Energy/Environmental Materials System
National Projects under OASIS Leadership

AKIRA KOHYAMA
OASIS, MURORAN INSTITUTE OF TECHNOLOGY
AGENDA

- What is OASIS?
- SiC/SiC R & D History and NITE-, NIC- Process
- Japanese Energy Strategy and OASIS Projects
- NITE-Process Development toward industrialization
- Conclusions
WHAT IS OASIS?

- **OASIS**
  (Organization of Advanced Sustainability Initiative for Energy/System Materials)
- was established March 2009.
- with special emphasis on
  - Research toward early deployment
  - Technology transfer to Japanese Industries
    - High level human resource education
Mostly based on large scale government funded projects:

Project Leader: A. Kohyama

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FISSION/FUSION MATERIALS SECTION

Fission/Fusion System & Materials

Fission
- LWR
  - Pressure vessel Steel
  - Joint SCC
  - Low Si PV Steel
  - SiC-Zircaloy
  - SiC/SiC Cladding
  - SiC/SiC Assembly
- GEN IV
  - SiC cladding / control rod
  - SiC wrapper tube
  - SiC steam generator (SFR)

Fusion
- ITER/BA
  - Large Melt F82H
  - HIP Joint F82H
  - W/SiC Heater for IFMIF
  - SiC/SiC Heater for IFMIF
- After DEMO
  - SiC First Wall
  - SiC-FCI for DCLL Blanket
  - SiC Diverter
  - SiC Limiter

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AEROSPACE POWER UNIT MATERIALS SECTION

Aerospace Power Unit Materials Section

Combustor

- Airplane Combustor
  - Combustor Afterburner Variable Slot
    - Ni Alloy/SiC
    - SiC/SiC
    - SUS/SiC
- Rocket Combustor
  - Combustor Nozzle Skirt Gas Generator
    - Ni Alloy/SiC
    - SiC/SiC
    - SUS/SiC

Turbo machine

- Disk, moving Blade
  - Turbine Blisk Disk Moving Blade
    - Ni Alloy/SiC
- Manifold, Stator Blade
  - Turbine Nozzle Stator Blade
    - Ni Alloy/SiC

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FRI is “to cover from atomic-scale to real system-scale, with multi-inspection methods/tools”; “Multi-scale” scheme for testing/evaluating materials and systems.
Process & Technology Integration from Lab.-scale toward Industry-scale
In OASIS

*Multi-Scale Structure Control in NITE Process and Advances in Thruster Fabrication*

SiC fiber: Dia. ~10μm

SiC nano powder: ~30nm

SiC crystal structure

β-SiC grain: ~300 nm

SiC/SiC Composite

500N Thruster: ~6dm

20N Thruster: ~2dm

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BACKGROUND OF OASIS ACTIVITY

- From the Japanese efforts in these decades, starting from the invention of PCS-type SiC fibers, NITE method to fabricate SiC/SiC composites was invented.
  - International Patents by A. Kohyama and Y. Katoh

- Efforts toward Industrialization:
  - IEST Co. Ltd., has started production of SiC fibers and SiC/SiC by NITE process since 2004.
  - IEST Co. Ltd., is now owned and operated by GUNZE.
  - Integrated industrial alliance toward early utilization of SiC/SiC is growing as JESSICA

- Two Major Directions
  - High Performance, Highly tailored Components.
    - Fuel cladding for LWR and Gen IV Reactor/
    - Blanket materials for Fusion Reactor/Transportation Systems
      - (Thruster nozzle and combustor liner)
  - Moderate Performance, large (UD, 2D, 3D) blocks

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JOINT VENTURE FOR ENERGY/SPACE BY SiC ALLIANCE (JESSICA)

- Toward the early realization and utilization of Advanced SiC/SiC (Cera-NITE™) in Energy and Space Systems.

