Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Nuclear Materials 337–339 (2005) 161–165
journal of nuclear materials
www.elsevier.com/locate/jnucmat

Spectroscopic study of hydrogen particle behavior in attached and detached divertor plasmas of JT-60U

H. Kubo [a,*], H. Takenaga [a], K. Sawada [b], T. Nakano [a], S. Kobayashi [c], S. Higashijima [a], N. Asakura [a], K. Shimizu [a]

[a] *Japan Atomic Energy Research Institute, 801-01 Mukoyama, Naka-machi, Naka-gun, Ibaraki-ken 311-0193, Japan*
[b] *Shinshu University, Nagano 380-8553, Japan*
[c] *Kyoto University, Uji-shi, Kyoto-fu 606-0011, Japan*

Abstract

Hydrogen particle behavior, especially H_2 molecule behavior, has been studied spectroscopically in attached and detached divertor plasmas of JT-60U. The decay lengths of the H_2 Fulcher line intensity in attached and detached divertor plasmas were roughly 1 cm and 4 cm, respectively. The fall in intensity of the H_2 Fulcher lines with distance from the divertor plates was reproduced by calculation using a neutral transport and a collisional radiative model code. Molecular assisted recombination was estimated to be as important as H^+–e recombination in a detached divertor plasma.

PACS: 52.20.Hv; 52.25.Ya; 52.55.Fa; 52.65.Pp; 52.70.Kz
Keywords: DEGAS; Divertor plasma; Hydrogen; JT-60U; Molecular effect; Spectroscopy

1. Introduction

In fusion plasma research, understanding of hydrogen particle (H_2, H and H^+) behavior in the divertor plasma is important to establish the capability of the divertor to control heat and particle loads [1]. In attached divertor plasmas, the H^+ ions recombine at the divertor plates, and the H_2 molecules and H atoms released from the divertor plates are ionized a short distance away. In detached divertor plasmas, which are attractive for mitigating the severe problem of concentrated power loading of the divertor plates, volume recombination of the H^+ ions is considered important in reducing the ion flux to the divertor plates. The H_2 molecules play an important role as a source of cold H^+ ions, but they may also play a role as a sink of the H^+ ions streaming toward the divertor plates by molecular assisted recombination (MAR) [2]. Recently, spectroscopic observation of the H_2 molecules in divertor plasmas and its analysis using a collisional radiative model have been performed to study the H_2 molecule behavior in ASDEX [3,4].

This paper presents a spectroscopic study of hydrogen particle behavior, particularly H_2 molecule behavior, in attached and detached divertor plasmas of JT-60U. Spatial intensity profiles of the H_2 molecule Fulcher lines have been measured; these profiles have been analyzed using a neutral transport and a collisional

* Corresponding author. Tel.: +81 29 270 7349; fax: +81 29 270 7419.
E-mail address: kubo@naka.jaeri.go.jp (H. Kubo).

0022-3115/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.jnucmat.2004.09.039

radiative model code. Contribution of MAR is estimated.

2. Experimental

The diagnostics for the present study are shown in Fig. 1. Using a visible spectrometer with 60-ch optical fiber arrays, H I Balmer-series lines and H_2 Fulcher lines ($d^3\Pi_u \rightarrow a^3\Sigma_g^+$) were observed. The spectrometer was a Czerny-Turner spectrometer with an image-intensified CCD camera. The spectral resolution and the spatial resolution were 0.29 nm and 1 cm, respectively. The spectral range covered in a discharge was 37 nm, and the Balmer-series and Fulcher lines were separately observed identical discharges. Electron temperature, electron density and ion flux at the divertor plates were measured with Langmuir probes. In the present study, we will investigate outer divertor plasmas, for which the viewing chords of the spectrometers were parallel to the outer divertor plates.

