筑波合同研究会
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Advanced Divertor R & D at Muroran Institute of Technology

- Liquid or Gas Cooling W-SiC/SiC Divertor Systems -

A. Kohyama, H. Kishimoto, Waleed . A. Mohrez Abdalla and Y. Kohno

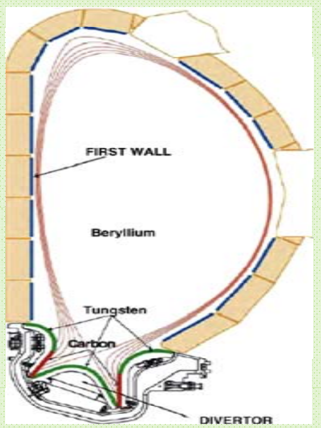
Muroran Institute of Technology

The main objective

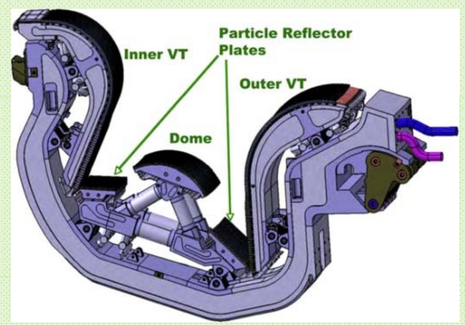
To present attractive advanced divertor systems with W-SiC/SiC by NITE process. Feasibility of divertor component fabrication with sufficient industrial background and sufficient performance verification

1- to define geometrical shapes and materials design to decrease the thermal shocks resulting not only from quasi-steady state plasma but also from the thermal load resulting from off – normal events.

2- to accommodate the high heat flux loads with the W-SiC/SiC designs in different regions of divertor according to the intensity of the plasma (like baffle and dome ,outer and inner vertical target where each of them has different plasma intensity)



Schematic of an ITER plasma facing regions with different plasma intensity



Schematic of an ITER divertor

The First Phase Plan

1: "In-situ" Plasma Exposure Test in LHD at NIFS

2: High Heat Flux Test under JABIS Facility at JAEA-Naka

3: Model Component Fabrication and Performance Verification at OASIS, Muroran Institute of Technology

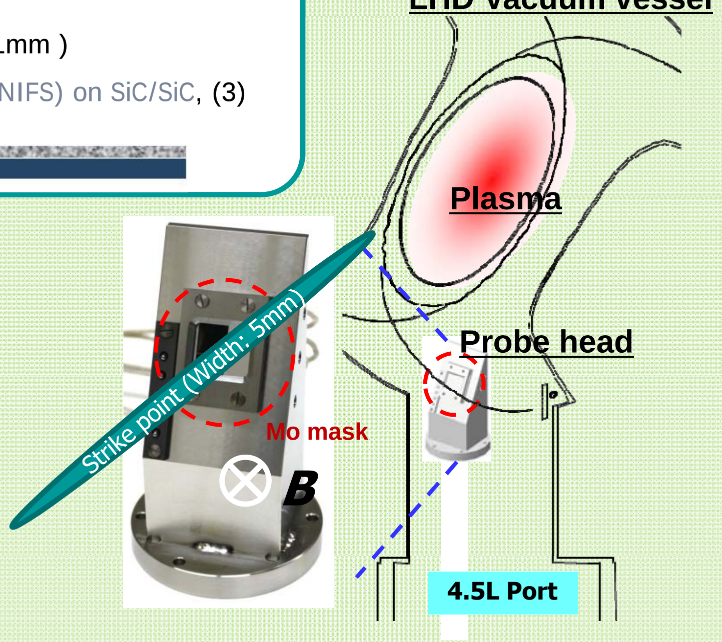
1: "In-situ" Plasma Exposure Test in LHD at NIFS

Specimen specifications

- Size : $10x30x1.5mm^3 \times 3$ piece (W thickness: 0.5-1mm)
- Types: (1)High purity W on SiC/SiC, (2)ALMT-W (NIFS) on SiC/SiC, (3) High Purity W on SiC/SiC

Experiment condition

- $(R_{ax}/B_t/\gamma/B_q)$= (3.6m/2.75T/1.254/100%)
- NBI #1, #2, #3, #4, #5 = as possible as high power injection, expected heat flux of divertor plasma is about 10MW
- No. of plasma shot: 1-2 shot in total
- Sample Preparation Due: End of Aug.
- Plasma Exposure Test Due: End of September

