Japan- US workshop on
Fusion Power Plants and Related Advanced Technologies with Participation of China
March 16-18, 2009
at University of Tokyo in Kashiwa, JAPAN

Development of High-Temperature LiPb-SiC Blanket

Yasushi Yamamoto, Kazuyuki Noborio,
Satoshi Konishi, Tatsuya Hinoki and Akira Kohyama
Inst. of Advanced Energy, Kyoto University

Activity in Kyoto University

Objective

Kyoto University pursues advanced blanket concept based on
LiPb – SiC – He combination
to be operated at 900 degree or above.

Research objective includes,

-to Establish a possible advanced blanket concept with supporting technology

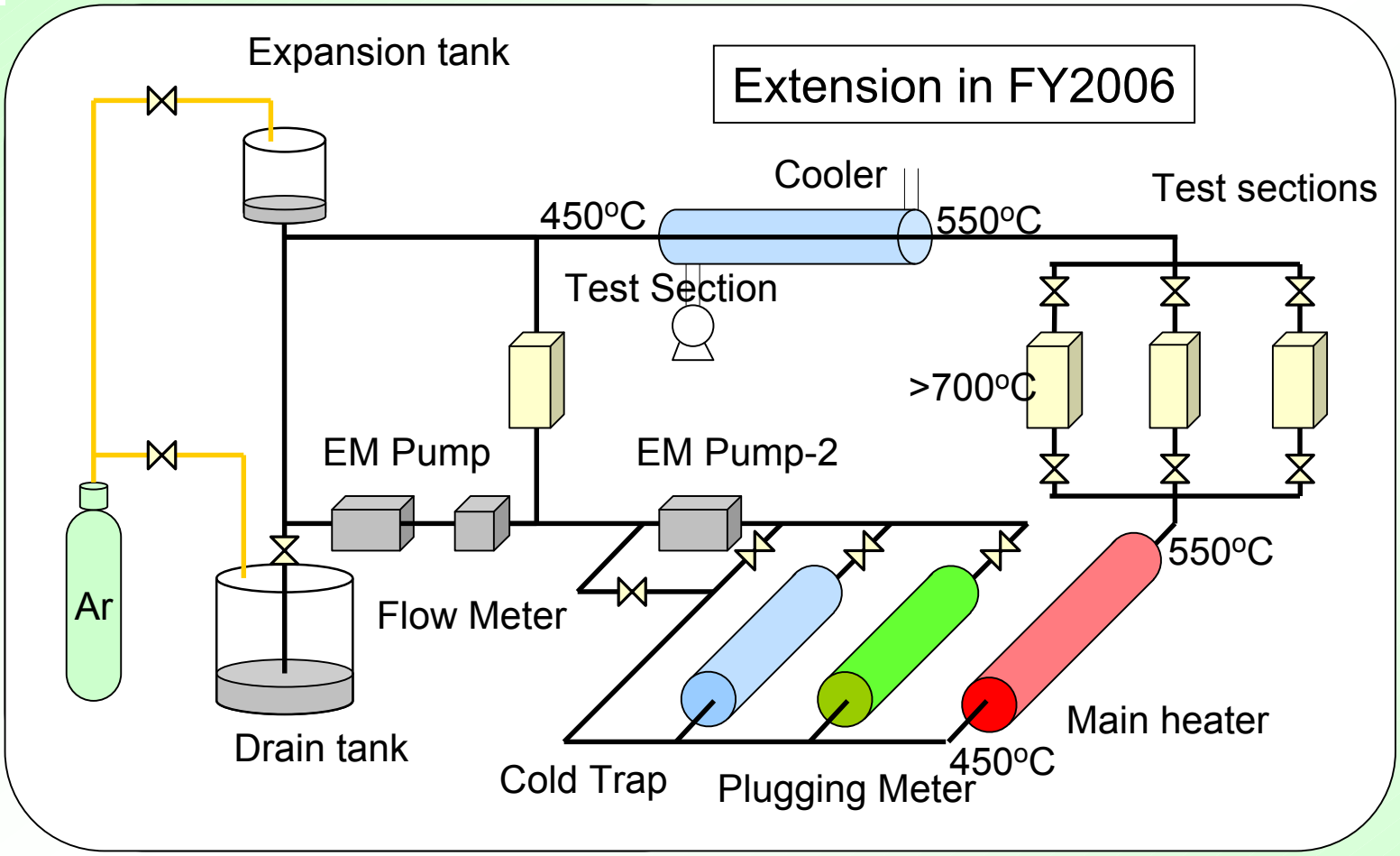
-to Demonstrate the attractiveness of fusion energy with safety and effectiveness i.e. high temperature efficient generation and hydrogen production, technical feasibility, adoptability to attractive reactor designs.

Research Items

Current research efforts are on the following tasks

Conceptual design with neutronics and thermo-hydraulics, MHD
LiPb-SiC-hydrogen system study: compatibility, solubility, permeability
LiPb technology : Loop experiment, purity control, high temperature handling
SiC component development : cooling panel, tubings, fittings and IHX
Mockup development : heat transfer, tritium recovery and control

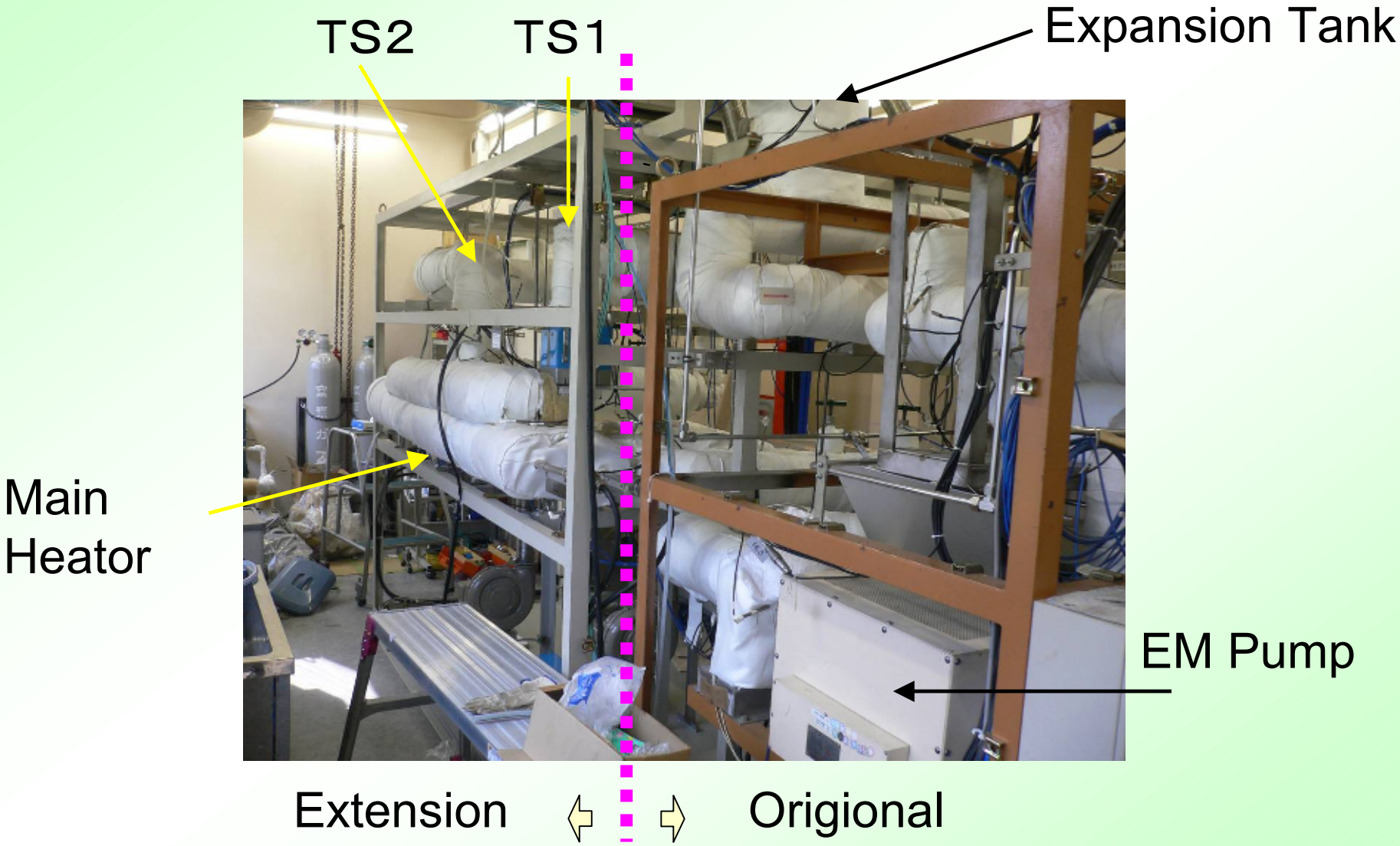
Conspectus of Li-Pb Loop at Kyoto Univ.



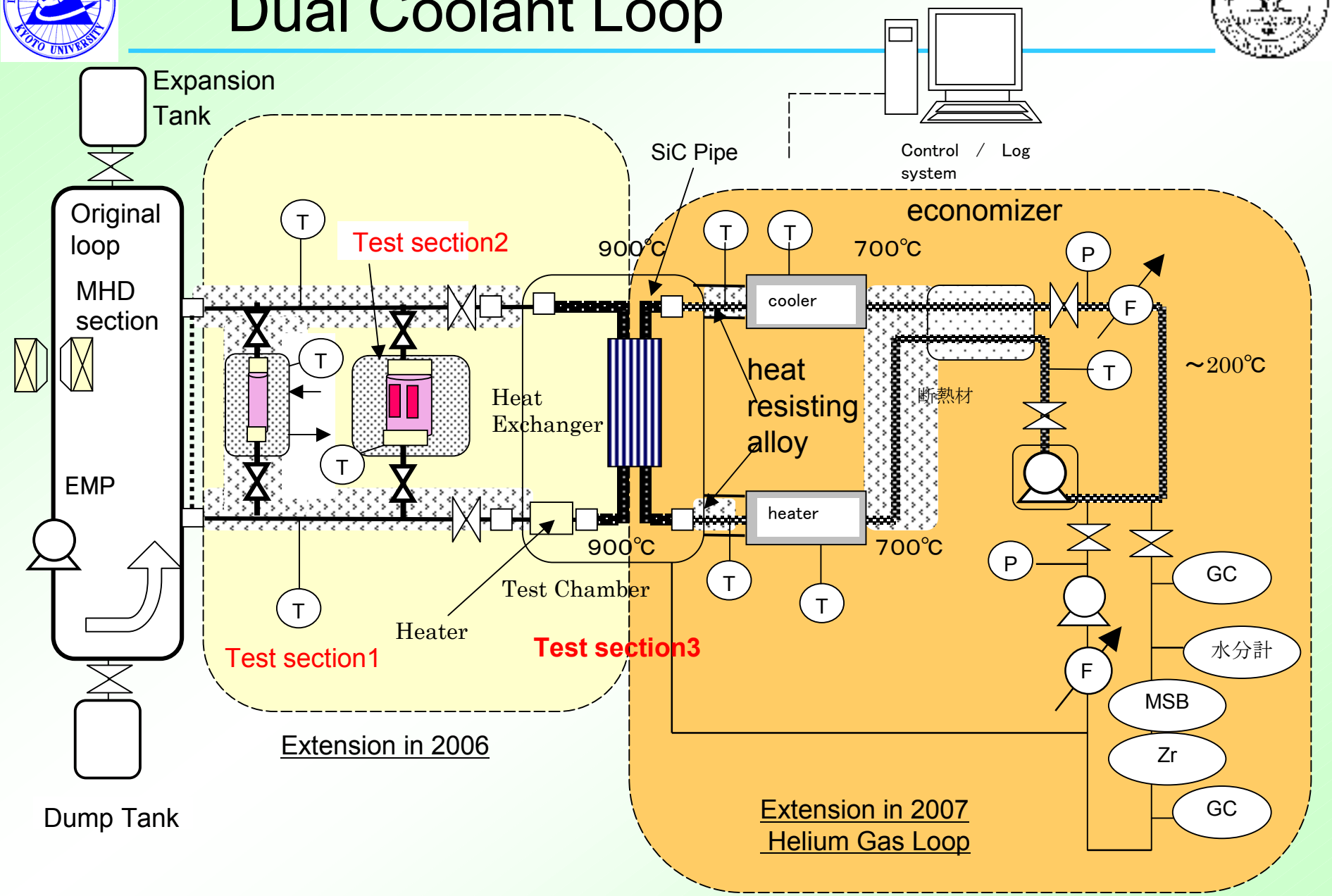
- Fluid: $Li_{17}Pb_{83}$
- Main Piping: 3/4inch, SUS316
- 2 EM pumps
- Flow rate: 3L/min