SiC nano-Powders:
- IEST, Bridgestone

NITE Processing:
- OASIS, IEST/Gunze, JUTEM, Kinzoku Giken

Application:
- OASIS, IEST, Moon-Craft, Gun-Dai, Hoku-Dai, Toshiba, Kobelco

Machining:
- Morise Precision

SiC Fiber/Fabrics:
- IEST/GUNZE

Fiber/Composite Coating:
- OASIS, Toyo Tanso

Evaluation/Analysis:
- OASIS, Osaka Univ., JAEA, Tohoku Univ., Hokkaido Univ.

NDT/NDI:
- KJTD, JAEA, Osaka Univ.

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SiC/SiC: International Strategy for Technology & Engineering database development

Industrial fabrication technology

- **Fibers:** Cef-NITE production is aiming over 1 ton/year from 2008 (Japan)
- **Woven fabrics production:** (1.5m width) has been started (Japan)
- **Coatings:** Continuous and large-scale R&D has just started (Japan)
- **Nano-Powders:** Pilot plant construction was finished (France)
- **SiC/SiC Composites:** Cera-NITE is commercially available (Japan)


- **Mission:** Engineering Database of advanced SiC/SiC for high temperature DEMO reactor application
- **Materials:** NITE-SiC/SiC from Japan, and CVI-SiC/SiC from Europe
- **Task 1:** Mechanical Properties, SSTT, Multi-scale modeling
- **Task 2:** Physical & chemical properties
SIC FIBER MAKERS

- **JAPAN**
  - NCK: Nicalon™
    - Joint Venture with GE/SAFRAN ⇒ NGS Advanced Fibers Co., Ltd.
  - UBE Ind.: Tyranno™
    - Cooperated with GUNZE(IEST Co., Ltd.)

- **USA**:
  - COI Ceramic: Sylamic

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**NICALON**
NCK (JAPAN)

NGS Advanced Fibers Co., Ltd.

GE, SAFRAN

http://www.ngs-advanced-fibers.com/jpn/index.html

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**Tyranno**
UBE Ind. (JAPAN)

Cef-NITE™
GUNZE (JAPAN)
IEST Co., Ltd.

**Sylamic**
COI Ceramic (USA)

http://www.coiceramics.com/sicfibers.html

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Fraunhoft HTL
GERMANY

KICET
KOREA

NUDT
CHINA

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1976: First reactor irradiation of pcs-SiC with Prof. Igata

**The History of SiC Composite R & D Under Kohyama Group**

<table>
<thead>
<tr>
<th>Year</th>
<th>Research Program</th>
<th>Major Subjects</th>
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<tbody>
<tr>
<td>1985</td>
<td>HPCFI Program (METI)</td>
<td>SiC/Al, SiC/Cu</td>
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<td>1990</td>
<td>AMG Program (METI)</td>
<td>SiC/SiC (PIP, MI)</td>
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<tr>
<td>2000</td>
<td>CREST-ACE Program (STA)</td>
<td>SiC/SiC (CVI, PIP, MI, LPS)</td>
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<tr>
<td>2005</td>
<td>IVNET: SiC/SiC GFR Core (MEXT)</td>
<td>SiC/SiC (NITE, +CVI, +PIP)</td>
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<tr>
<td>2010</td>
<td>IVNET: SiC/SiC IHX (MEXT)</td>
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<tr>
<td>2015</td>
<td>INSPIRE Project (METI)</td>
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<tr>
<td>2020</td>
<td>SCARLET Project (MEXT)</td>
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<tr>
<td>2025</td>
<td>FIAT Project (METI)</td>
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</tbody>
</table>

HPCFI: High Performance Composite Materials for Future Industries
AMG: Advanced Materials Gas-Generator
CREST-ACE: Core Research for Evolutional Science and Technology – Advanced materials for Conversion of Energy
IVNET: Innovative Nuclear Energy Technology development
SIPSAM: Support Industry Program/SiC/SiC for Al Die-Casting Machine by Hot-Chamber Method
SIRIUS: SiC Integration Research for Innovative Utilization of Geothermal Energy Source
SCARLET: SiC Fuel Cladding/Assembly Research Launching Extra-Safe Technology
INSPIRE: Innovative SiC Fuel-Pin Research
FIAT: LWR Fuel with Increased Accident Tolerance