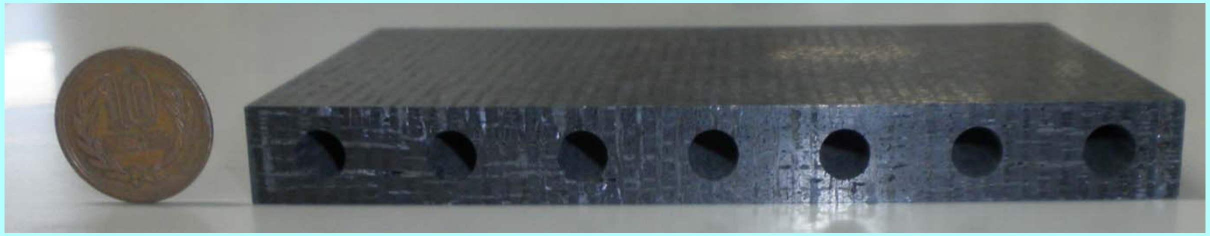


2: High Heat Flux Test under JABIS Facility, at JAEA-Naka

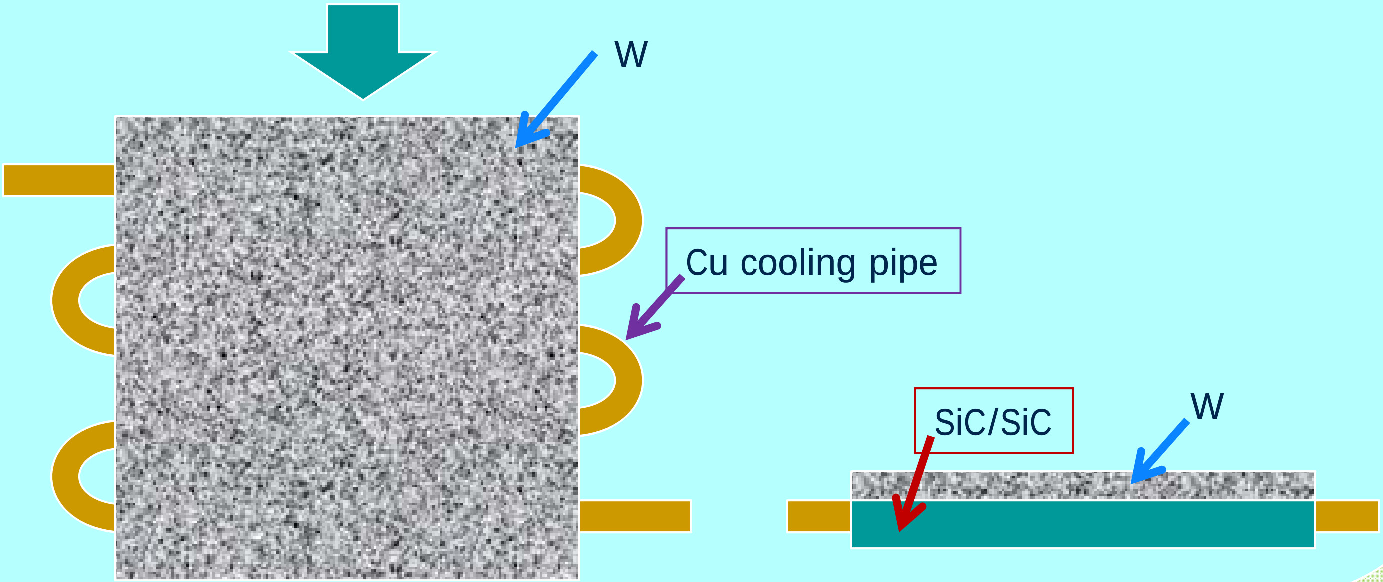
TBD very soon

Potential Test Object –under preparation -

10mmx100mmx10mmW-SiC/SiC Water Cooling Panel



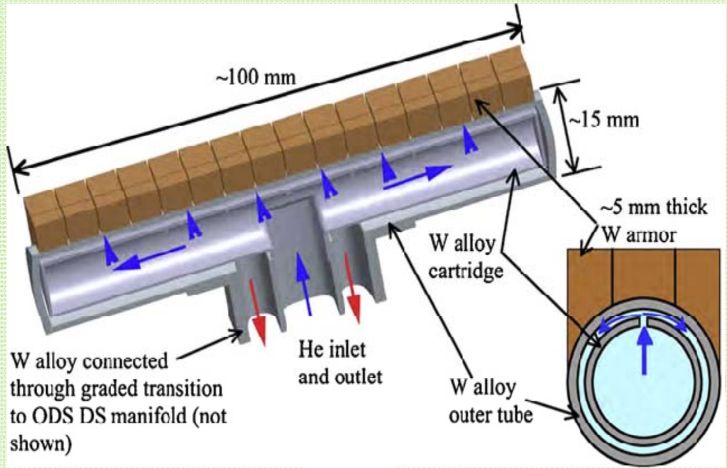
2D SiC/SiC Plate with cooling channels



Representing Divertor Designs

- Finger and T tube Concepts -

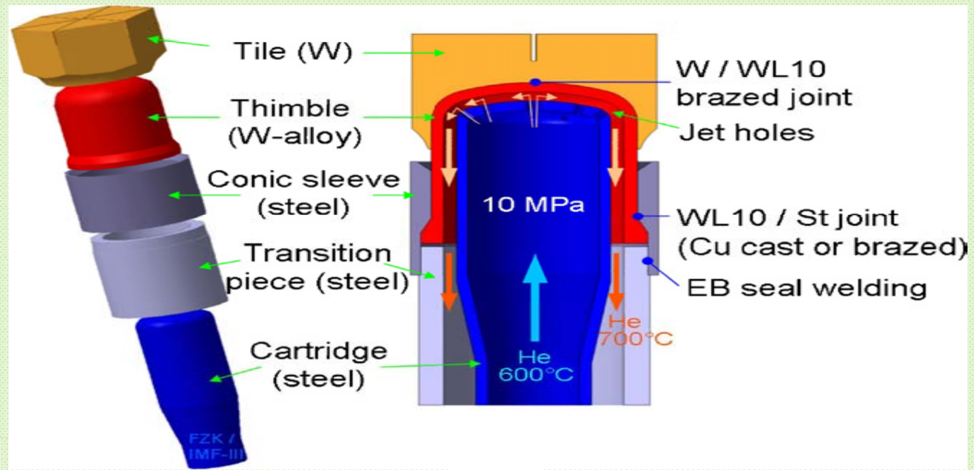
T Tube Concept*



W-alloy cartridge is changed to SiC/SiC
(+cooling efficiency improvement with
low thermal conductivity SiC/SiC
+higher radiation damage tolerance)

W-alloy outer tube can be changed to SiC/SiC
(+high heat load tolerance with high thermal
conductivity SiC/SiC
+high radiation damage tolerance)

Finger Concept**



Inner cartridge (steel) is changed to SiC/SiC
(+cooling efficiency improvement with
low thermal conductivity SiC/SiC
+higher radiation damage tolerance)

W-alloy thimble can be changed to SiC/SiC
(+high heat load tolerance with high thermal
conductivity SiC/SiC