- Temperature at Test Section > 700°C
- 〃 at pipe ~450°C
- 3-test sections → simultaneous tests
- 1week (~100h) continuous operation

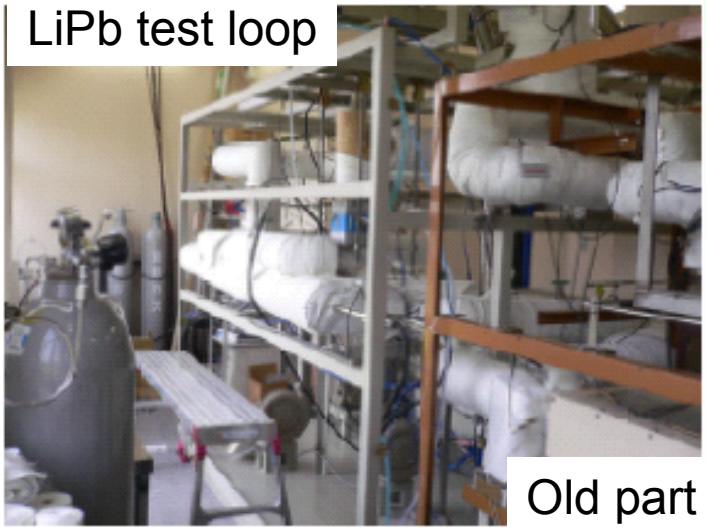
Overview of Li-Pb Loop at Kyoto Univ.