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CREST-ACE Program (1997-2002) Structure

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Advanced SiC/SiC by NITE Process

NITE: Nano-Infiltration and Transient Eutectic Phase Process

- Inexpensive/Time-saving New Process
- Excellent mechanical properties
- High thermal conductivity
- Excellent hermeticity / helium-tightness
- Complex shapes and thin-wall production
- Excellent radiation resistance anticipated

High Ductility Type

High Strength Type
NITE-SiC/SiC: COMBUSTION CYCLE TEST
- BY MHI-NAGASAKI -

No detectable damage. No degradation in strength.

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Improvements in Melt Infiltration Method
- strength and thermal conductivity -

Crest-Ace

25 μm

CREST-ACE MI-SiC

Conventional MI-SiC

Residual Si

Flexural Strength (MPa)

New-MI (CREST-ACE)  Conventional MI  Pres. Less sintering

Thermal Conductivity (W/mK)

New-MI (CREST-ACE)  Conventional MI  Pres. Less sintering

SiC micro-powder as filler
+ Low residual Si
+ Fine dispersion of Si
makes
Further improvement in TC
R & D OF SiC ROTATING TARGET FOR “DEEME” PROJECT

Direct emission of electron by Muon to electron conversion; “DeeMe” is a J-Parc Project for Physics using 300 -3 GeV Proton from J-Parc.

The current graphite target should be changed to SiC from test sensitivity

Graphite Rotating Target

“NITE” Target - 1/3 model -

NITe Process
Nano-Infiltration and Transient-Eutectic
high performance/large flexibility in shape and size

“NIC” Target – process R & D -

NIC Process
Nano-Infiltration and In-situ Carbonization
low cost/moderate performance/shape and size flexibility

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4 types of power sources are defined as “Base Load”

Those are:

- Nuclear
- Coal
- Hydroelectricity
- Geothermal

“Increased safety margin” is the baseline requirement toward revival of nuclear power source:

“Increased Accident Tolerance of LWR-Fuel” becomes the key words for OECD/NEA, bi-lateral activities of USA (and Japan/Korea)

May starts with small scale power source for:

- Isolated area oriented base power,
- R & D of Sub-marine resource
There are strong needs of Ultra-safe Fission Reactors Where, "LWR-Fuel with Increased Accident Tolerance" are inevitable.
NATIONAL R & D PROJECTS FOR BASE-LOAD POWER SOURCE UNDER OASIS LEADERSHIP

- Basic/Fundamental Support on Science and Technology
  **FEEMA Project** (MEXT): *Since 2009*

  For Energy and Environment

- Outer-Dual Layered Pipe for DCHE Type Geothermal Electricity:
  **SIRIUS Project** (MEXT/JST): *Since 2012*

  For Geothermal

**FEEMA: Facility for Environment and Energy Materials Assessment**

**SIRIUS: SiC Integration Research for Innovative Utilization of Geothermal Energy Source**

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NATIONAL R & D PROJECTS FOR BASE-LOAD POWER SOURCE UNDER OASIS LEADERSHIP

- Fuel Cladding/Channel Box R & D for LWR (BWR): **INSPIRE Project** (METI): *Since 2012*
  For Nuclear Fission

- Fuel Cladding/Channel Box R & D for LWR (PWR): **SCARLET Project** (MEXT/JST): *Since 2012*
  For Nuclear Fission

- R & D of Accident Tolerant Fuel for LWRs: **FIAT Project** (MEXT/JST): *Since 2014*
  For Nuclear Fission

**INSPIRE**: Innovative SiC Fuel-Pin Research

**SCARLET**: SiC Fuel Cladding/Assembly Research Launching Extra-Safe Technology

**FIAT**: LWR Fuel with Increased Accident Tolerance

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BACKGROUND OF PROJECTS “INSPIRE” & “SCARLET”

Based on the “Basic Energy Policy” (June, 2010) and reflecting the after-effects of East Japan Earthquake (March 11, 2011), “The 4th Phase Basic Plan of Science and Technology” (Aug. 2011) was issued. The Revised Version of “Framework of Nuclear Energy Policy for 2012” had been prepared, but was cancelled on October 2, 2012, where the followings were emphasized.

