Fusion Technology Development for DEMO in the Broader Approach Activities

Presented by Takeo NISHITANI

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In parallel to the ITER program, Broader Approach activities are initiated by EU and Japan aiming at DEMO. BA consists:
1) Satellite Tokamak, 2) IFMIF-EVEDA, and
3) International Fusion Energy Research Center (IFERC)
In the roadmap of Fusion Energy in JA and EU, DEMO is expected to start operation in the middle of 2030’s.

<table>
<thead>
<tr>
<th>Year</th>
<th>2000’s</th>
<th>2010’s</th>
<th>2020’s</th>
<th>2030’s</th>
<th>2040’s</th>
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<tr>
<td>CE</td>
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**ITER**
- Construction
- HH, DD

**ITER-TBM**
- Major part of ITER construction will have completed
- Q > 10 burning control will have achieved
- Completion of ITER Operation

**DEMO**
- Initial design spec
- Engineering design activity
- Fabrication design activity
- Construction
- Commissioning
- Steady state operation
- Power Plant

*Roadmap toward DEMO in Japan*

*proposed by the Fusion Energy Forum of Japan in response of the Ministry of Education, Culture, Sport, Science and Technology of Japan*
In the DEMO development, the most important component is breeding blankets which has to withstand high neutron flux.

Integrated and effective development of Blanket structural materials and breeding/multiplying materials is essential in the Blanket development.

demoCREST (R=7.3m)
Based on the discussion at the 1st Workshop on BA DEMO R&D, following 5 generic R&D items are planned to be implemented in BA according to the common interest of each party for DEMO.

- Materials Engineering for DEMO Blanket
- SiCf/SiC Composites (Reduced activation ferritic martensitic (RAFM) steels)
- Advanced Tritium Breeder / Neutron Multiplier for DEMO Blanket
- Tritium Technology including tritium-material interactions

Dual Cool LiPb type blanket

pebble bed blanket
Reduced activation ferritic martensitic (RAFM) steels are considered as the most promising candidate materials for structural applications in DEMO. Establishment of the fabrication technology of RAFM steels in DEMO relevant scale and the database for standardization for DEMO are important issues.

1) Establishment of the fabrication technology including joining technology, and accumulation of the materials database.
2) Development of appropriate models and techniques to incorporate the fracture/rupture properties of the irradiated materials.
3) Development of methods to predict the deformation and fracture behavior of structures under irradiation by modeling/simulation.

Mockup of F82H first wall and side walls for JA TBM fabricated by Hot Isostatic Pressing (HIP) to form cooling channel structure
In the large scale production of the RAFM steel, impurity control is important because we have to use impure ion such as scrapped steel.

As the secondary melting process, Electro Slag Remelting (ESR) was performed using the ingot as the electrode. As-ESRed ingot was forged into square bar shaped slabs with 400mm x 150mm cross-section.

It was found that all Ta-rich oxides were removed by ESR.
In recent years, considerable advances have been made in optimisation, characterization, and fabrication and joining technologies of Eurofer.

In the joining technology of Eurofer for the TBM fabrication, EB- and Laser welding better for thin sheets,
Optimum heat treatment for TBM: (700°C, EB), (740°C TIG)
R&D on SiCf/SiC Composites

Based on the recent progress of high performance SiC fibre reinforced SiC matrix (SiC$_f$/SiC) composites, SiC$_f$/SiCs can be regard as a potential candidate material of the DEMO reactor, which enables to achieve higher thermal efficiency compared to metallic materials.

1) Development of test standards and material database of mechanical properties of SiC$_f$/SiC

2) Development of material database of physical/chemical properties of non-irradiated and irradiated SiC$_f$/SiC and ceramics.

Examples of NITE(nano-infiltration transient eutectic phase sintering)-SiC/SiC
Double notch tensile test indicated notch insensitivity and very minor size effect on proportional limit tensile stress (PLS) and fracture strength (UTS).

For flow insert of SiC in the Dual cool Pb-17Li blanket, the compatibility between SiC materials and a Pb-17Li liquid metal is of particularly high interest.

As a preliminary work, static tests of SiC and Pb-17Li was carried out which indicated that the SiC material had not reacted with Pb-17Li. Penetration of Pb-17Li was only observed into the open porosity was due to the cutting of the specimen before test.
Advanced neutron multipliers with lower swelling and higher stability at high temperature are desired for pebble bed blankets in DEMO. Beryllides such as Be$_{12}$Ti and Be$_{12}$V are the most promising advanced neutron multipliers.