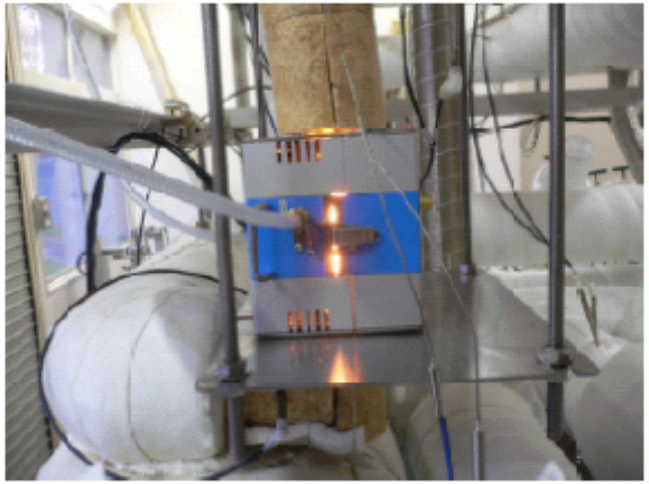


Dual Coolant Loop

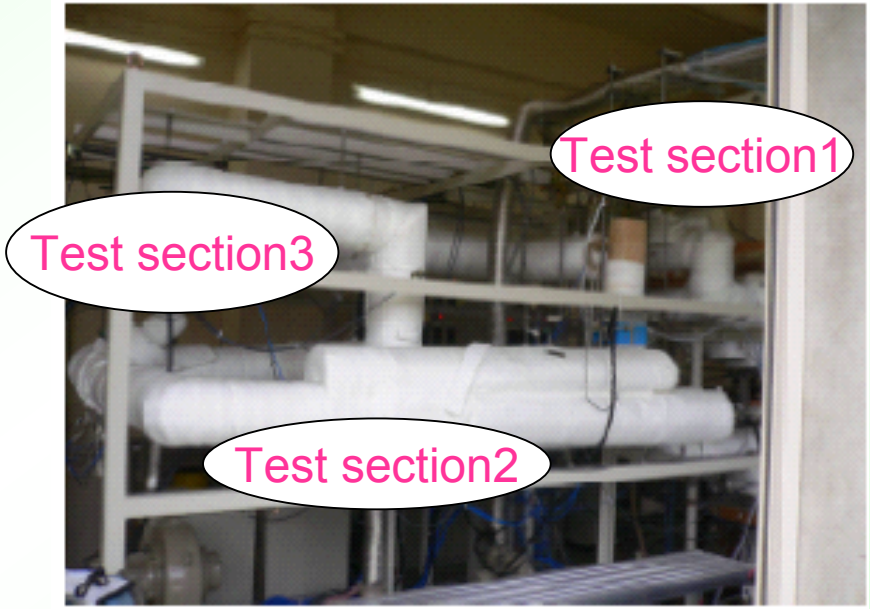


LiPb Loop

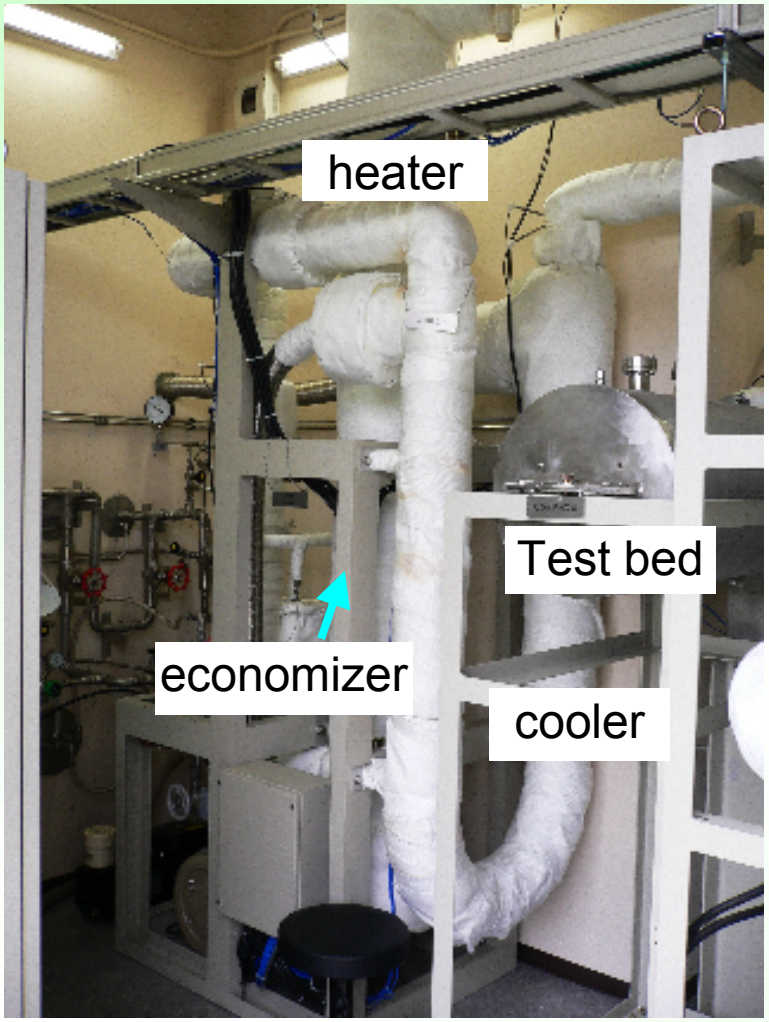




900 C test section



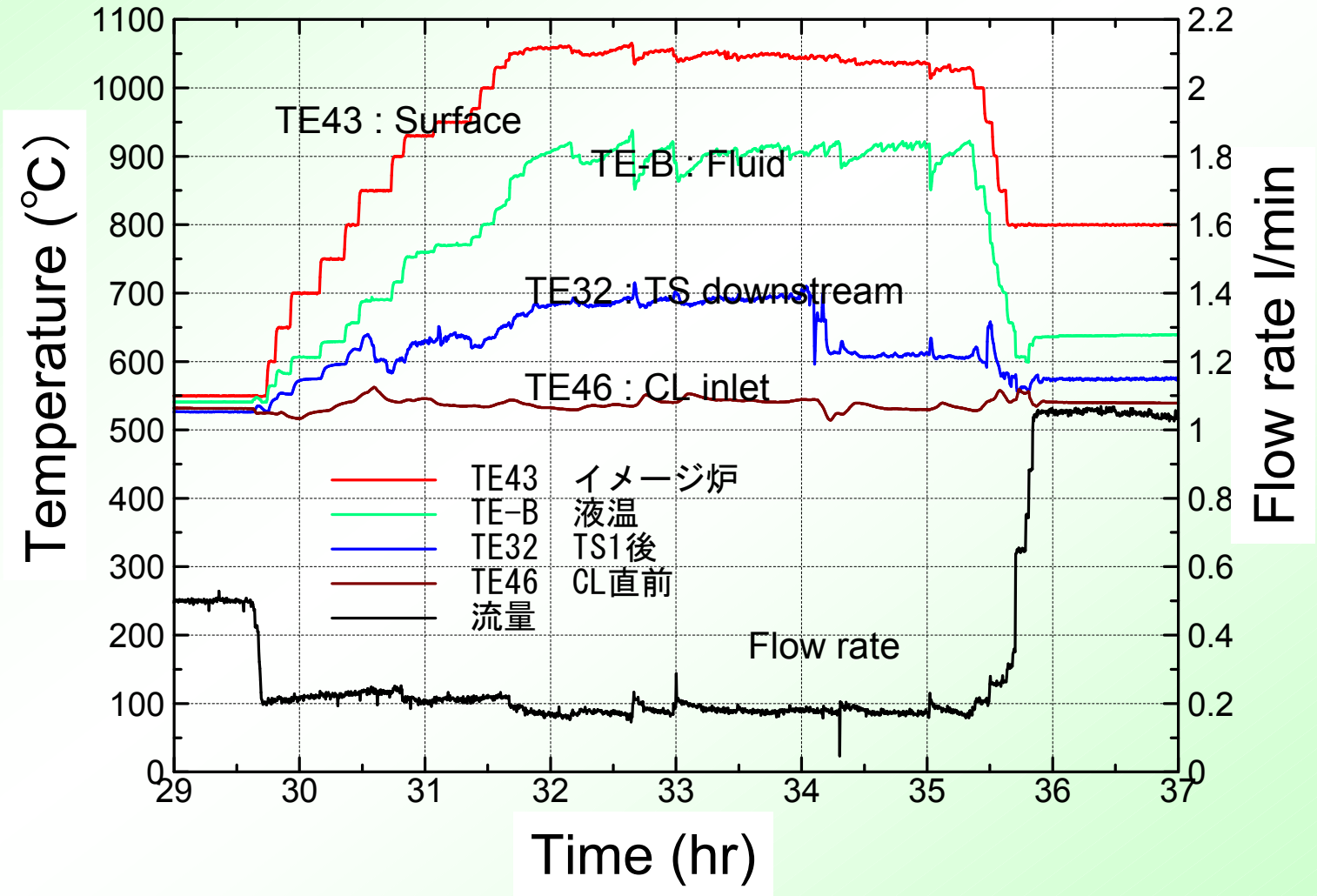
He Loop



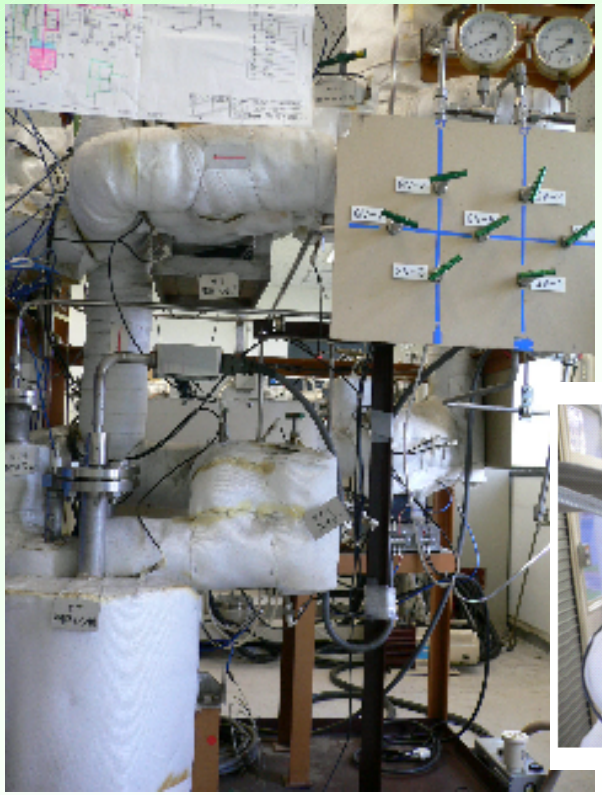
High temperature helium loop was added to test heat exchange
From liquid metal to helium