- Restructuring of nuclear energy policy towards safety assurance and recovery of public trust.
- Restructuring of nuclear energy policy under large drop of energy dependence on nuclear.
- Establishment of ”The Highest Level of Nuclear Safety” is strictly required.

METI Program on “Innovative Nuclear Research and Development” has been changed from 2012 to be emphasized on “Basic Technology Development for Nuclear Safety Innovation”

MEXT Program on “Innovative Nuclear Research and Development” has been changed from 2012 to be emphasized on “Basic Technology Development for Nuclear Safety Innovation”

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METI PROGRAM FOR
“ENSURING NUCLEAR SAFETY TECHNOLOGY”

- 2 Similar Project on SiC/SiC Fuel Pin and Channel Box
  - Based on CVD/CVI (Toshiba Corp. + Ibiden, Tohoku Univ., Univ. Tokyo)
  - Based on NITE Method (Muroran I. T. + Tohoku Univ., NFD)

Project restructuring/
Budget Modification
Was done
(Toshiba: 3 years)

Annual Budget:
150 Million Yen
For the two project
(INSPRIRE:100MY/2014)
## THE CURRENT PROJECT PLAN (APRIL 1, 2013)

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<td>Halden Irrad. Segment Fab.</td>
<td>Fuel Pin Element Fab.</td>
<td>Comp. Test Fac. Design and Fab.</td>
<td>Comp. Test under BWR Condition</td>
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<td>Halden R. Irradiation</td>
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<td>3: Neutron Irradiation Effects of the NITE-SiC/SiC</td>
<td>BR2 Capsule Design &amp; Fab.</td>
<td>End-cap Joining Tech. Integration</td>
<td>Capsule Fabrication</td>
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<td>4: Wrap UP</td>
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SiC/SiC Fuel Cladding

Un-coated SiC/SiC tube

Surface
+30° -30°

10 mm

Monolithic SiC coated SiC/SiC tube

10 mm

Cross-section

Density;
2.8 g/cm³

2 mm

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Baseline Concept:
Replaceable SiC/SiC cladding from Zircaloy cladding is to be developed. Thus the specification is aimed to satisfy ASTM Standard B 353-91, which is for LWR application. Project “INSPIRE” is targeting to produce 10mm inner diameter, 1 mm wall thickness and 200mm long claddings with sufficient gas tightness.

**Dimensional Accuracy:**
- Diameter: ±0.05mm
- Straightness: 1/1200
- Wall Thickness: ±10%
- Roundness: 1/2000  (Accomplished)

**Baseline Mechanical Properties:**
- Axial Tensile Strength: 300MPa
- Hoop Strength: 100MPa (Comp)/300MPa (Tens.)
- Fracture at accident: no straight/ crystallographic through thickness fracture (>0.2% Pseudo-plasticity)

**Environmental Resistance:**
- Neutron Damage Resistance:
  1) Soundness check up to 10GWD/t exposure at Halden Reactor under BWR water condition.
  2) Confirm mechanical property degradation less than 5% at BR2 reactor irradiation.

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SiC/SiC Fuel Cladding

10mm\text{id} \times 1.0\text{mm}\text{t} \times 20\text{mm}\text{l} \text{ NITE-SiC/SiC Tube}
"INSPIRE" PROJECT IRRADIATION PLAN
FUELED RODS UNDER BWR CONDITION IN THE HALDEN REACTOR

Proposed test rig

- The irradiation is to be carried out in a test rig within a pressure flask, cooled by water at BWR thermal-hydraulics and chemical conditions (see figure).
- The rig will accommodate 6 test rods, typically 20 cm long, arranged in two cluster, as shown in the figure on the right hand side. The rods will be equipped with cladding elongation detector for measuring on-line the amount of pellet-cladding mechanical interaction (PCMI) and cladding permanent growth due to PCMI and neutron irradiation.