--- Recent Work ---

Compatibility between Be-Ti, Be-V alloys and structural materials (RAFM steel F82H).

The growth rates of the reaction layer on F82H were about 1/1000 as small as that of metal beryllium at the blanket operation temperature.
Presently-available beryllium alloy ($\text{Be}_{12}\text{Ti}$ and $\text{Be}_{12}\text{V}$) is too brittle material to produce pebbles.

1) the development of a technology that allows the fabrication of pebbles despite of the extreme brittleness of beryllium alloy.

--- Recent Work ---

Large BeTi-rods were fabricated successfully in FZK

Chemical composition: Be – 30.8 wt.% Ti
In DEMO pebble bed blankets, advanced tritium breeders with high temperature compatibility and re-use capability are desired. JA and EU have been promoting the development of fabrication technologies of Li$_2$TiO$_3$ pebbles by the direct wet process and of Li$_4$SiO$_4$ pebbles by melt-spraying including the reprocessing.

1) Production of advanced breeder pebbles and the characterization of the pebbles on physical, chemical, mechanical and other properties.
2) Studies on reprocessing and re-use of tritium breeder materials.

Concept of Recycle Flow for tritium breeder
In order to study on reprocessing and re-use of tritium breeder materials, preliminary investigation of dissolving process was performed.

Lithium resources of 90% above were recovered by the aqueous dissolving methods using HNO₃ and H₂O₂.

<table>
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<tr>
<th>Li ceramics</th>
<th>Solvent</th>
<th>Dissolving yields of Li, Ti, Si</th>
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<tbody>
<tr>
<td>Li₂O</td>
<td>HNO₃</td>
<td>Li: 96-100%</td>
</tr>
<tr>
<td>Li₂TiO₃</td>
<td>H₂O₂ + HNO₃</td>
<td>Li: 91±3%, Ti: Low</td>
</tr>
<tr>
<td>HNO₃</td>
<td></td>
<td>Li: 93±4%, Si: 84%</td>
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R&D on Tritium Technology

The tritium technology is one of the most significant subjects in the DEMO plant. The R&D subjects for monitoring and analysis of tritium in fueling and blanket loops are required from the viewpoint of the control of the loops. Also basic tritium behavior for blanket materials and demonstration of practical operation durability should be studied for the DEMO design and the safety.

1) Tritium Accountancy Technology such as micro GC technology, advanced tritium gas monitors, etc.
2) Basic Tritium Safety Research such as Tritium behaviour in advanced materials to be used in DEMO.
3) Tritium Durability Test such as endurance tests of fuel cycle components at high tritium exposure.

Blanket tritium system
- He weep gas
- Blanket materials
- Tritium
- Permeation
- Coolant
Rokkasho Site for Broader Approach Activities

Japan

Aomori Airport
Misawa Airport

BA Site

Pacific Ocean
Rokkasho Site for Broader Approach Activities

East

Present Status

Sout

h

West

4 September 2008

Future Image

IFMIF/EVEDA Accelerator Building

Main Power Station (30 MVA)

Guard Station

Water supply Facility

Drain Processing Facility

DEMO R&D Building

CSC & REC Building

Administration & Research Building
As a part of the Broader Approach activities from 2007 to 2016, research and developments on blanket related materials and tritium technology have been initiated toward DEMO by EU and Japan.

Recent results

As a preparatory work on the RAFM steels, 5-tone heat of RAFM steel (F82H) was done recently, which control of indicated that unexpected impurities was important in the large scale of RAFM steels.

Double notch tensile test to evaluate failure behavior was performed for NITE-SiCf/SiC composites with different size and different notch depth. It was found that neither significant notch sensitivity nor specimen size effect was observed in proportional limit tensile stress and fracture strength.

On the neutron multiplier, reactivity of Be-Ti and Be-V alloys for F82H was investigated. The reactivity of Be-Ti and Be-V alloys was much smaller than that of beryllium metal. Large rods (about 30 mm in diameter) of Be-Ti were fabricated successfully.

In the study of reprocessing of tritium breeder materials, it was found that lithium resources of 90% above were recovered by the aqueous dissolving methods using HNO$_3$ and H$_2$O$_2$. 

SUMMARY