Fig. 2 shows time evolution of several plasma parameters in the L-mode discharge (plasma current: 1.5 MA, toroidal magnetic field: 3.5 T, NBI heating power: 4 MW) to be investigated. By a feedback technique using H_2 gas puffing, the electron density was raised and then maintained at 52% of the Greenwald density limit. After onset of an X-point MARFE at 7.9 s, the gas-puffing rate decreased. The ion fluxes to the inner and the outer divertor plates rolled over around 6.3 and 7.2 s, respectively. They decreased drastically, when the MARFE appeared. Therefore, partial detachment started gradually before the MARFE onset, and the detachment became pronounced after the MARFE onset. The H_ε line intensities were integrated over the outer divertor plasma (between the outer divertor plates and the X point) and the inner divertor plasma. The H_ε line intensities increased continuously with electron density, but at the MARFE onset the intensity in the outer divertor rose

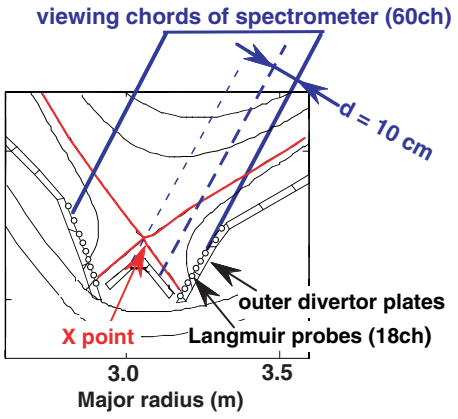

Fig. 1. Divertor diagnostics for the present study.

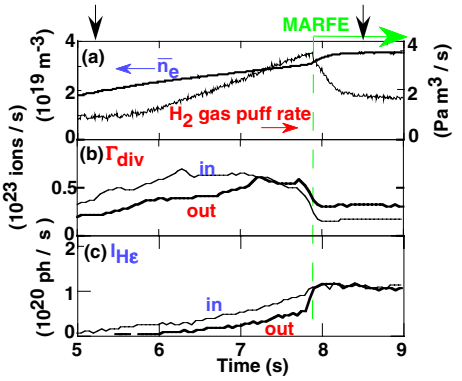

Fig. 2. Time evolution of plasma parameters in an L-mode discharge. (a) Line-averaged electron density in the main plasma and H_2 gas puff rate, (b) ion fluxes to the inner and the outer divertor plates, and (c) intensities of $H\varepsilon$ ($\lambda = 397.0$ nm) line emission from the inner and the outer divertor plasma.

rapidly. Before the MARFE onset, the H_ε emission profile had peaks around the inner and the outer strike points. When the MARFE appeared, the emission profile had a peak around the X point, in addition to the peaks around the two strike points.

In the next section, an attached divertor plasma at 5.2 s and a detached divertor plasma at 8.5 s (indicated by arrows above in Fig. 2) will be discussed. In the attached divertor plasma, the electron temperature and density measured with the Langmuir probe near the outer separatrix strike point were 20 eV and $0.7 \times 10^{19}\ m^{-3}$, respectively. In the detached divertor plasma, as described in the next section, the electron temperature and density near the outer divertor plates were estimated from the Balmer line spectrum to be 0.4 eV and $1 \times 10^{20}\ m^{-3}$, respectively.

3. Results and discussion

For the Fulcher line spectra, the Q branches of the $v = 0$–0, 1–1 and 2–2 bands were identified. Near the outer divertor plates in the attached divertor plasma, the rotational temperatures for the $v = 0$–0, 1–1, 2–2 transitions were 0.040, 0.057, 0.046 eV, respectively. Fig. 3(a) shows the intensity of the Fulcher $v = 1$–1 Q3 line, which was one of the most prominent lines, as a function of the distance from the outer divertor plates. It was estimated that spectral contamination of the Q3 line was small, since its line width was explained by the spectral resolution of the spectrometer and the rotational temperature was well determined including the line. In the attached divertor plasma, the decay length of the line intensity was ~1 cm, and this suggests that H_2 molecules were localized near the divertor plates. In the detached divertor plasma with a MARFE, the decay length was ~4 cm, suggesting that H_2 molecules