§14. Effects of Particle Control in the End Region on the Central Plasma Characteristics in GAMMA-10

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1. Introduction

Edge plasma control is now recognized as the key to achieving high-performance core plasma confinement in magnetic fusion experiments. The first-of-a-kind systematic investigation of effects of wall recycling on core confinement was conducted in TFTR[1], whereby particle recycling from the graphite bumper limiter was reduced by thermal degassing and helium discharge conditioning prior to confinement discharges, having led to the discovery of "Supershot" regime. In the "Supershot" confinement regime, the energy confinement time in has been found to increase with decreasing edge particle recycling from the limiter.

An empirical correlation was found in Doublet-III experiments that whenever wall recycling is reduced, energy and particle confinement is improved even as the H-mode is not achieved[2]. This was explained as the energy transport along with the edge particle flow is dominated by convective heat transport such that:

$$q_{\|conv} = 5k\,\frac{(T_e+T_i)}{2}\,\Gamma_{wall} \qquad (1)$$

where $q_{\|conv}$ is the parallel convection heat flux, k is Boltzmann's constant, T_e and T_i are the electron and ion temperatures, respectively. It is clear from Eq. (1) that the control over wall recycling would result in a reduction in heat flux, whereby energy confinement improves. It follows from these arguments that reduced wall recycling can be considered as a necessary condition for improved core confinement.

Similar reduced recycling effects have been observed in a number of toroidal fusion devices, including even stellarators and spherical tokamaks, over the past several decades although the physics behind these effects is not thoroughly understood.

The present work is intended to investigate whether or not such wall recycling effects on core confinement can be observed in mirror machines such as GAMMA-10. It is expected that particles recycling effects, if any, may be observed, using reflective end plates which separate the end cell from the central cell.

2. Experimental results

A schematic diagram of the end plate prepared for this purpose is shown in Fig.1. Employed as the end plate materials are graphite and tungsten, completely different in hydrogen recycling characteristics. Recognize that graphite is an absorbing surface whereas tungsten is essentially a reflecting surface[3]. These two materials can readily be exchanged in-situ by flipping the end plate, as shown in Fig.1.

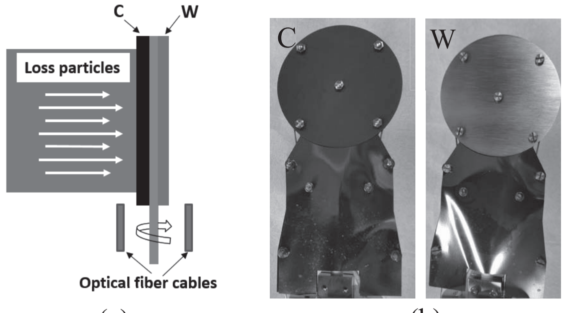

Fig. 1 A schematic diagram and photos of the end plates.

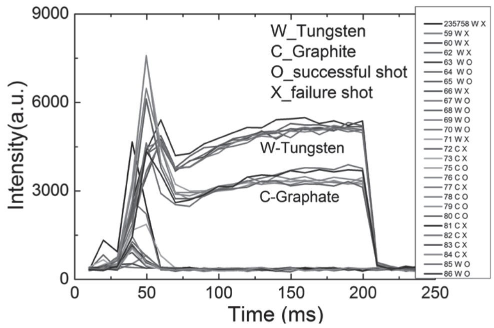

Fig. 2 Hydrogen recycling over the C and W end plates.

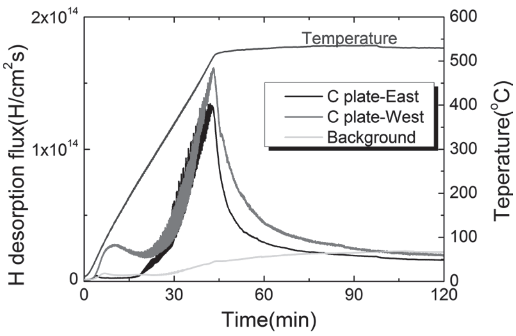

Fig. 3 Hydrogen retention in C plates measured by TDS.

Shown in Fig.2 are the spectroscopic data for H_α taken as the measure of hydrogen recycling, for the C and W end plates. It is found that hydrogen recycling is reduced with C plates in the end part. And the amount of hydrogen retention in the C-plates has been obtained by post-exposure TDS measurements, as shown in Fig.3. As a result, H retention is 1.01×10^{17} H/cm^2 and 1.30×10^{17} H/cm^2 for C-plate in the East and West end respectively. For particle flux $\Gamma_i = 4\times10^{18}$/cm^{2}s [4], with total exposure time ~1.2s, the ratio of retained /incident hydrogen is ~2.1%-2.7%. In the shots with C and W plates in the end parts, however, no clear difference in plasma parameters has been observed.

1) Strachan, J. D., Nucl. Fusion **39**(1999)1093.
2) M. Nagami et al., Nucl. Fusion **24**(1984)183-200.
3) Post, D. E. and Behrisch, R. "Physics of plasma-wall interactions in controlled fusion" Plenum Press (1986).
4) Y. Nakashima, et al Journal of Nuclear Materials 438 (2013) S738–S741