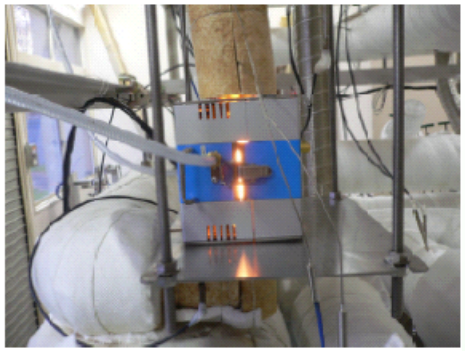
Increase operation temperature

achieve the fluid temperature of more than 900℃

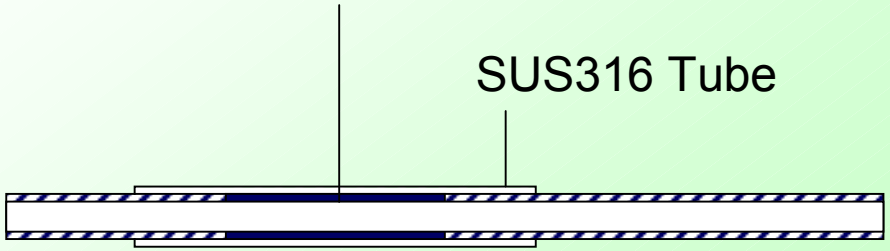


LiPb loop and SiC insert

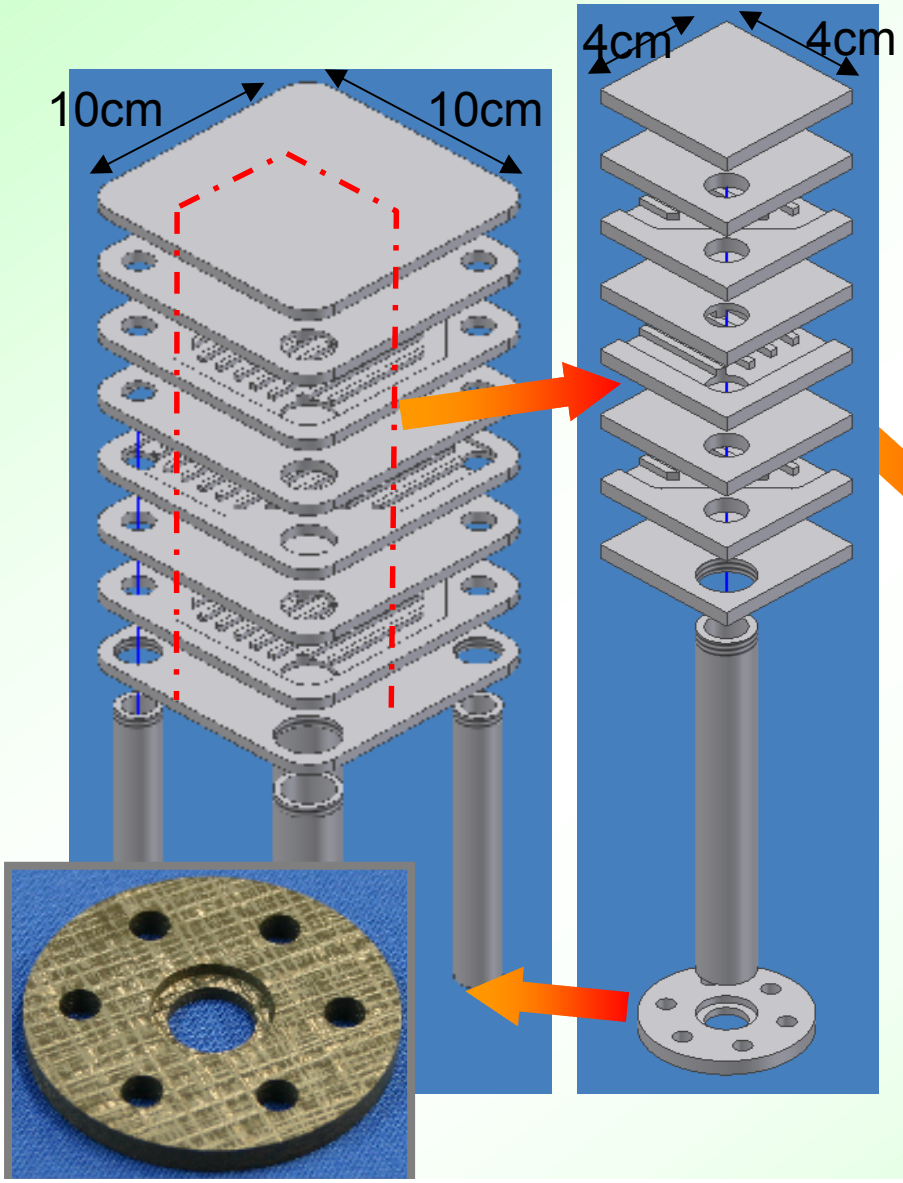




SiC/SiC Tube 149mm

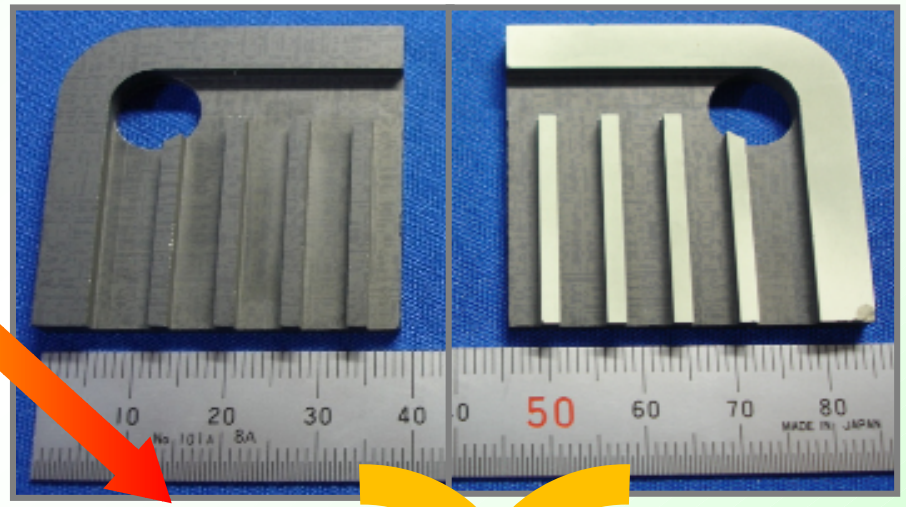


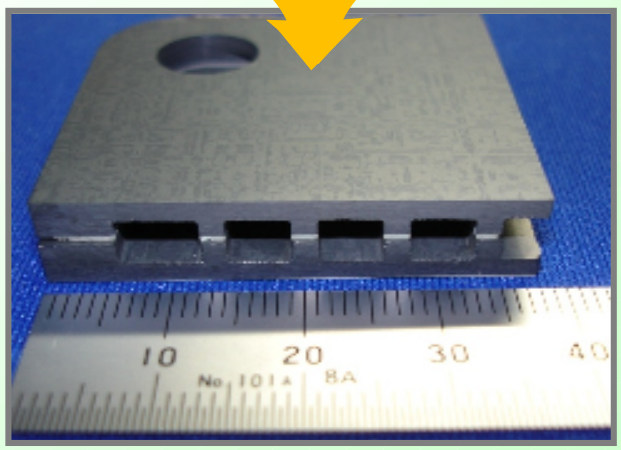
Scale Model R&D



NITE SiC

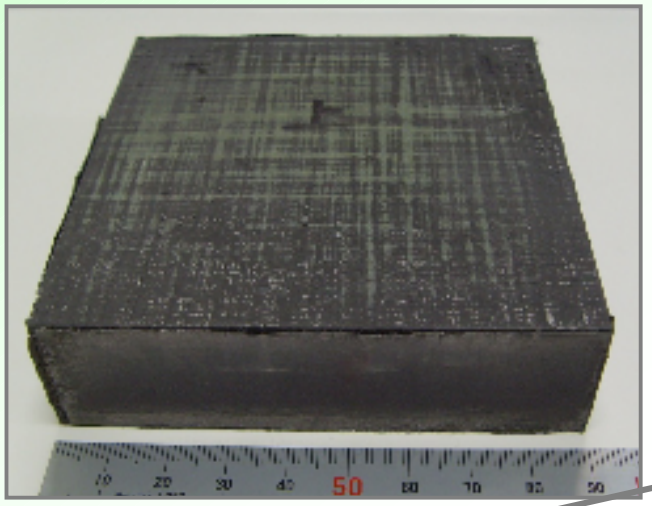
40mm × 40mm × 4ply



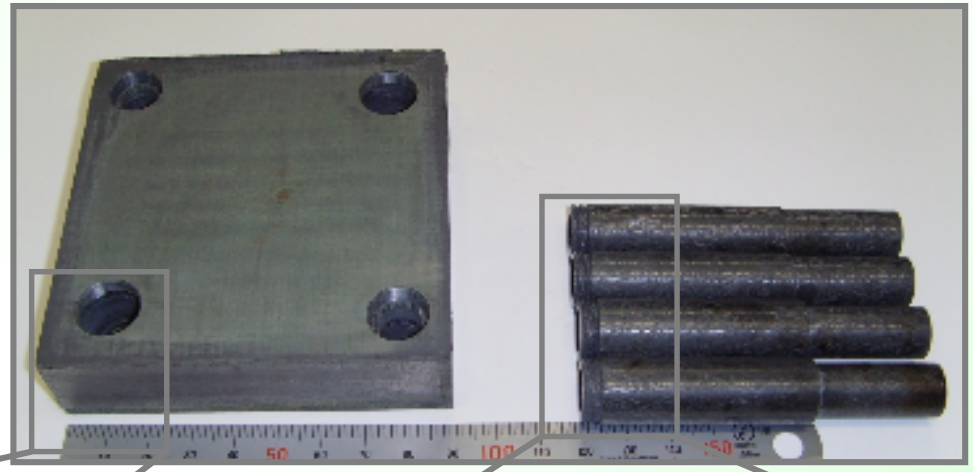


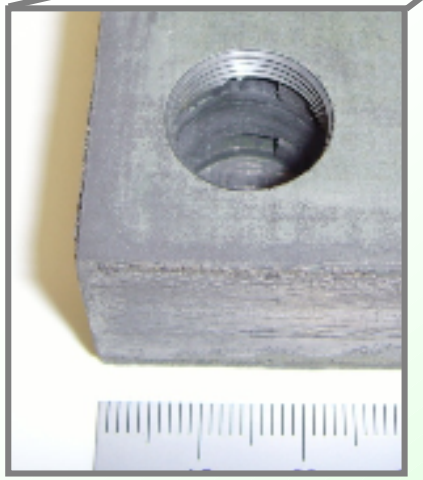
IHX structure and tube

Piled plates

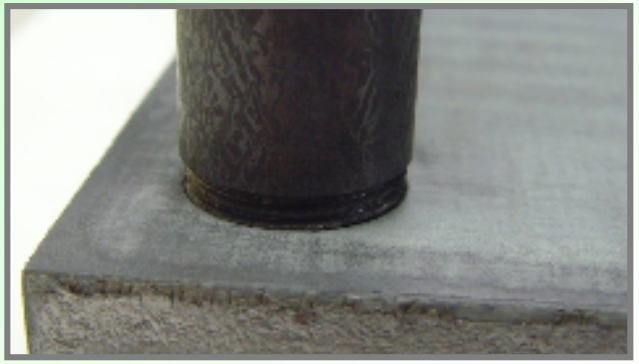


Attaching SiC tubes

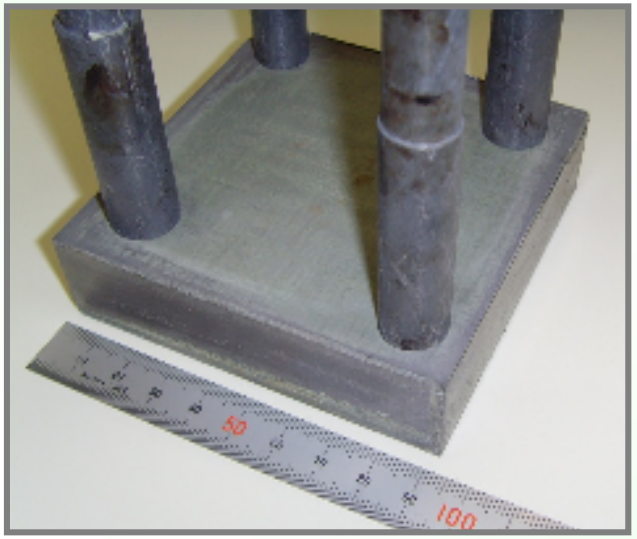


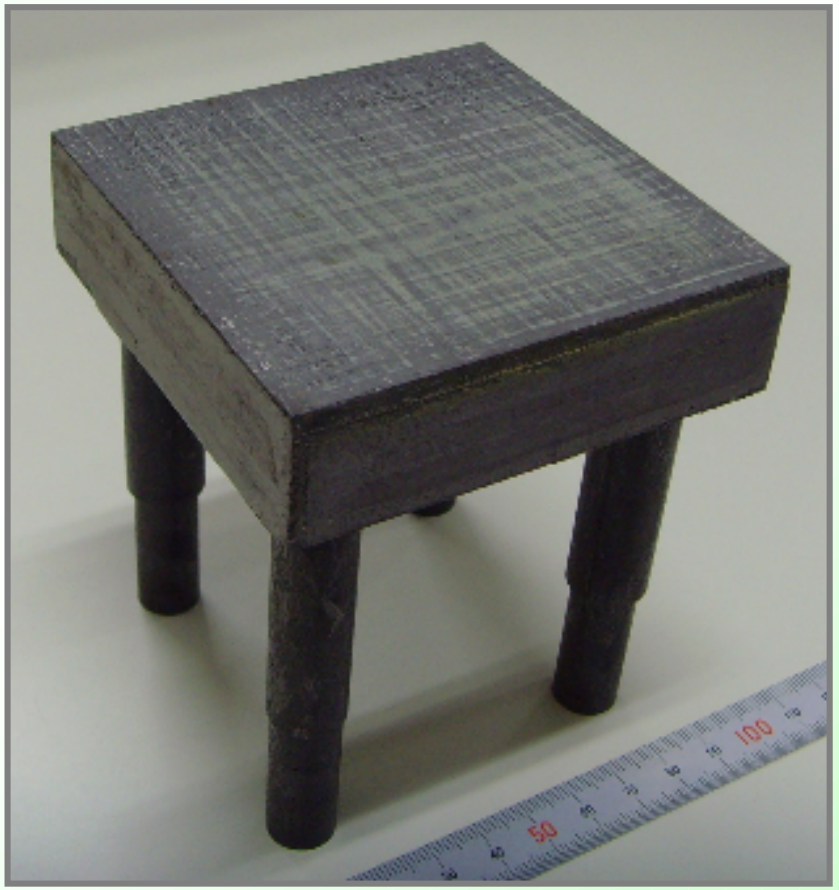


Assembled scale model IHX



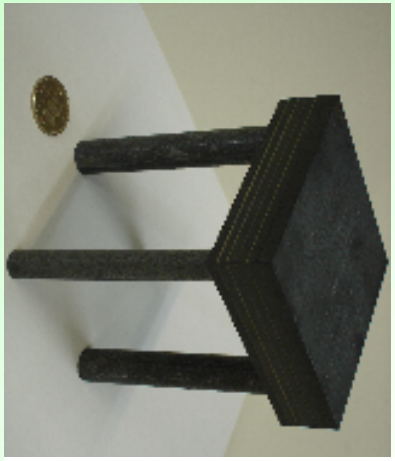
Screw joint





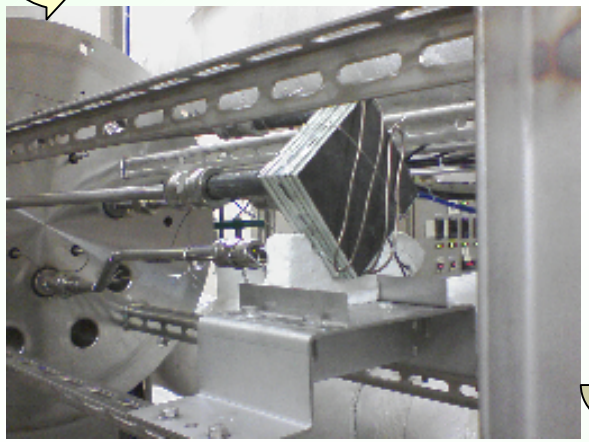
Scale model completed

LiPb circulated >900°C



SiC module

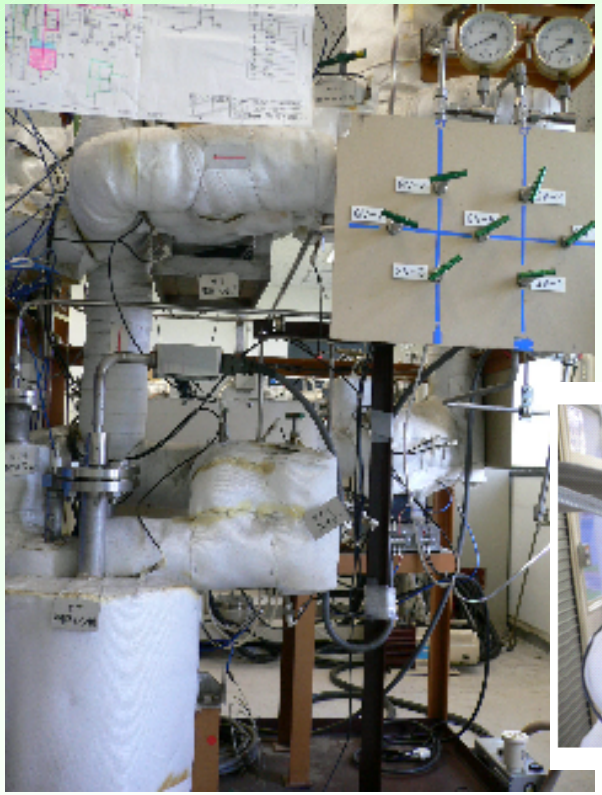
Loop operated >900 ° C
Only in the test vessel