+high radiation damage tolerance)

* A.R. Raffray,et al, T. Ihli ,et al

** T. Ihli, R. Kruessmann ,et al , P. Norajitra ,et al

3: Model Component Fabrication and Performance Verification

- at OASIS, Muroran Institute of Technology -

The modified design concepts of the “Finger” type and “T Tube” type are the basic design concepts with W-SiC/SiC model elements by NITE method

1: W-SiC/SiC flat plates with W-alloy variations

2: Modified T shaped NITE SiC/SiC tube components with W surface layers

3: Modified finger components with double walled SiC/SiC tubes and W surface

Facility installed December 2010

Main Features of OASIS/Muroran I. T.

Proto-type Large Scale Production Line of NITE-SiC/SiC is under operation
W-SiC/SiC divertor components can be made with sufficient flexibility
Integrated performance evaluation system is ready in FEEMA

SUMMARY

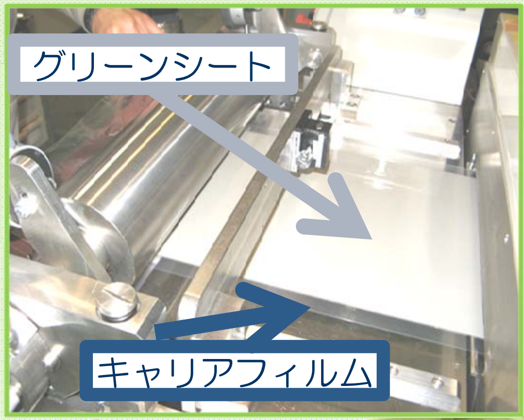
Based on the large scale production capability of NITE-SiC/SiC products at OASIS, Muroran Institute of Technology

