are requested in an advanced tokamak. High level of neutrals near plasma can degrades the energy confinement and increases the particle flux to wall to result in more impurity flux into plasma. High pressure in the divertor chamber can produce large power radiation to reduce the heat load onto the divertor target plates and then to obtain radiation divertor or detachment divertor discharges. Therefore, pressure measurement is important for advanced tokamak operation and researches on particle transport and balance necessary to improve plasma confinement. Commercial hot cathode ionization gauges are not competent for the measurement of neutral gas pressure due to strong magnetic field, energetic particles and strong noise environment, as well as fast response (1–10 ms) requirement of neutral gas pressure measurement in tokamaks. ASDEX-type hot cathode ionization gauges capable of working in strong magnetic field and strong noisy environment

* Corresponding author. Fax: +86 28 82850956.
E-mail address: wangmx@swip.ac.cn (M.X. Wang).

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were used to measure neutral gas pressure at interesting locations in some tokamaks, such as ASDEX, JET, DO-D, TdeV, et al. [1,2].

HL-2A is a tokamak with upper and lower closed divertors. In order to research on particle behaviors, and to control the neutral gas pressure actively to further obtain radiation or detached divertor discharges in the divertor chamber, a special fast ionization gauge (fast gauge for short) similar to ASDEX-type gauge is developed to measure the neutral gas pressure in the main chamber and the divertor chamber of the HL-2A tokamak during discharges [3]. This paper presents the results of neutral pressure in the main chamber and the lower divertor chamber in flat top phase and discusses the effects of wall conditioning and fuelling on the neutral pressure.

2. Experimental arrangements

The fast gauge with the resolution of 3 ms and the measurement range of 6×10^{-5}–1.4 Pa for H_2 has been developed to measure neutral pressures in the main chamber and the lower divertor of HL-2A. It is designed into a plate tetrode. A thick filament is used as the thermal cathode to be sufficiently strong to withstand the $E\times B$ (electromagnetic force) force. The fast gauge is operated in modulation–demodulation of electron emission current and ion current to discriminate a small signal from noisy environment in tokamaks.

Main parameters of the HL-2A tokamak are major radius of $R = 1.64$ m, minor radius of $a = 0.4$ m, volume of 26 m^3 and inner surface of 67 m^2. Ultra high vacuum of 4×10^{-6} Pa is achieved by 8 sets of turbo-molecule pumps in the upper and lower closed divertors with the speed of 8×3500 l/s, 2 sets of condensation pumps with the speed of 2×10000 l/s in the main chamber. The base pressure without discharges is measured with the commercial ionization gauges located at the pumping systems. The fixed and movable limiters and the divertor throat are covered with about 2.8 m^2 graphite tiles. About 13 m^2 of CFC sheets is attached on the surface of main chamber. The neutral pressure is measured by two sets of fast ionization gauges fixed in the mid-plane of main chamber and in the lower divertor chamber, as shown in Fig. 1. Since the fast gauges are powered off during siliconization, variation of the sensitivity coefficient of the fast gauge can be neglected.

3. Experimental results

It has been well known that low neutral pressure near plasma can reduce the energetic neutral particle flux to wall, which can decrease the level of impurities into plasma and be correlated with the lower power threshold of L–H transition, improve plasma confinement performances. Therefore, the neutral pressure in the main chamber and divertor chamber is researched in HL-2A.

Discharges with highest line-average density of 2.5×10^{13} cm^3 are obtained before wall conditioning. After siliconization, plasma with higher density and longer duration can be easily obtained in HL-