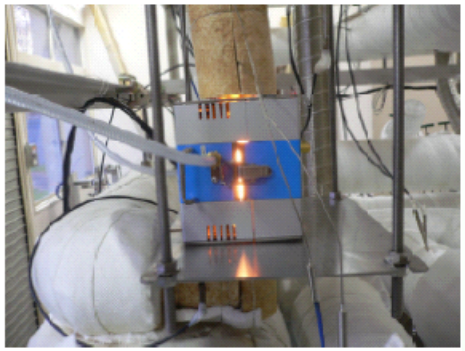


IHX heat transfer from LiPb to He

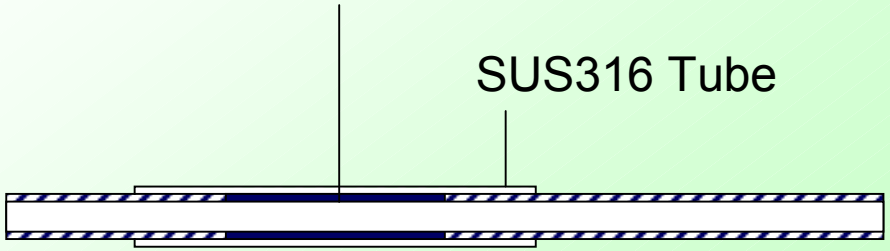
Installed in 900 ° C vessel

LiPb loop and SiC insert



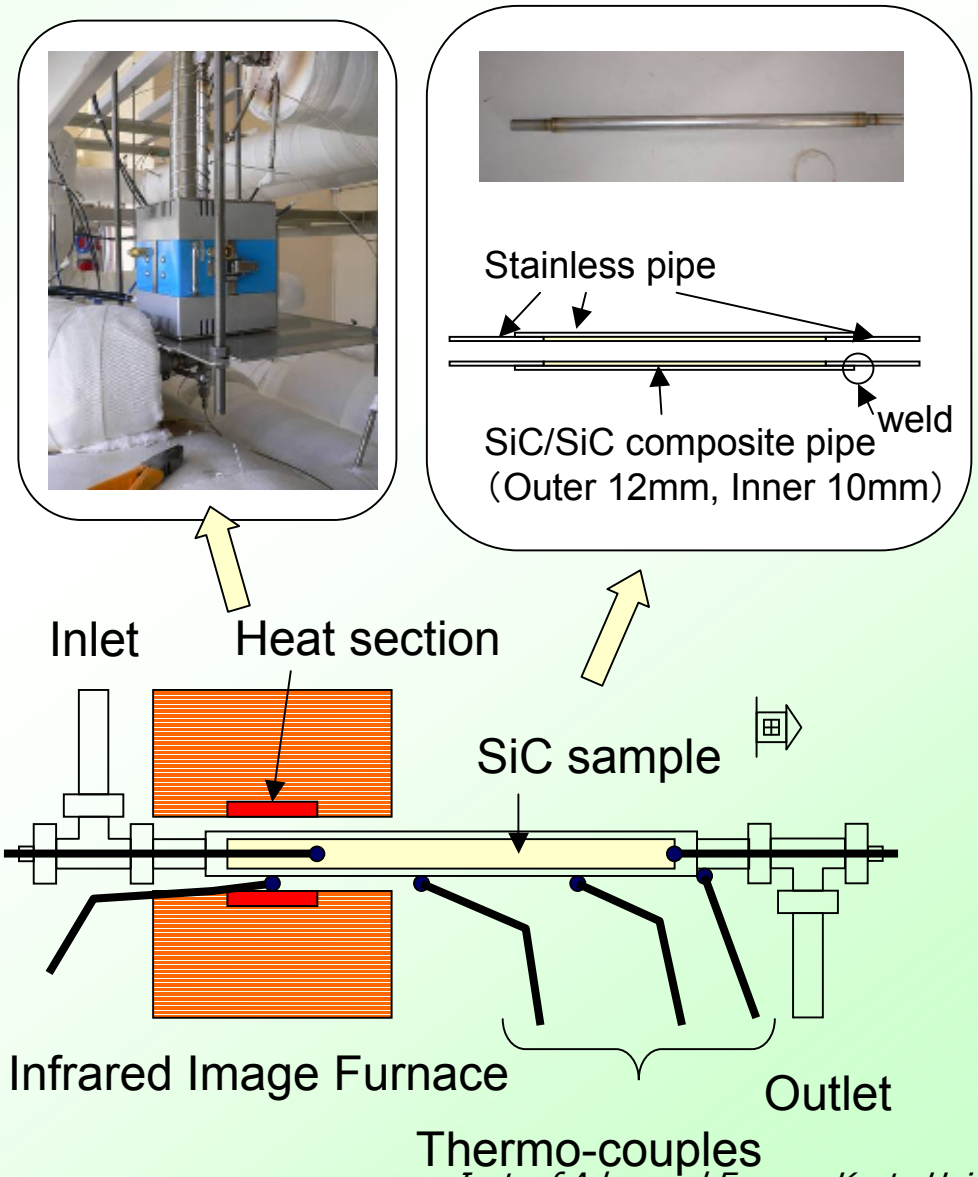


SiC/SiC Tube 149mm

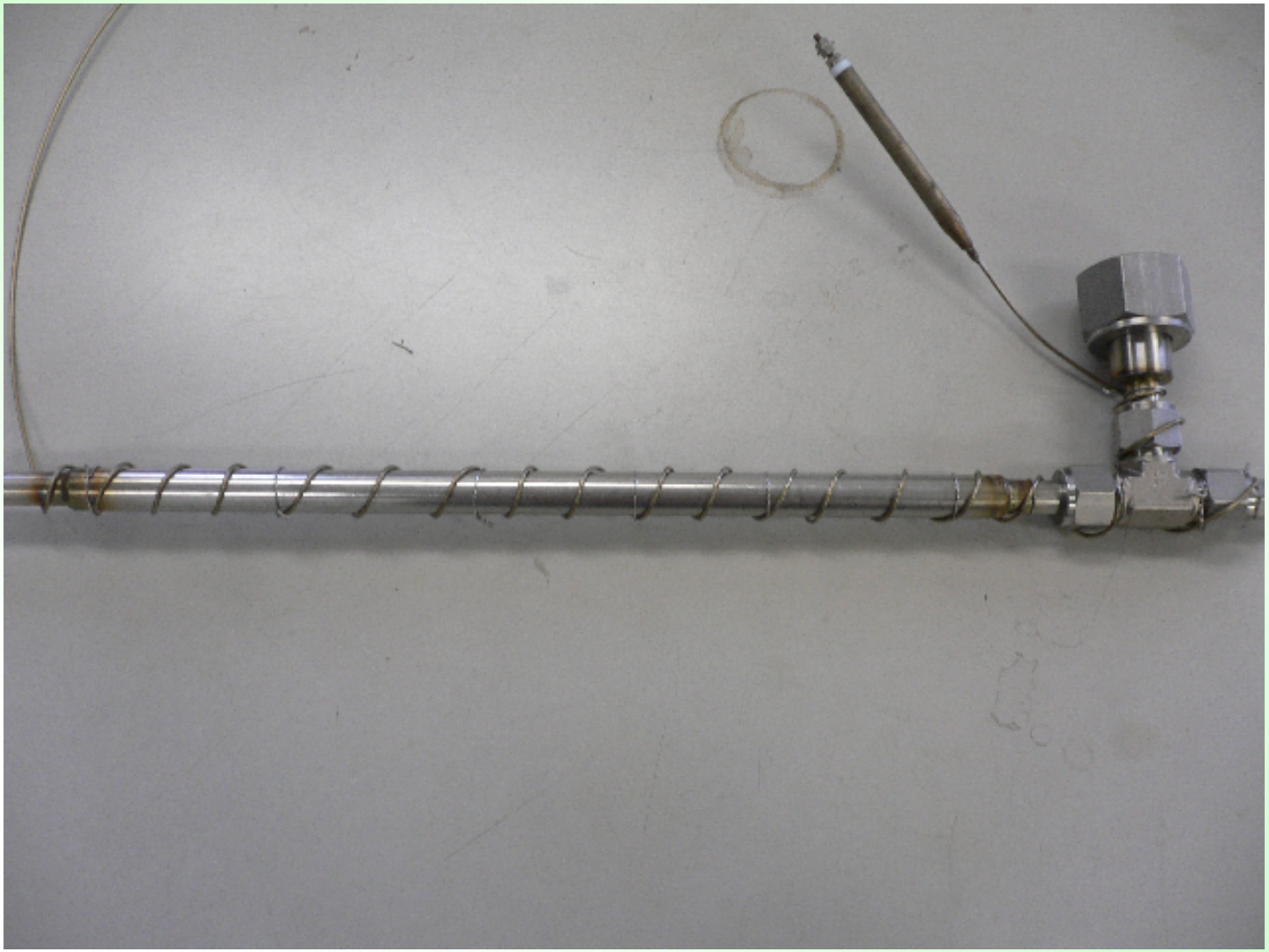


Compatibility tests

- Sample : SiC/SiC composite pipe with outer diameter of 12mm, thickness of 1mm, and length of 35cm.
- Enclosed in a SUS pipe.
- Heated by an Infrared Image Furnace (maximum temperature on the outer surface of the SUS pipe > 1000°C).
- Measure real fluid temperature by inserting thermo-couple into the pipe.



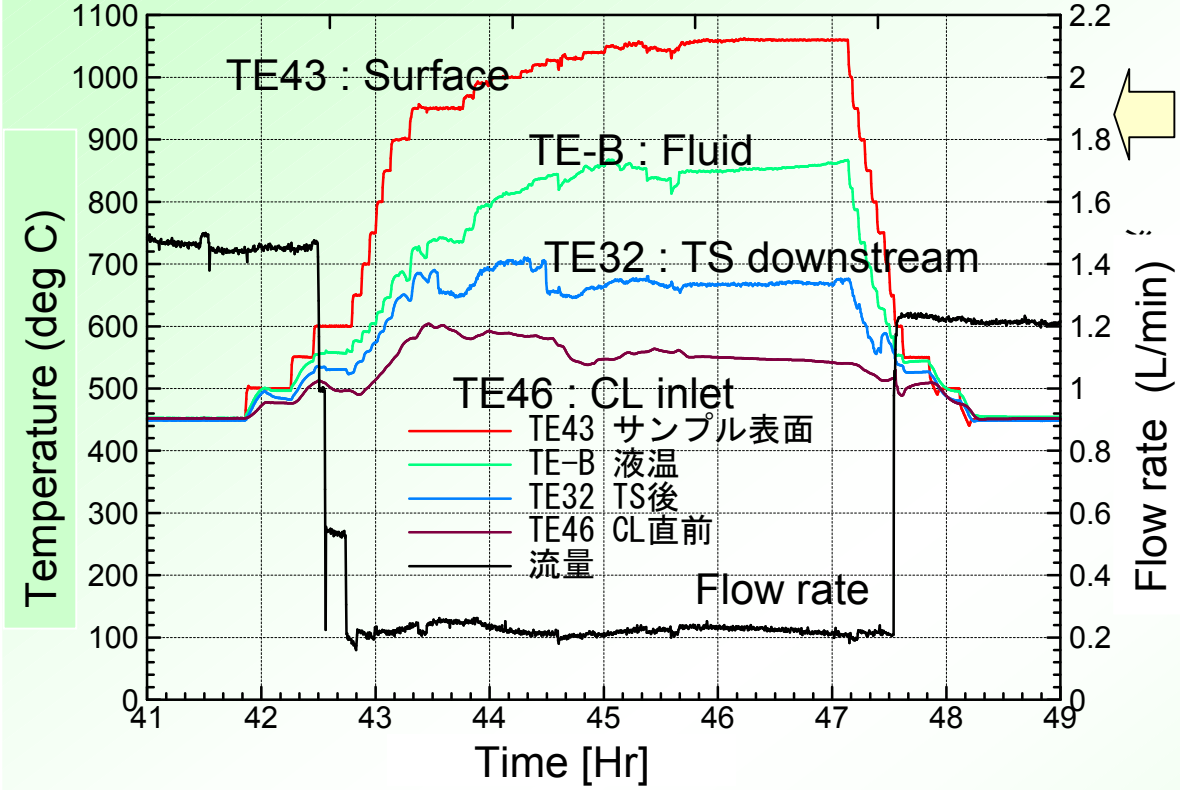
Test Section 1 Before install



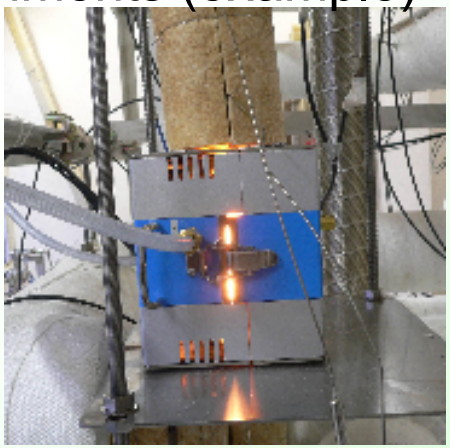
Test Section 1

With an Infrared Image Furnace (4.8kW)

