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Measurements of H-atom Density by a Catalytic Probe

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ABSTRACT

One of the important plasma parameters in tokamaks is the density of neutral hydrogen atoms which can be measured by catalytic probes. The method is based on the catalytic recombination of H atoms on the metal surface. In order to prevent a substantial drain of atoms by the probe, it should be made as small as possible. But still this effect can not be neglected. Therefore a study of the influence of a catalytic probe on the H-atom density was performed. The source of neutral H-atoms was inductively coupled RF hydrogen plasma. The gas from the discharge vessel was leaked to an experimental chamber through a narrow tube with the diameter of 5 mm and the length of 6 cm. Charged particles created in the discharge vessel were recombined on the walls of the narrow tube, so that the gas entering the experimental chamber was a mixture of hydrogen atoms and molecules only. The density of H-atoms in the experimental chamber was measured with two nickel catalytic probes. One probe was at fixed position and the other one was made movable. A change in the probe signal of the fixed probe was measured versus the position of the movable probe. The measurements were performed at the pressures between 10 Pa and 200 Pa and at two different RF powers 200 W and 300 W. It was found that the density of neutral hydrogen atoms was reduced for about 20% due to the presence of the probe. This result was independent from the pressure in the experimental chamber.

1 INTRODUCTION

One of the most important plasma parameters is the density of neutral hydrogen atoms which can be measured by catalytic probes [1-4]. A catalytic probe is basically just a piece of metal immersed into a H rich atmosphere. As a catalyst material nickel is usually used. In order to prevent a substantial drain of atoms by the probe, it should be made as small as possible. A typical dimension of a catalytic probe is 1 mm. The method is based on the catalytic recombination of H atoms on the metal surface. The probability for recombination of H-atoms ($H+H \rightarrow H_2$) on nickel surface is 0.2. During a recombination event a certain amount of energy (4.48 eV) is released on the metal surface causing the catalyst to heat up. The heating rate is a function of the H-atom density in the vicinity of the catalyst. By taking into account physical laws it is possible to derive the atom density from measurements of the catalyst temperature. Due to recombination of H-atoms on the probe surface, the probe itself disturbs the H-atom density. The aim of the present work was to study the influence of a catalytic probe on the H-atom density.

2 EXPERIMENTAL

The experiments were performed in a vacuum system shown in Figure 1. The system was pumped with a two-stage oil rotary pump with a pumping speed of 16 m3/h. The discharge chamber was a Pyrex cylinder of the length of 200 mm and of the inner diameter of 36 mm. A Pyrex tube of the inner diameter of 5 mm and length of 6 cm leaded to the post-discharge chamber, which was also a Pyrex cylinder of the length of 400 mm and of the inner diameter of 36 mm. Plasma was created inside the discharge chamber with an inductively coupled RF generator, operating at the frequency of 27.12 MHz and at the output power of 200 W and 300 W. Commercially available hydrogen was leaked into the discharge chamber. The pressure was varied in the range from 10 Pa to 200 Pa. At these discharge parameters the electron temperature was 5 eV and the ion density was about 10^{16} m^{-3}. The charged particles created in the discharge chamber were effectively recombined on the walls of the narrow tube between the discharge and post-discharge chamber so its density in the latter was negligible. The density of neutral hydrogen atoms in the post-discharge chamber was measured with the nickel catalytic probe shown in Figure 2. Details of the probe construction and its operating characteristics can be found elsewhere [5]. The H-atom density was close to 10^{22} m^{-3}.