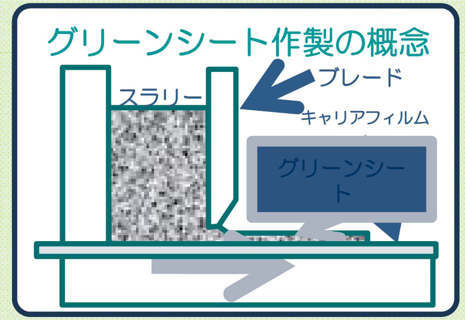
Extensive R & D efforts of advanced divertor with W-SiC/SiC systems are on-going including collaborative activities with BA, NIFS, JAEA and Universities

W-SiC/SiC divertor systems will bring further attractiveness of Fusion Power Energy under realistic domestic R & D scenario

グリーンシート作製装置
(Green sheet manufacturing machine)

セラミックやセラミック複合材料を製造する際の中間素材(グリーンシートやプリプレグシート)を作成します。セラミック粉末やセラミック前駆体に樹脂等を混合したスラリーを基盤(キャリアフィルム)上に薄く、膜状に作製したものをグリーンシート、強化繊維を含むものをプリプレグシートと呼びます。



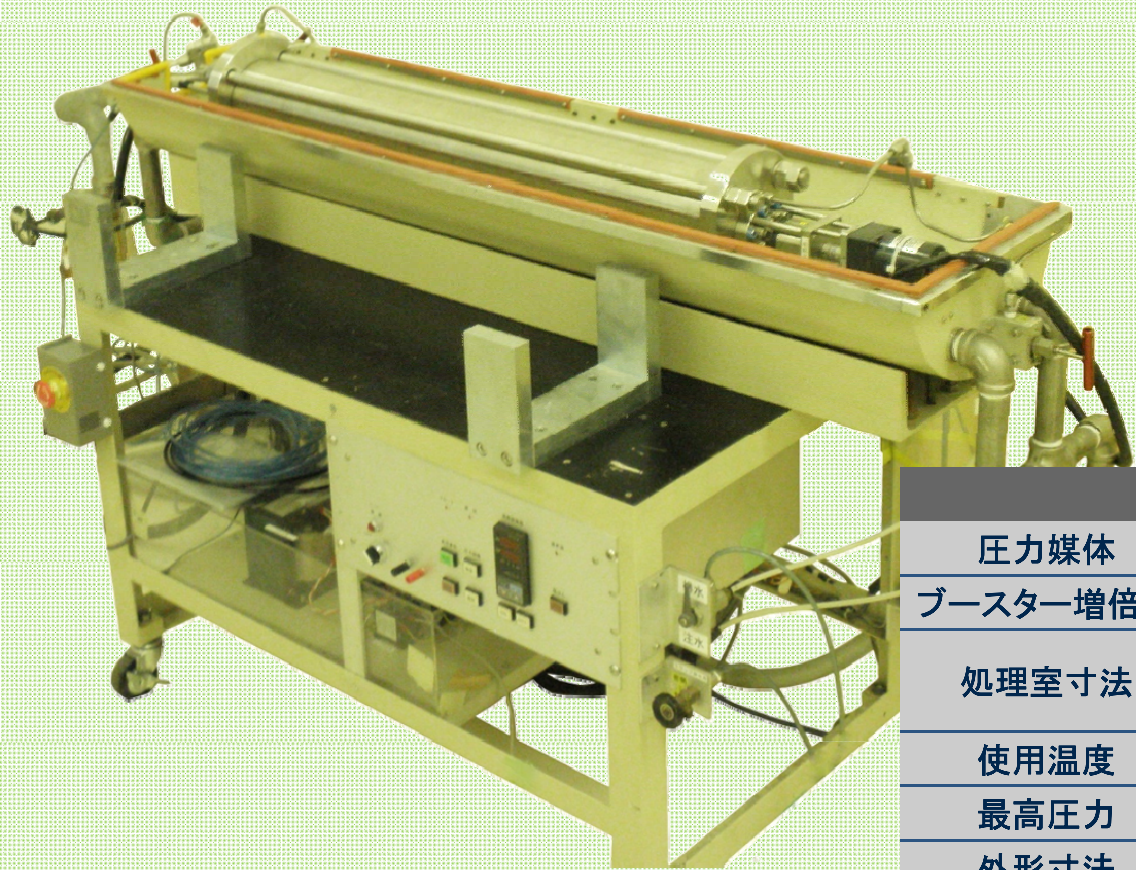


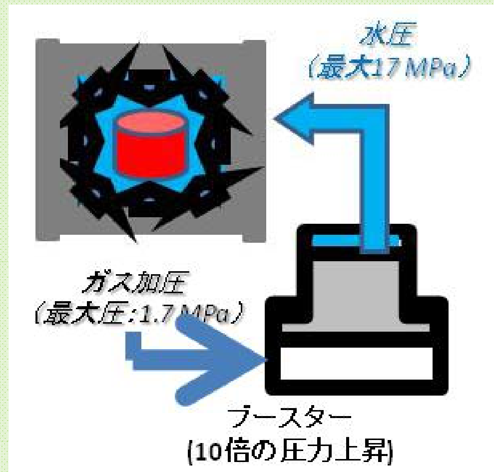
基材	PETフィルム(50μm×300mm)
ロール面長	400mm
ライン速度	0.05～1.0m/min
塗工圧	50～100μm
最高乾燥温度	80℃
最高巻径	300mm
外形寸法	6005mm^{W}×950mm^{D}×1586mm^{H}

温間等方圧加圧装置

(Warm Isostatic Press; WIP)

セラミック複合材料の近似成型の中間処理や樹脂系複合材料の近似成型に用いられます。現状では最大17MPaの等方圧(静水圧)と最高200℃の加熱によるWIP処理により中間成型体であるプリフォームの成型や内部欠陥除去等行っています。

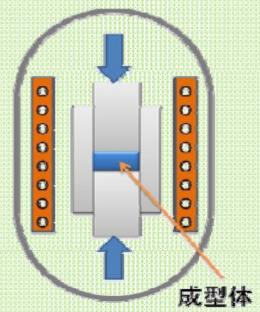




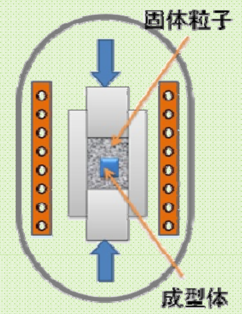
WIP	
圧力媒体	水 （油、液状高分子等も利用可）
ブースター増倍力	10倍