Test rods

- The six rods may contain different variants, such as different cladding or end-plug material.
- The fuel pellets will be fabricated at the IFE establishment at Kjeller, under agreed specifications. The cladding tube and the end plugs will be provided by the customer, who is also to define, in consultation with Halden, the rod inner pressure. Currently, atmospheric pressure is foreseen. The fuel rod assembly, gas filling and end-plug welding will be realized by IFE following further discussions and under agreed specifications.

In-reactor operation

- It is foreseen that the test will be run at power conditions typical for commercial fuel, i.e. 20-25 kW/m at beginning of irradiation and then gradually decreasing. The PCMI and permanent cladding strain will be assessed continuously during the irradiation.

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PRELIMINARY CONCEPT OF THE TEST ROD FOR "INSPIRE" IRRADIATION IN HALDEN REACTOR

- 6 rods/rig: 1 rod of Zircaloy/ 1 rod of un-fuelled SiC/SiC/ 4 SiC/SiC rods with 2 material/fuel variants
- Open end SiC/SiC rods with Zircaloy end-parts will be provided by M.I.T.
- Fuelling /end-cap joining by EBW will be done at/by Halden R. P.

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ZIRCALOY + SiC/SiC JOINT TEST SAMPLE

10mm id, 0.7mm t NITE-SiC/SiC Tube

Zirconium alloy (Zircaloy) End-cap

Silicon Carbide/Silicon Carbide (SiC/SiC) Cladding
MEXT PROGRAM ON “INNOVATIVE NUCLEAR R & D”

The Sub-title has been changed from 2012:
“Basic Technology Development for Nuclear Safety Innovation”

- 11 Projects have been approved.
- 3 Projects are “material oriented”, where two Projects are on Ceramic Composite Materials.
  ◆ R & D of Innovative Reactor Core Materials Application Technology (*Toshiba Corp.*)
    –mainly on C/SiC
  ◆ R & D of Basic Fabrication Process Technology of SiC/SiC Fuel Cladding for Extra-Safe Reactor Core (*Muroran I. T.*)

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WHAT IS PROJECT “SCARLET”?

◆ Establish Solid – Basis of Making SiC/SiC Fuel Cladding/Assembly as Japanese Innovation for “Nuclear Safety” and make-a-way to the early realization of the SiC/SiC Fuel Pin Assembly into Nuclear Power Reactors.
  ◆ Proof-of-the-reality of SiC/SiC Fuel Cladding as a replacement of Zircoalloy Fuel Cladding in a short term.
  ◆ Feasibility Demonstration of SiC/SiC Fuel Cladding Sodium Cooling Fast Reactor and GFR.
  ◆ Establish large scale production basis of SiC/SiC Fuel Cladding by NITE-Method\(^1\).
  ◆ Integrate technologies of making SiC/SiC Fuel Pin and Fabricate Fuel Pin/Reactor Irradiation Capsule with SiC/SiC fuel pin element.
  ◆ Evaluate Properties of SiC/SiC Cladding, SiC/SiC Fuel Pin, as long as 1 meter, including environmental tolerance evaluation under light water reactor and LMFBR.

\(^{1}\): Japan and International patent by A. Kohyama and Y. Katoh

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(1) Time Period: November, 2012 – March 2016
(2) Project Structure
Background
The present proposal addresses a testing of the integrity of unfueled segmented rods having SiC as cladding material after reactor irradiation. For this purpose, 15 SiC rod segments sealed by means of end plug welding are contained in the rig. The proposal is intended to respond to a request set forth by members of the Muroran Institute of Technology in Japan and Halden reactor experts.

Test rig
A schematic of the proposed rig is shown in the next page. The rig is meant for operation in a Halden loop under PWR conditions, i.e. at 155 bar and 290°C inlet temperature. It contains 6 rods, of which three are with zircaloy cladding and UO2 fuel, and three are segmented rods having SiC cladding without fuel inside. The SiC rods are outlined in the following section. The fuelled rod parameters (dimensions and fuel enrichment) will be based on Halden assessments.

