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

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It has widely been recognized that particle recycling from plasma-facing components in magnetic fusion devices can affect core confinement performance. This was first manifested by the "Supershot" confinement experiments in TFTR[1)], whereby particle recycling from the graphite bumper limiter was reduced by thermal degassing and/or helium discharge conditioning prior to confinement discharges. In the Supershot confinement regime, the energy confinement time in has been found to increase with decreasing edge particle recycling from the limiter. Similar reduced recycling effects have been observed in a number of toroidal fusion devices, including 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 mirrors 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.

Generally, the total heat flow along the magnetic field line is considered to be the sum of convection and conduction effects such that:

$$q_{//} = q_{//\,conv.} + q_{//\,cond.} \qquad (1)$$

Here, it is extremely important to point out here that the SOL collisionality, ν_{SOL}, plays a key role in determining the heat loss mechanism to the plasma-facing component. Also, for the same plasma temperature and density, ν_{SOL} is linearly proportional to connection length.

If $\nu_{SOL} <10$, as a general guideline, the heat loss will be "sheath-limited" to be given by[2)]:

$$q_{//} \approx q_{//\,conv.} = \left\{ \frac{1}{2} m_i v^2 + \frac{5}{2} k(T_e + T_i) \right\} n_{edge} v \qquad (2)$$

This is easily met by small-to-medium size devices such as NSTX in which lithium is used as the plasma-facing materials to reduce n_{edge}.

As opposed to that, if $\nu_{SOL} >20$ is established, the heat loss will become "conduction-dominated" to be expressed as[2)]:

$$q_{//} \approx q_{//\,cond.} \approx -\kappa_{0e} T_e^{\frac{5}{2}} \frac{dT_e}{dx} \qquad (3)$$

This may be met by relatively large machines including JET. Because mirrors are inherent with short connection lengths, the heat flow is expected to be sheath-limited in which case the edge density plays an important role, as indicated by eq. (2).

A schematic diagram of the end plate prepared for this purpose is shown in Fig. 1. Employed as the end plate materials are titanium and tungsten, completely different in hydrogen recycling characteristics. Titanium is well known to form hydride (TiH_2), keeping the recycling coefficient: $R_e <1$ for a typical pulse length of 100ms in GAMMA10, whereas tungsten re-emits essentially all hydrogenic species, meaning that $R_e \sim 1$[3)]. These two materials can be interchanged in-situ by flipping the end plate. Also, a sheet heater (see Fig. 3) is inserted in between these end plates, so that pre-exposure degassing as well as post-exposure TDS can readily be done.

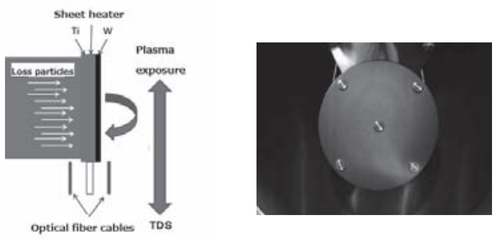

Fig. 1 A schematic diagram and a photo of the end plate.

Shown in Fig. 2 are the spectroscopic data on H_α, as the measure of hydrogen recycling, for the Ti and W surfaces of the end plate. Recognize that there is about a factor of 2 difference, as predicted. However, no clear change in central plasma parameters has been observed. The TDS data are shown in Fig. 3 from which the total hydrogen retention has been evaluated to be of the order of 10^{16} H-atoms/cm^2, smaller than one would predict.

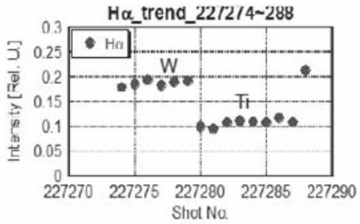

Fig. 2 Shot-by-shot H_α data taken for the W and Ti plates.

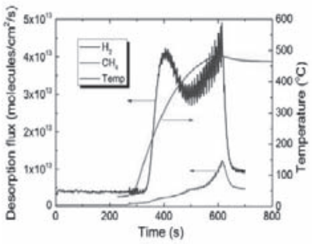

Fig. 3 Post-exposure TDS data up to about 450^{o}C.

1) Strachan, J. D., Nucl. Fusion **39**(1999)1093.
2) Stangeby, P. C, "The plasma boundary of magnetic fusion devices", IoP (2000).
3) Post, D. E. and Behrisch, R. "Physics of plasma-wall interactions in controlled fusion" Plenum Press (1986).