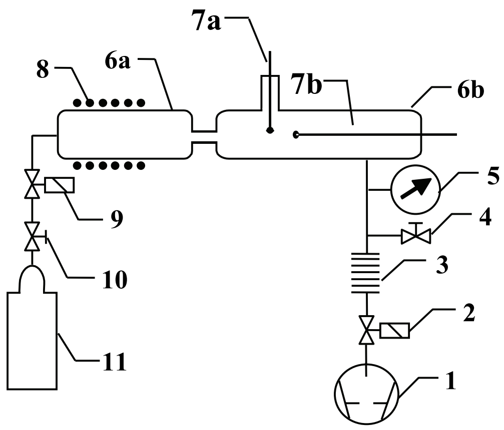

Figure 1: Schematic of the experimental setup: 1 – rotary pump, 2 – gate valve, 3 – Hopkins trap, 4 – air inlet valve, 5 – vacuum gauge, 6a – discharge chamber, 6b – post-discharge chamber, 7a – fixed Ni catalytic probe, 7b – movable Ni catalytic probe, 8 – RF coil, 9 – leak valve, 10 – high-pressure valve, 11 – oxygen.

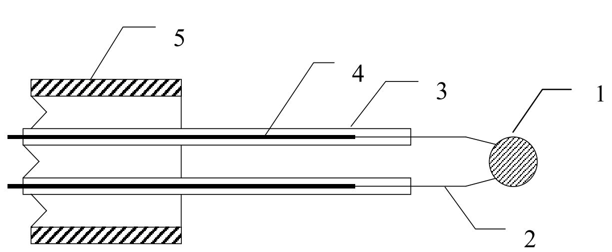

Figure 2: Nickel catalytic probe: 1-Ni disc, 2-thermocouple wires, 3-thin glass tube, 4-kovar wire, 5-glass tube.

To study the influence of a catalytic probe on the H-atom density two nickel catalytic probes were mounted in the post-discharge chamber as shown in Figure 1. One probe was at fixed position and the other one was made movable. A change in the probe temperature of the fixed probe was measured versus the distance z from the movable probe (Figure 3). z = 0 when the movable probe was just near the fixed probe.

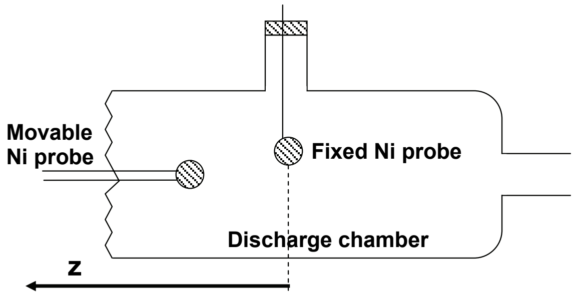

Figure 3: Detail of the discharge chamber with fixed and movable probe.

3 RESULTS

The temperature (T_p) of the fixed probe versus the distance z from the movable probe at different pressures is shown in Figure 4. In Figure 4a the discharge power was 200 W, while in Figure 4b the discharge power was 300 W. As shown in Figure 4 the temperature of the fixed probe is lower when the movable probe is positioned just near the fixed probe (z = 0). The temperature can be lower as much as 100 K in comparison with the case when the movable probe is far away from the fixed probe. As shown in Figure 4 the presence of the probe changes the density in the range of 5 cm from the probe.