Experimental Conditions



Changes of temperatures and flow rate during experiments (example)



Infrared furnace

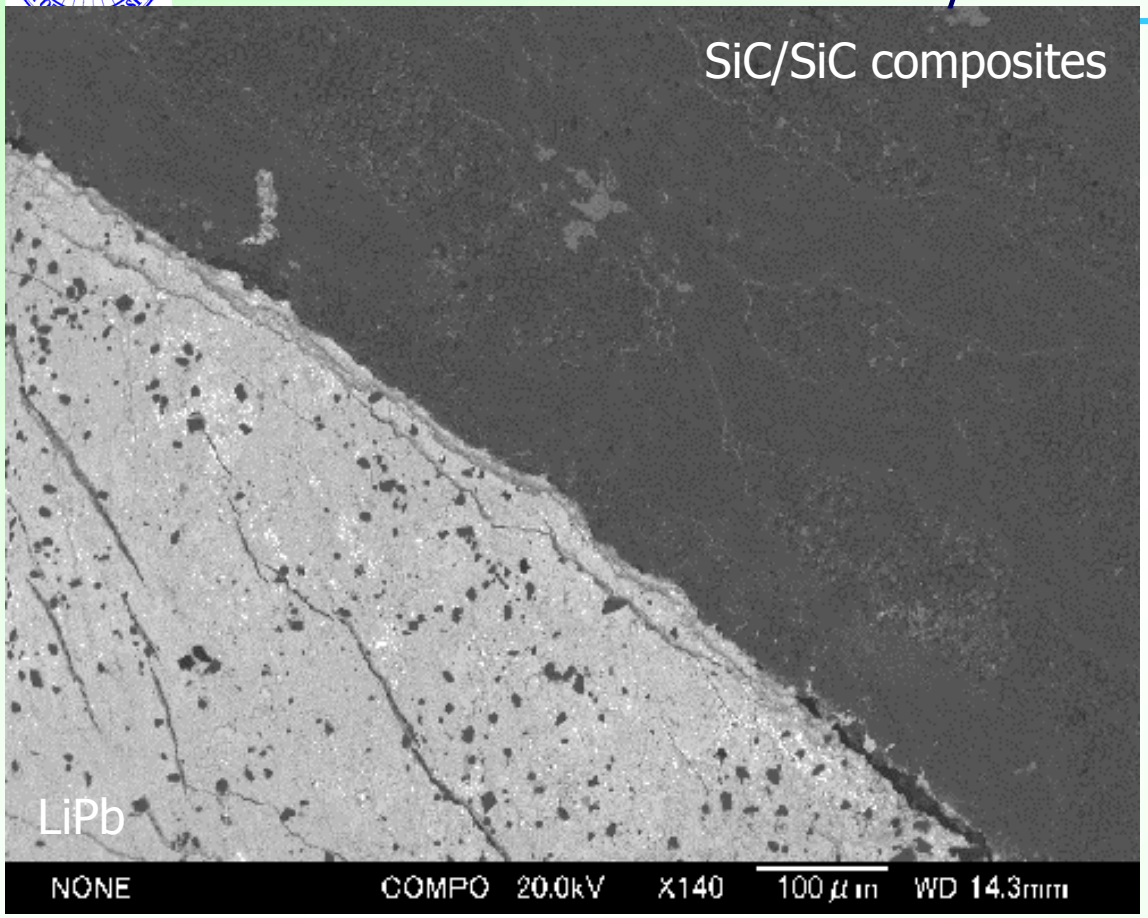
Achieve the temperature on the heat section > 1000°C and the fluid temperature > 860°C.

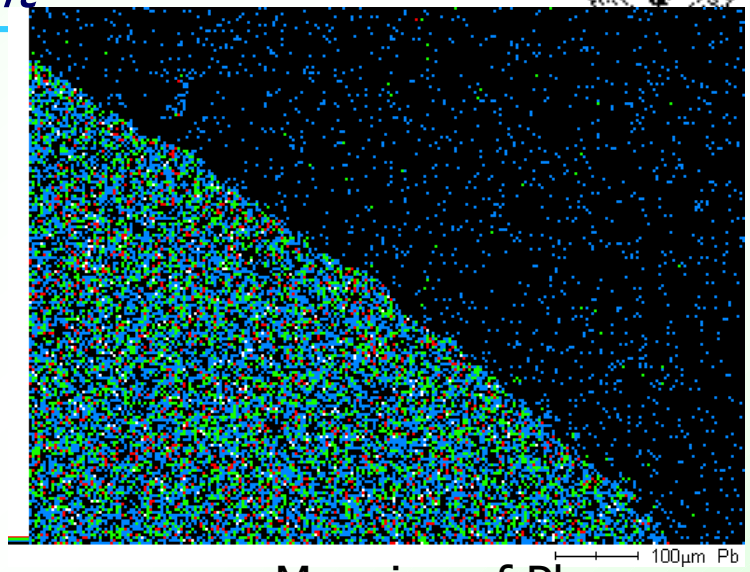
Due to temperature limits of main piping and valves, corrosion experiments have carried out with fluid temperature of 700°C for 2 weeks.

Test Section 1 after experiments

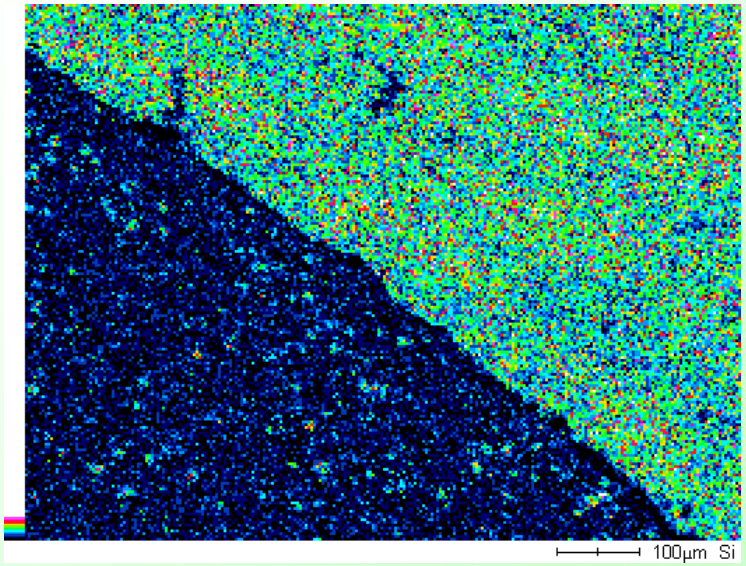
Pre-heater and thermo-couples need to replace

Residual LiPb on the SiC/SiC surface after experiment





Mapping of Pb



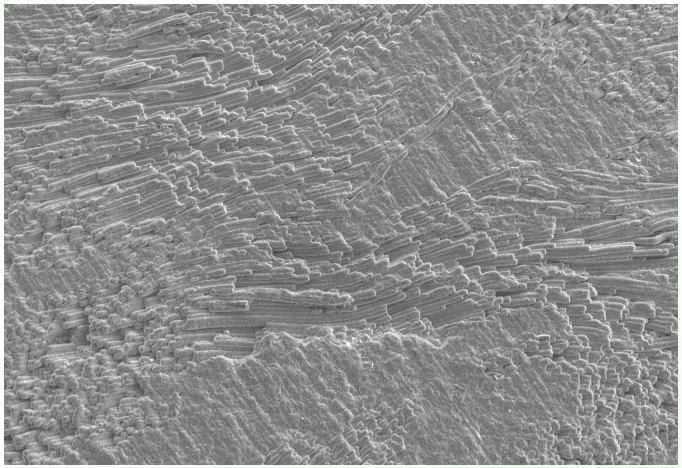
Mapping of Si

No reactive product is observed in interfacial layer between SiC/SiC composite and LiPb

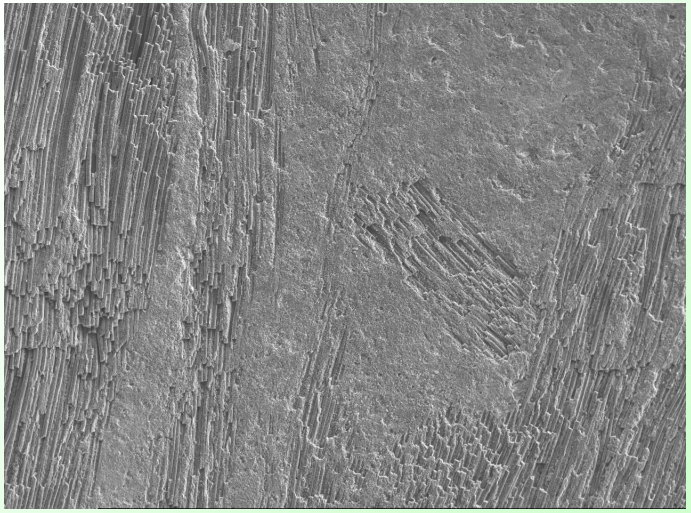
Inst. of Advanced Energy, Kyoto Univ.