Operation
The test will be run under PWR conditions, i.e. 155 bar and 290°C inlet temperature. The irradiation will occur in two Halden reactor cycles of 80 - 100 full power days. The irradiation contemplated in this proposal is currently foreseen to occur in two Japanese fiscal years (2014 and 2015). Inspection of all segments test will occur at the end of irradiation.
METI PROGRAM ON “ACCIDENT TOLERANT FUEL”

Domestic Back-up Activity connecting with:
ATF task of
“Civil Nuclear Energy Research and Development Working Group; CNWG”
Under bi-lateral commission between US-Japan

Goal: By 2022, develop and test, in an existing LWR, an advanced fuel rod which tolerates loss of active cooling in the core for considerably longer time period than existing fuel.

Objectives:
- Significantly reduce or eliminate hydrogen generation
- Reduce spent fuel volume through increased burnup
- Reduce Fuel Pin Failures & Increased reliability
- Improve Economics & Permit Power Upgrades
WHAT IS PROJECT “FIAT”? 

◆ Connecting with US-J Bi-lateral Commission of CNWG
  ◆ “ATF” R & D was agreed to conduct as one of mid-term cooperation of the LWR R & D Sub-WG
  ◆ Three cooperative tasks have been identified
    ◆ ATF Attributes and Matrices Identification and Quantification
    ◆ Accident Tolerant Fuel and Core Component
    ◆ ATF Test Methods, Facilities and

◆ Domestic Activity for 2014
  ◆ OASIS, Muroran Institute of Technology is managing the project
  ◆ JAEA, Osaka Univ., Tohoku Univ., Hokkaido Univ., Nagaoka U. Tech., Fukui Univ., RIST, NFD, GUNZE and other companies are joining
LEGAL AND PROJECT ARRANGEMENT

U.S. – Japan
Government-to-Government Agreement
March 12, 2012

DOE-MEXT
Implementing Agreement

DOE-NRA
Implementing Agreement

DOE-METI
Implementing Agreement

DOE-JAEA
Advanced Reactor R&D Project Arrangement

DOE-JAEA
Fuel Cycle R&D and Waste Management Project Arrangement

DOE-METI and DOE-JAEA
Light Water Reactor R&D Project Arrangements

ATF is Intermediate Term Cooperation
As research for effective utilization of geothermal energy, OASIS is promoting the SIRIUS Project in collaboration with Gunze Co. Ltd., Japan. The DCHE (downhole coaxial heat exchanger) is the new innovative geothermal generation system, which is performed power generation by closed type heat exchanger system using high performance inner and outer tube. In the SIRIUS Project, in order to realize further attractive geothermal generation, excellent heat- and environmental- resistant materials for outer tube are mainly developed. The mechanistic verification experiment of pressurized water type DCHE system has been performed using Phase-2 facility. The verification of electric generation is planned by the binary type system.
The FEEMA Facility under OASIS provides opportunities to evaluate material behaviors under Complex/Ultimate severe environments, such as super-critical water environment, corrosive/erosive environment, ultra-low temperature environment. This Project aims to make a great contribution to the society with the emphasis on industrial supporting efforts through FEEMA utilization.

The FEEMA Project was designated as “Promotion of Advanced R & D Facility Utilization” in Fy2009 by the Ministry of Education, Culture, Sports, Science and Technology, JAPAN (MEXT). From 2013, the second phase of this activity has been started and the budget for facility upgrading also has been approved.
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FABRICATION OF CMC (CERAMIC MATRIX COMPOSITES)

Fiber Architecture
- 3D Fabrics/2D Satin, Braiding, UD/X-Ply/Winding

Matrix Densification Method
- RS/LPS
- NITE
- Slurry Infiltration
- Sintering
- FCVI
- Pyrolysis
- Polymer Impregnation