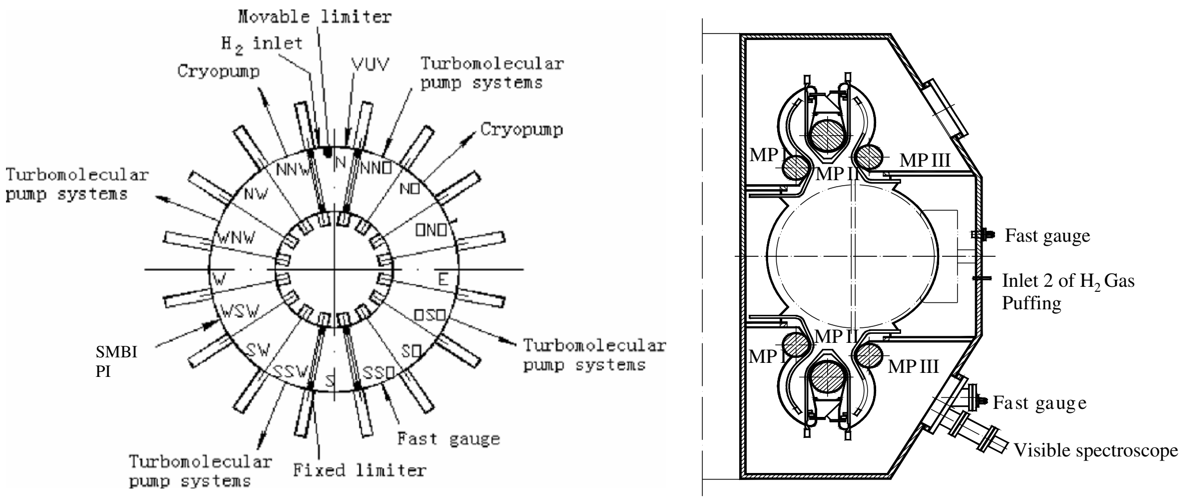

Fig. 1. Toroidal hardware arrangement and poloidal arrangement of fast ion gauge in HL-2A.

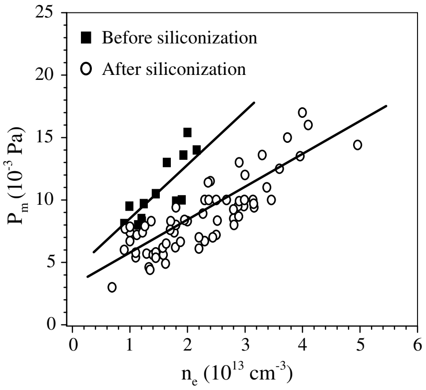

Fig. 2. Neutral pressure before and after in-situ siliconization.

2A. Fig. 2 shows comparison of the neutral pressure before and after siliconization. The neutral pressure in the main chamber is $(0.5–2) \times 10^{-2}$ Pa for line-average density of $(0.5–2.5) \times 10^{13}$ cm^3 in limiter configuration with original wall state, i.e. graphite tiles, CFC and stainless steel. After siliconization, the pressure in main chamber decreases to $(0.45–3) \times 10^{-3}$ Pa for line-average density within $(0.5–5) \times 10^{13}$ cm^{-3}, which results from reducing the hydrogen recycling of the first wall. After siliconizaiton, the pressure in main chamber, emission intensity of Hα, as shown in Fig. 3, drops transiently with electron density rise during supersonic molecule beam injection (SMBI) or the 2nd pellet injection (PI), while OVI and loop voltage do not vary. This has never been observed with normal gas puffing (GP) or without siliconization. The results imply that the boundary particle confinement is improved. While the electron density does not rise, the pressure in the main chamber shown in Fig. 3(b) does not drop transiently during the 1st and 3rd pellet injection. It indicates that the transient drop in pressure near plasma occurs in the case of fuelling into plasma with SMBI or PI after siliconization.

Although it is difficult to move the location of plasma striking point on the divertor target plates due to the limitation of magnetic field configuration of HL-2A, it is also observed that the pressure in the divertor chamber rises when the location of the striking point moves to the bottom of the outer vertical target plates. The dependences of the pressure in the main chamber and the lower divertor on line-average density in divertor configuration are shown in Fig. 4. The pressure in the main chamber and the lower divertor chamber increases with line-average density. The pressure in the main chamber is $(0.13–2.7) \times 10^{-2}$ Pa for line-average density of $(0.3–4) \times 10^{13}$ cm^3 in divertor configuration, about 50% lower than that for limiter one due to the reduction of plasma–wall interaction in the main chamber, while the pressure in lower