Observation of SiC/SiC composite pipe after high temperature experiments

Observe samples after 700°C, 2week(~200hour) Operation



Outer surface x100



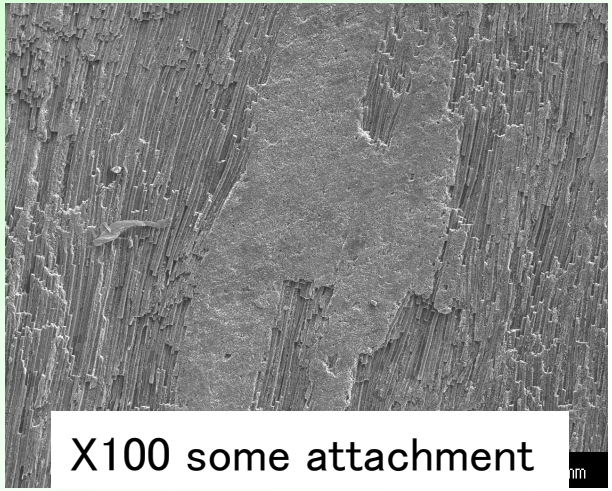
Inner surface x100

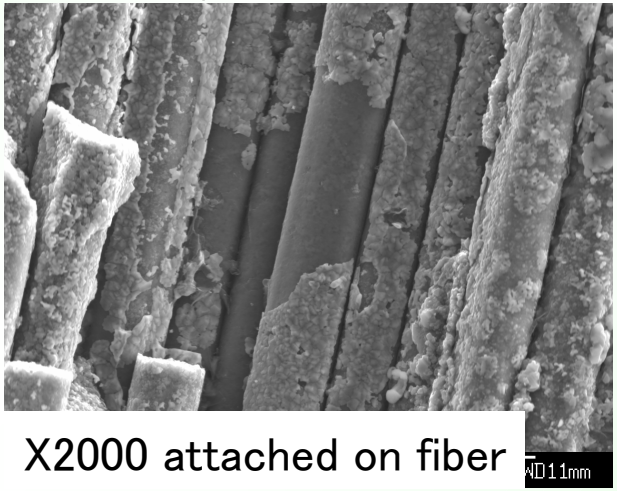
Outlook: there are silver attachments on the surface (Pb was completely removed by acetic acid)

No significant corrosion is observed

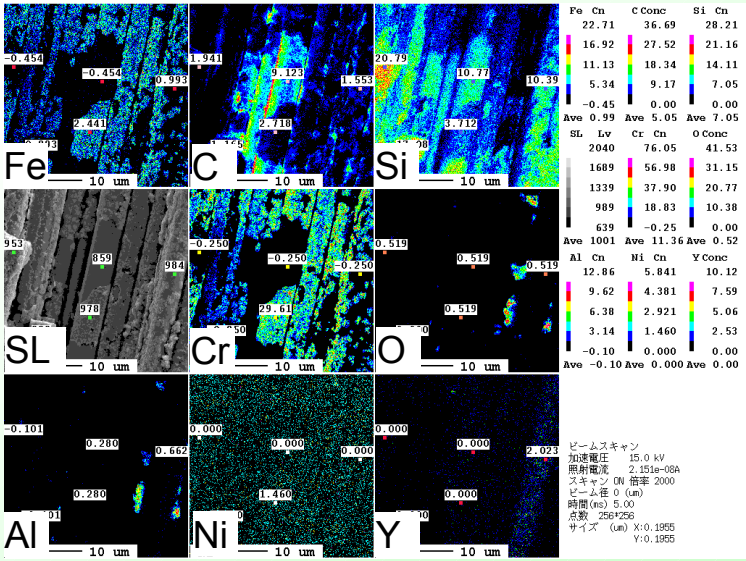
Adhesion of metals on SiC surface

Observations of SiC surface after compatibility test



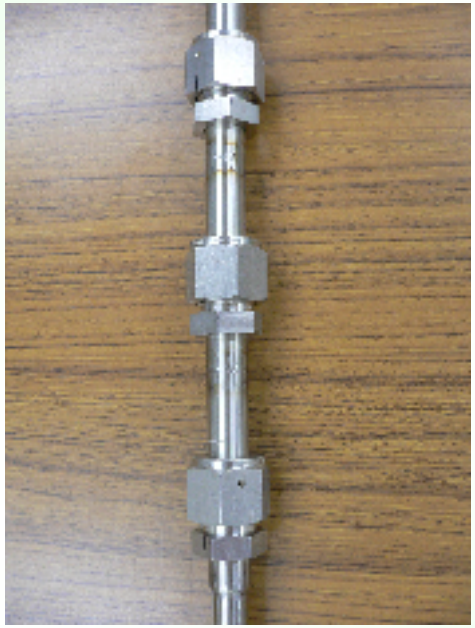


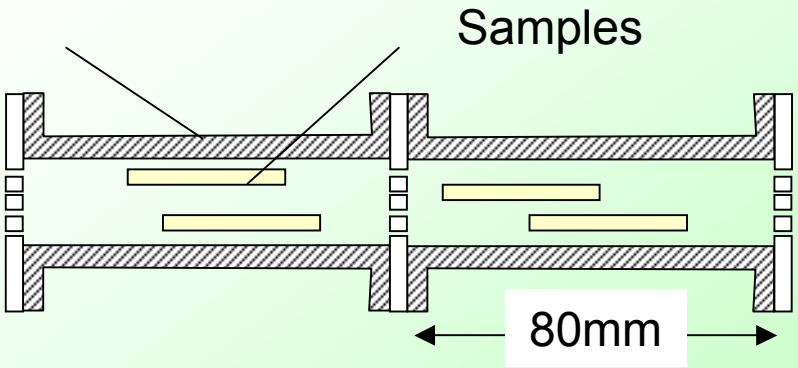
- No corrosion is observed after 200-hours experiment with maximum temperature of 900℃, for SiC/SiC composite, but there are some attachments on the surface.
- They attach on the fiber
- Through element analysis, the element are identified as Cr and Fe。
- Adhesion of Pb, removal of SiC, reactive layer are not observed.



Test Section 2 : Compatible test of metal

- Sample
  F82H
  4.5mm x25mmx2mm
  weight ~2g
- Temperature 350~650℃
- Flow rate 0.5~2 L/min



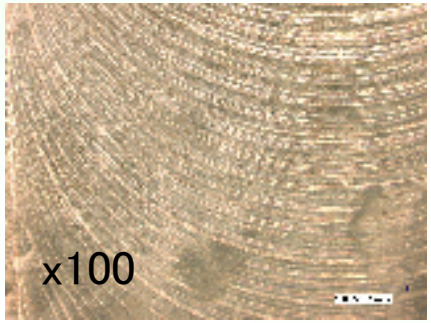


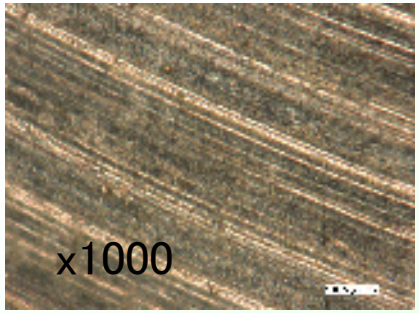
Corrosion test of ferritic steel

2007/8/30 ~100 Hour

No weight loss,

Processing marks are clearly observed.

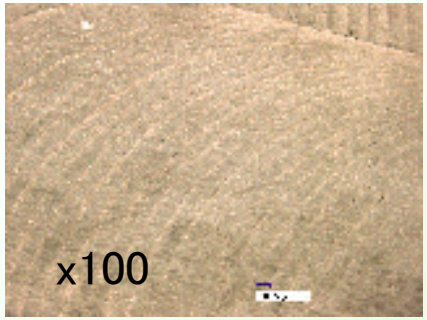


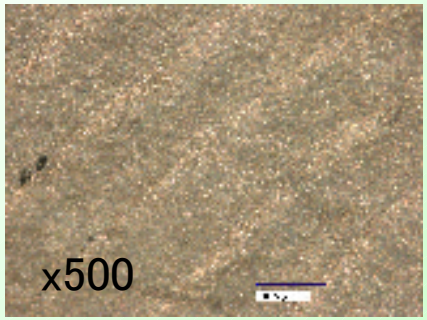


2007/11/30 ~500 Hour

Weight loss ~7mg

Processing marks become unclear.





Test is still undergoing

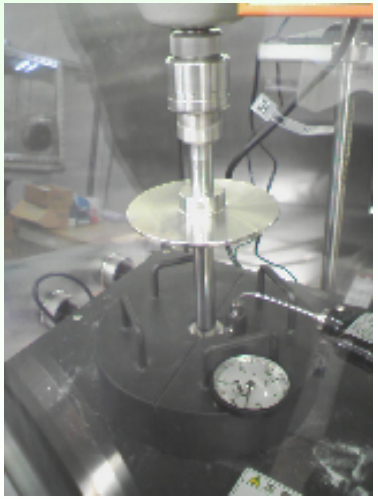
Compatibility tests in GB

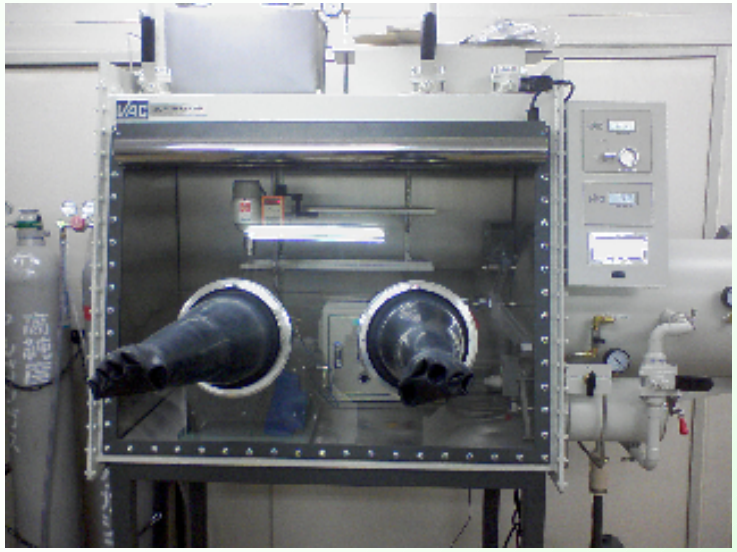
Accelerated test with

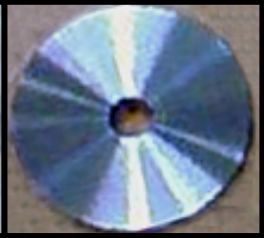
Rotating disk samples

・RAFM, SiC was tested.

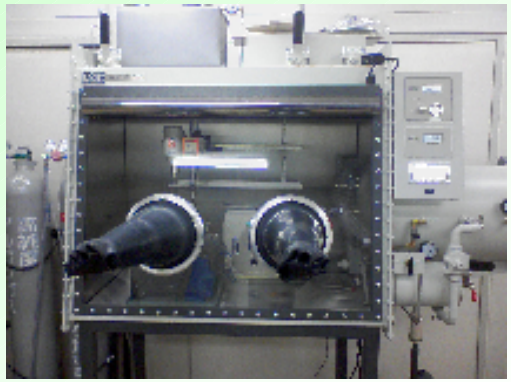
・corrosion measured as a function of relative flow velocity.





