S3-1

S3: 磁気核融合実証炉に於ける熱・粒子制御の問題点と液体金属ＰＦＣによる解決の可能性
Key issues associated with power and particle control in a magnetic DEMO fusion reactor and the possible resolutions by the use of liquid metal PFCs.

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1. Exhaust power handling issues

Exhaust power and particle handling by plasma-facing components (PFCs) such as divertor is one of the critical issues, affecting the successful operation of a magnetic fusion power reactor. Tungsten has been employed for PFCs in a number of existing magnetic fusion experiments and is also envisaged to be used for the divertor target plate in the International Thermonuclear Experimental Reactor (ITER), brazed on an actively cooled heat sink made of copper alloys [1].

Because the operation temperature of the ITER divertor target plate is currently designed to range from 800 to 1000^{o}C, one immediately predicts that tungsten would suffer from thermomechanical stress cracking along with operation ramp-up and down processes, due to its exceptionally high ductile-brittle transition temperature (DBTT) of around 400^{o}C [2].

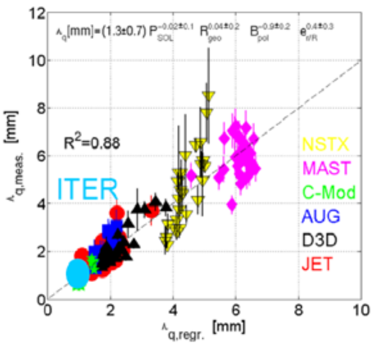

Fig. 1 Divertor power deposition profile e-folding length scaling [3].

Recently, a new scaling law on the SOL thickness vs. divertor power deposition profile has been proposed [3]. As shown in Fig. 1, the ITER divertor power deposition e-folding length is predicted by this scaling law to be only ~1mm, implying that the maximum power deposition could exceed 50MW/m^2.

In most of the recent design studies for fusion DEMO power reactors, used for the divertor heat sink are reduced activation ferritic steel alloys, such as F82H, the thermal conductivities of which are typically one third of those of copper alloys. It follows from these arguments that the exhaust power in DEMO reactors cannot be handled by any divertors in conventional designs, necessitating the development of innovative divertors such as those to employ liquid metals.

2. Exhaust particle handling issues

Turning to the boundary control issue, core plasma performance has often been observed to be correlated with edge densities determined by particle recycling from PFCs in a variety of experimental situations. From the database shown in Fig. 2, one can learn that reduced wall recycling would lead to high performance

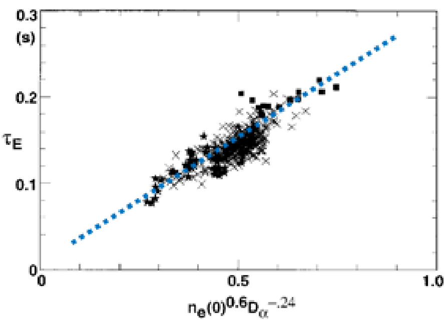

Fig. 2 Energy confinement time as a function of wall recycling, measured as the intensity of D_α, data taken from TFTR experiments [4].

plasma confinement. Due to its large hydrogen absorptivity, lithium has been employed as the coatings to cover PFCs in small devices such as CDX-U as well as medium-to-large devices, including TFTR, NSTX, EAST, etc. Results indicate that core performance has significantly been improved with the use of lithium PFCs.

Following these successful applications of lithium as the coatings over PFCs, the liquid lithium divertor (LLD) concept has actually been implemented in NSTX, hoping that the surface saturation time be extended. It has turned out, however, that the saturation time is not so different from that with lithium coatings [5]. This again points to the need for a new liquid metal PFC concept development.

3. Invited lecturers for the symposium

So, where do we go from here to resolve all the power and particle control issues not only in ITER but more importantly in the magnetic fusion DEMO reactor? For this symposium, the following 5 lecturers have been invited to discuss this situation:

1. *Dr. Masa ONO* (PPPL, USA) is invited overseas from NSTX, which is being upgraded to NSTX-U to be operated within a few years. He will first describe the experiences with lithium PFCs in NSTX. Then, the discussion will be extended to the near future plans for NSTX-U in which lithium PFCs, either in the solid or in liquid phase, will be employed. Finally, he might also mention the possible use of liquid metal PFCs in a fusion nuclear science and technology (FNST) reactor.

2. *Dr. Juansheng HU* (AS-IPP, China) is also invited overseas from EAST in which a variety of lithium PFC concepts have aggressively been implemented. These include lithium coatings on conventional PFCs, lithium pellet injection; liquid lithium limiter based on the TE-MHD concept [6]; and most recently a flowing liquid lithium limiter called “FLiLi”. He will review some of the recent data on EAST experiments, and then hopefully extend the discussion to future tokamaks.

3. *Dr. Michiya SHIMADA* (fmr QST) joins the symposium to advocate the MAG-LIMD concept (magnetically guided liquid metal divertor) in which a liquid metal swirls by itself along the magnetic field, and thus no electrode is necessary to induce **JxB** force for liquid convection, avoiding the electrochemical erosion issue.

4. *Prof. Changhong HU* (Kyushu Univ.) has decided to jump into the field of plasma fusion research from the oceanography community with much experience, and will talk about the fluid dynamics aspect of the “free surface” issue, which we cannot avoid in the development of innovative liquid metal PFCs for magnetic fusion experiments.

5. *Prof. Masatoshi KONDO* (Tokyo Institute of Technology) will discuss the materials compatibility issues. Although a number of lithium PFC concepts have successfully been implemented in magnetic fusion experiments, there has always been a question such as “Can this experience be directly extended to a DEMO reactor?” from the safety point of view as well as the materials compatibility point of view. One of the alternative materials being proposed is tin, which, however, may not be 100% acceptable from the point of view of chemical compatibility with other metals in contact. He will discuss all these chemistry issues and hopefully give us a materials choice guideline.

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