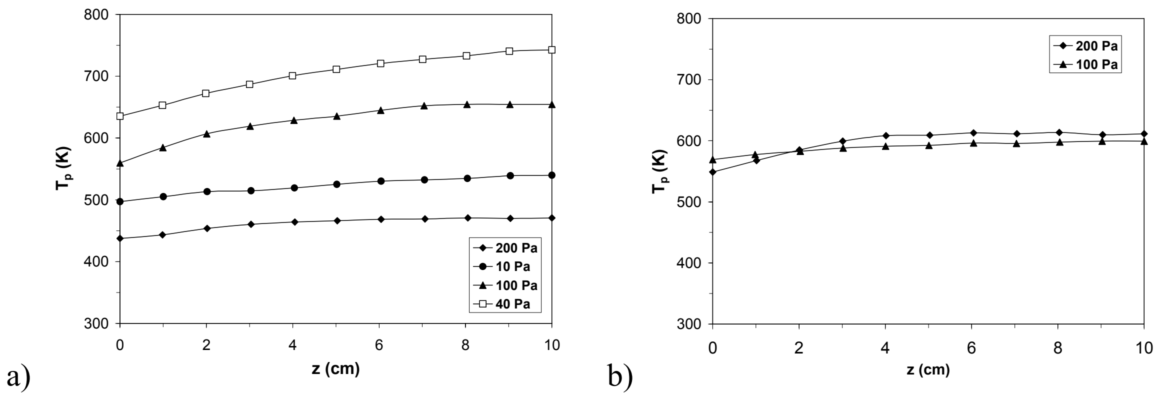

Figure 4: Temperature of the fixed Ni catalytic probe (T_p) versus the distance z from the movable probe. The parameter is the pressure. The RF power was: a) 200 W and b) 300 W.

In Figure 5 is shown relative difference in temperature (T_p-T_0) of the fixed probe versus the distance from the movable probe for the case of 200 W (Figure 5a) and 300 W (Figure 5b). Here T_0 is the temperature of the fixed probe, when the movable probe is so far away (more than 5 cm) that it does not disturb the H-atom density any more. The results in Figure 5 show that the H-atom density is decreased for about 20 % in the vicinity of the probe. This result is independent of the pressure and the discharge power.

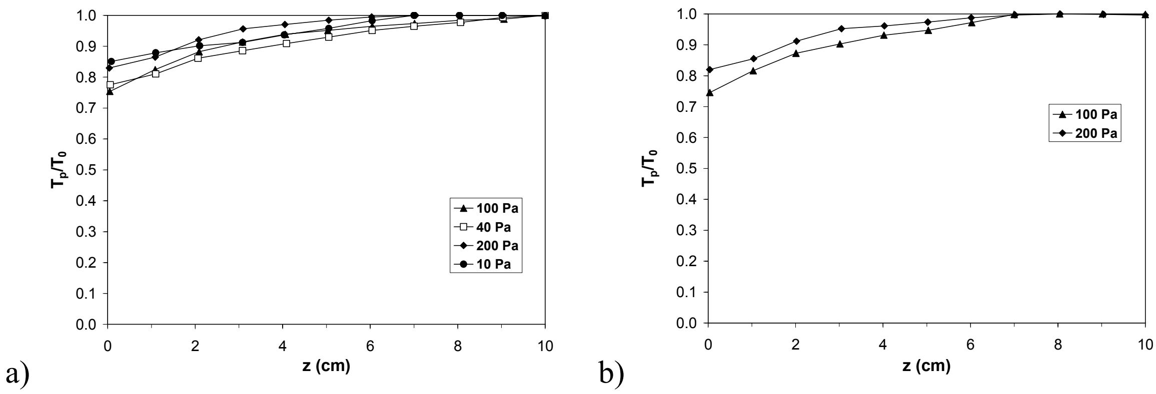

Figure 5: Relative temperature of the fixed Ni catalytic probe (T_p/T_0) versus the distance z from the movable probe. T_0 is the temperature of the fixed probe, when the movable probe is very far away. The parameter is the pressure. The RF power was: a) 200 W and b) 300 W.

4 CONCLUSIONS

Because of the catalytic recombination of hydrogen atoms on the probe surface, the probe itself causes a decrease of the H-atom density in its vicinity. Therefore the catalytic probe is made very small (the diameter of the probe tip was 2 mm), but still, this effect can not be neglected. A change in the probe signal of the fixed probe was measured versus the distance from the movable probe. The measurements were performed at the pressures between 10 Pa and 200 Pa and at two different RF powers 200 W and 300 W. It was found that the density of neutral hydrogen atoms was reduced for about 20% due to the presence of the probe. This result was independent from the pressure in the experimental chamber and the discharge power. The density of neutral hydrogen atoms was reduced in the range of 5 cm from the probe.

ACKNOWLEDGMENTS

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