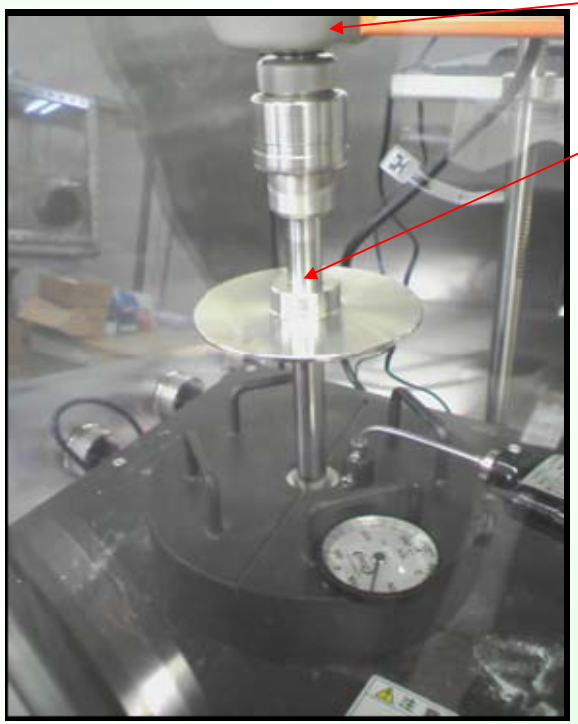
	SUS316	F82H	SiC/SiC
Before			
After			

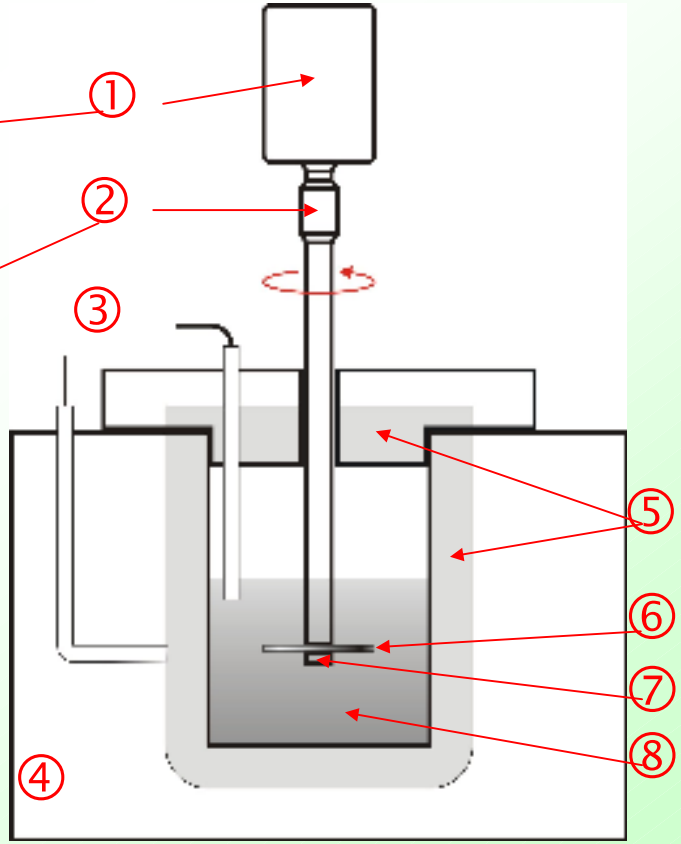
Setup of rotating disk experiments



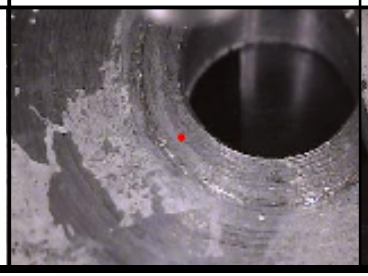
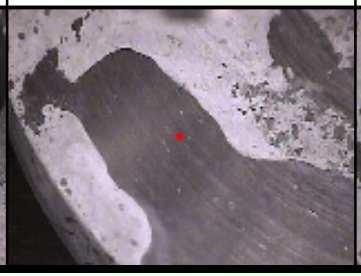
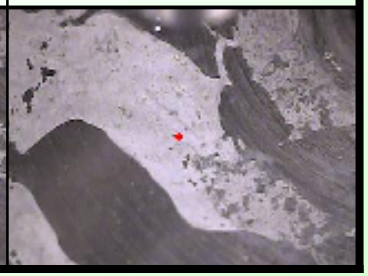
Contained in Ar glovebox
O2, H2O <1ppm

①motor
②shaft
③TC
④furnace
⑤alumina
⑥disk sample
⑦alumina
⑧LiPb



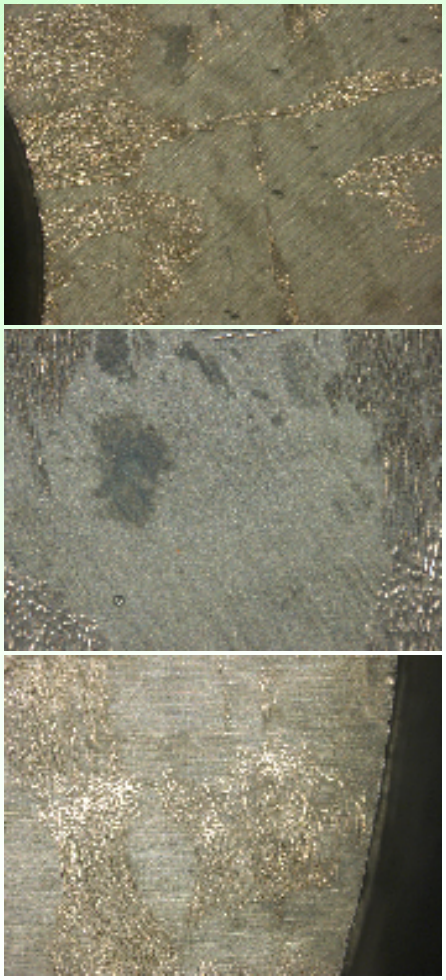


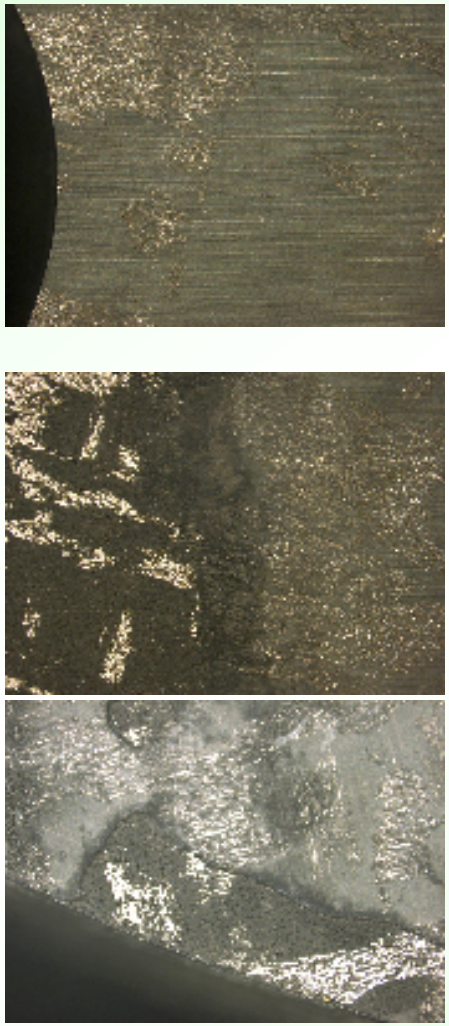
Ferritic steel disk experiments

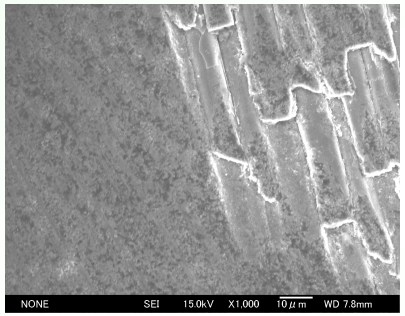
(c) F82H (+650°C, 100h)	Before test	Part under the support bar	Metal luster part	White part
Cr	8.0	7.6	8.0	6.2
W	2.0	2.0	2.0	2.0
Mn	0.5	-	-	-
V	0.2	0.2	0.1	0.2
Observation section	-			

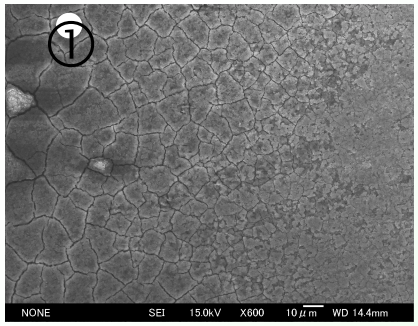
- RAFM showed corrosion at high temperature
- dependence on relative flow velocity is observed, but not clear
- SiC had metal deposit
- selective solution of Cr was found.

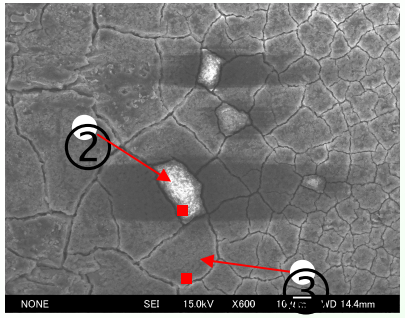
SiC disk experiments

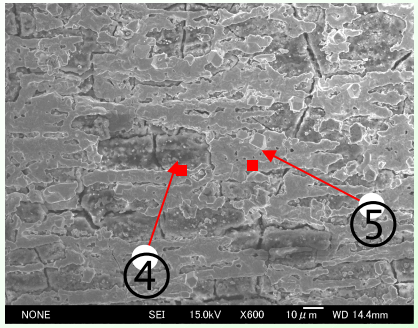












① Si(55.9),C(29.5),O(1.59)

② Si(36.5),Pb(19.5),O(17.3),C(16.7)

③ Si(38.0),Pb(22.0),C(17.4),O(13.4)

④ Si(45.3),Pb(21.4),O(15.5),Fe,Cr

⑤ Cr(51.2),Fe(44.93),C(2.82),O,Si

650C,100hr

850C,100hr

Summary and current status

LiPb loop operation

- liquid LiPb/He at ～900℃with ～10KW heat test operational.
- compatibility, heat exchange, hydrogen permeability.

Experiments

Compatibility

- SiC tested with LiPb for corrosion and compared with steel.
- Metal deposits on SiC found but no corrosion obwerved.

Hydrogen permeation

- Permeability of SiC composite higher than powder and fibers.
- SiC/SiC composite showed complex permeability behavior.

Heat transfer

- Function of Nu and Re obtained for test sample
- Function for plate fin structure measured with scale models.
- Performance equivalent to steel structure.

Conclusion and future work

Fabrication

- scale models fabricated to form heat exchange structure.
- 10 cm square model being tested in this fiscal year.

System and component design

- full scale model designed.
- indirect cycle plant designed.
- advantages of IHX being analyzed.

Demonstration

- heat exchange test under relevant condition on going.
- feasibility of SiC/SiC IHX will be confirmed by this program.
- application with different nuclear reactors will be considered.

-Supercritical water, supercritical carbon dioxide, liquid metal, IS process, hydrogen, and fusion.