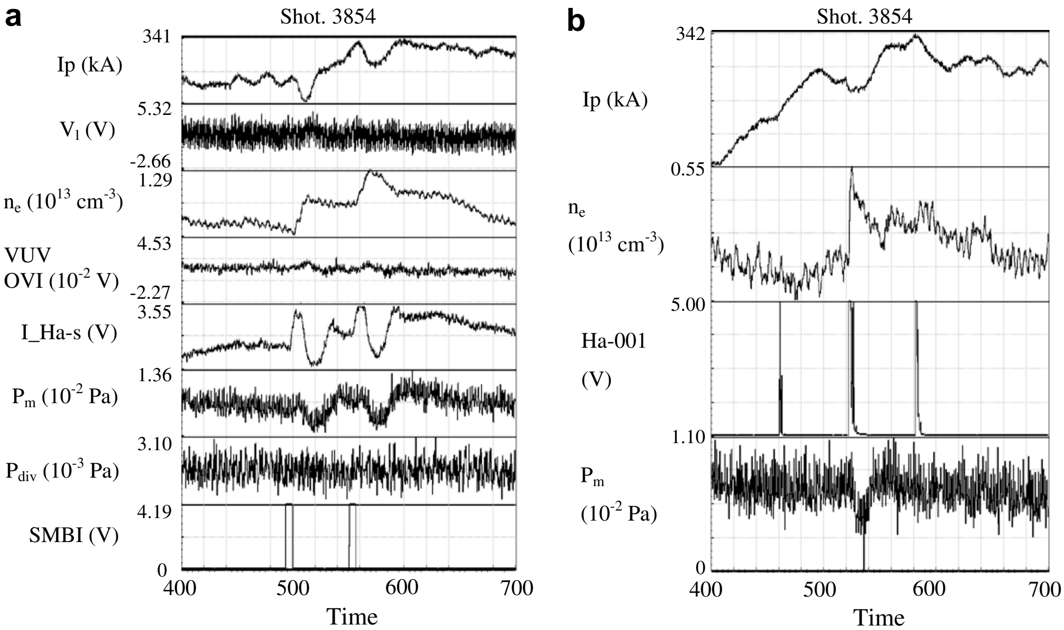

Fig. 3. Effects of SMBI and PI fueling on plasma parameters after in-situ siliconization. (a) SMBI, (b) PI.

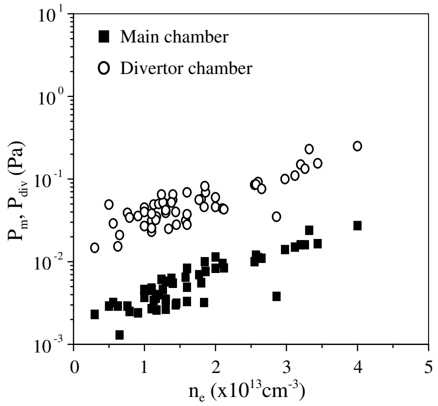

Fig. 4. Neutral pressures in main chamber and in divertor chamber versus line-average density.

divertor is $(1.5–24) \times 10^{-2}$ Pa. The compression, defined as a ratio of the pressures in the divertor chamber to that in the main chamber, is from 8 to 24.

The width of the throat between the main chamber and the divertor chamber is only 3.6 cm. It is difficult for SOL plasma to be all diverted into the divertor chamber at high density. The relative high neutral pressure in the main chamber is contributed primarily by plasma limiter and wall surface interaction due to the short distance from the separatrix to the limiter (surface) and secondly by the neutral flux from the divertor chamber to the main chamber by leaks between the divertor chamber and the main chamber in HL-2A due to the special divertor configuration.

4. Conclusions

A fast ionization gauge capable to work in a strong magnetic field and noisy environment is developed for the pressure measurement in the main chamber and the divertor chamber of the HL-2A tokamak. The neutral pressure in the main chamber is $(0.5–2) \times 10^{-2}$ Pa for line-average density of $(0.5–2.5) \times 10^{13}$ cm^3 with limiter configuration, while the neutral pressure in the divertor chamber is $(0.75–5) \times 10^{-3}$ Pa. The neutral pressure in the main chamber for divertor configuration is $(0.13–2.7) \times 10^{-2}$ Pa for line-average density of $(0.3–4) \times 10^{13}$ cm^3, 50% lower than that for the limiter one due to the reduction of plasma–wall interaction in the main chamber. The pressure in the divertor chamber is $(1.5–24) \times 10^{-2}$ Pa, which further rises when the strike point moves toward the bottom of the vertical target plates. The maximum compression of the neutral pressure between the divertor chamber and the main chamber is a factor of 24. It is difficult for SOL plasma to be all diverted into the divertor chamber at high density, which may be a reason of the low pressure compression. After in-situ siliconization, the neutral pressure in the main chamber decreases to $(0.45–3) \times 10^{-3}$ Pa for line-average density within $(0.5–5.5) \times 10^{13}$ m^{-3}. The transient improvement of boundary particle confinement is observed during SMBI or PI, which needs more experiment to researches. These behaviors are not observed during the GP and without the siliconization. The relative high neutral pressure in the main chamber is contributed primarily by plasma limiter interaction due to the short distance from the separatrix to the limiter surface and secondly by the neutral flux from the divertor chamber to the main chamber by leaks in HL-2A due to the special divertor configuration.

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