Final State

Fiber Coating
- I-CVD Coating
- Mild oxidation
- PIP
- others

NITE: Nano Infiltration and Transient Eutectic Phase (Process)
PIP: Polymer Impregnation & Pyrolysis
RS/LPS: Reaction Sintering/Liquid Phase Sintering
FCVI: Forced-flow Chemical Vapor Infiltration

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**ORIGINAL NITE PROCESS**

**(NANO-INFILTRATION & TRANSIENT-EUTECTIC PHASE)**

- **Cef-NITE™**
  - Highly Crystallized SiC fiber (Dia 7.5 μm - )
  - SiC fibers or Fabrics
  - Mixed Surry
  - Green Sheet

- **Fi-NITE™**
  - SiC nano powder (Particle size – 30nm)
  - Partly supplied from Nanomakers (France)

- **Cera-NITE™**
  - Hot Press, HIP, P-HIP
  - Impregnation
  - Prepreg Sheet
  - Preform

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NITE PROCESS FOR
PROJECTS “INSPIRE” & “SIRIUS”

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SiC nano powder (Particle size ~30nm)
SiC fiber (Dia ~10 μm)
SiC fiber/Fabric
Prepreg sheet
Green Sheet
Preform
Hotpress / Hot Isostatic Press / Pseudo-HIP
Block
Mechanical Joint
Tube
Plate
Cylinder
Tube
Mechanical Joint
SiC/SiC Basic Products
NITE PROCESS FOR PROJECT “SCARLET”

Highly Crystallized SiC fiber
(ϕ7.5 μm, 800 Filaments per Tow)

Pre-composite ribbon
Width : 10 mm

SiC nano-powder
(30-150 nm)

Mixed slurry

Green-sheet

Pre-composite Ribbon Winding

(Pre-composite)

Hot-roller Press Forming

Cylindrical Pre-composite ribbon

(winding angle)

Mandrel

Winding of pre-composite ribbon

Pressure roller

Foming by pressure roller

Hot Isostatic Press (HIP) or Pseudo-HIP

SiC/SiC cladding tube

A. Kohyama: Organization of Advanced Sustainability Initiative for Energy System/Material, Muroran Institute of Technology
NITE-PREFORM TUBE BY PCR AUTO-WINDING

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GREEN & UD/2D PREPREG SHEET FABRICATION LINE:
ON 40CM CARRIER FILM

Facility installed: December 2010

Facility up-grade: Aug. 2012

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LARGE-SCALE PRODUCTION CAPABILITY
- NITE-TUBES IN OASIS -

φ12 mm x 200L mm; Currently 20 tubes/ month
Long SiC/SiC (500L-mm) preform production has been accomplished

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Objectives:

• To confirm potentiality of Tungsten mono block with active cooling SiC/SiC pipe under heat flux load up to 30Mw/m².

• The high heat flux test with Jaea Electron Beam Irradiation Stand (JEBIS Facility).

Specification of JEBIS Facility:

• Output 400kW
• Max. acceleration voltage 100kV
• Max. electron beam current 4A
• Electron beam pulse duration 1ms - CW
• Max. heat flux 2GW/m² (in 0.8cm²)
• Max. heating area 1800cm² (at 0.2MW/m²)
• Coolant system Closed loop, purified water, 4MPa
Phase 1 (first trial)

SiC/SiC tube is fitted to the hole of W monoblock, and Cu pipe was inserted through SiC/SiC tube. Cu pipe is connected to the water cooling loop of JEBIS.

Phase 2 (the second trial to go 2014)

SiC/SiC pipe is fitted to the hole of W monoblock, about 10cm, and SUS pipes are blazed to SiC/SiC and are connected to the water cooling loop of JEBIS.
Conclusions

- The Japanese efforts to accelerate SiC/SiC utilization in fission/fusion energy systems have been steadily growing and making steady progresses.

- The two major directions have been identified and the efforts including JESSiCA will become an important activity to support LWRs, Gen-IV Reactors, ITER/BA and other Energy related and Aero-space related activities.

- Full range R & D, starting from fundamental materials research to process development/technology integration for industrialization is very important as university activity supporting industries and national projects, where OASIS projects are good examples.