処理室寸法	150mm$^{\Phi}$x（400-1500mm）^{L}
使用温度	MAX 200℃（水使用の場合）
最高圧力	17 MPa（173kgf/cm^2）
外形寸法	1700mm^{W}×600mm^{D}×950mm^{H}

熱間加圧装置
(Hot Press; HP)

HP処理とは、高温で一軸加圧を行う事で、セラミックや金属、及びそれらの複合材料などの成型や接合、材料内の欠陥の補修などを行う手法です。また、固体粒子の流動性を用いて熱間等方圧加圧（HIP）のような擬似静水圧状態での成型（擬似HIP）も行われます。



HPの原理
高温、一軸加圧により難焼結性の物質等の成型・接合を行う。



擬似HIPの原理
流動性のある固体粒子を圧力媒体とし擬似静水圧状態を作り出し、成型等に利用する。

多目的高温加圧炉 (FVPHP-R-5)	
温度	最高 1900℃
使用雰囲気	N_2、Ar、真空
プレス荷重	9.8×10^2～4.9×10^4N
発熱体	黒鉛
ダイス寸法	$120^{\Phi}\times110^{H}$ 黒鉛
真空度	1.0×10^{-4}Pa
装置重量	1.5 ton

熱間等方圧加圧装置
(Hot Isostatic Press; HIP)

HIP処理とは高圧ガスによる等方圧(静水圧)の負荷を高温で行う事により材料の成型を行い、焼結、拡散接合、内部欠陥の除去等を行うことです。NITE法を始めとして、セラミック複合材料の近似成型(Near-Net Shaping)や金属等との接合技術開発に主として用いられています。

HIP成型の原理
高圧ガスにより試料に加わる等方的な圧力（静水圧）で成型します

JAEAより貸出手続き中

	O_2-Dr. HIP		
加熱装置	Pt-Rh	Gr	Mo
使用ガス	Ar,Ar+O_2^*	Ar,N_2	Ar
処理室寸法	50mm$^{\phi}$×60mm^{H}	50mm$^{\phi}$×75mm^{H}	75mm$^{\phi}$×100mm^{H}
最高温度	1500℃	2000℃	1500℃
最高圧力	200 MPa（2040 kgf/cm^2）		
外形寸法	1315mm^{W}×1100mm^{D}×1300mm^{H}		
装置重量	1100 kg		
備考	Gr：グラファイト,Mo：モリブデン※Ar+O_2*（O_2：MAX20%）		