Partitioning and Transmutation Studies at JAEA

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Fuel Cycle with Minor Actinides
- Homogeneous / Heterogeneous / Double Strata -

- Management of High Level Waste
  - Key for sustainable energy production
  - Target: Np/Am/Cm & Specific FPs

- MA management by power reactor
  - Homogeneous recycle to all FR
  - Heterogeneous recycle to selected FR

- Double-strata cycle
  - Dedicated cycle for transmutation
  - Independent to upper cycle uncertainty
  - Demands of electricity
  - Transition from LWR to FR
  - Construction schedule
  - Separate desired target materials
  - Optimized transmutation system
Wastes from P-T cycle
- Difference of waste form -

**Cycle without P-T**

- NPP(LWR/FR)
  - Spent fuel
  - Reprocessing
  - HLW
  - Glass 5,500m³

**Cycle with P-T**

- NPP(LWR/FR)
  - Spent fuel
  - Reprocessing & partitioning
    - Tc & PGM
    - Utilized 16m³
    - LLW 11,000m³
    - Calcined 700m³
    - Glass 1,200m³
  - Metals & rare earths
  - Sr-Cs 16m³
  - Utilized 11
  - MA

- Dry reprocessing
  - Soluble FP
  - Metallic FP
  - ZrN
  - Hull
  - Sodalite 70m³
  - Alloy 60m³
  - 80m³ 480m³

- Fuel fabrication

Addition by ADS

- ADS transmutor

= heat-generating waste
= cold waste
= LLW

Waste volume per 32,000 HMt of 4-year cooled 45GWd/HMt LWR spent fuel (=40 years operation of 40GWe generation)
Disposition of P-T cycle waste
- (1) Reduction of waste forms amount -

- **Metals & REs** are vitrified into highly waste-included (30%) glass form
- **Sr-Cs** are stabilized into the calcined waste form
  - Sr and Cs are separated by hydrous titanium oxide and zeolite with recovering rate over 99.6%.
  - Temperature of waste doesn’t exceed sintering temperature (1200°C) and limitation of non P-T glass waste is applicable.
  - The leach rate of Sr-Cs is about $10^{-5}$ g/m$^2$/day and is 100 times lower than that of glass form.
Disposition of P-T cycle waste - (2) Heat generation and storage periods -

- **Standard grass waste** requires 50 years storage for conventional repository (~44.4m²/form). Since heat generation retains due to $^{241}\text{Am}$ ($T_{1/2} = 432.2$ yr), glass waste can’t be disposed of in the compact manner.

- **Sr-Cs waste** requires 130 years and 320 years storage for conventional and compact repository, respectively.

- **Metals & REs waste** can be disposed of in very compact configuration (~0.95m²/form) after 45 years storage.
Disposition of P-T cycle waste - (3) Reduction of repository area -

- Repository area for unit power generation can be reduced to 15% or 1% than those of glass waste, if 130 or 320 years storage can be acceptable for Sr-Cs waste.

- The reduction of waste leads to prolong lifetime of the repository.

- Facility scale of hundred-years storage for Sr-Cs waste is smaller than that of repository for the conventional glass waste* (about 20% of repository).

Activities for Partitioning in JAEA
- FaCT program and Basic Studies -

<table>
<thead>
<tr>
<th>NEXT Process*</th>
<th>The other methods &amp; technologies</th>
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<tbody>
<tr>
<td>U selective separation</td>
<td>Crystallization</td>
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<td>Precipitation by pyrrolidone</td>
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<td>Solvent extraction by TBP (modified PUREX)</td>
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<td>Solvent extraction by N,N-dialkylamide</td>
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<td>U-Np-Pu co-recovery</td>
<td>Co-extraction by TBP</td>
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<td>Solvent extraction N,N-dialkylamide</td>
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<td>An(III)+RE separation</td>
<td>Extraction chromatography (CMPO, TODGA)</td>
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<td>TRUEX (Solvent extraction by CMPO)</td>
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<td>Solvent extraction by DGA-extractants</td>
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<td>Solvent extraction by DIDPA</td>
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<tr>
<td>An(III)/RE separation</td>
<td>Extraction chromatography (BTP, HDEHP)</td>
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<td>SETFICS (Solvent extraction by CMPO with DTPA)</td>
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<td>TALSPEAK (Solvent extraction by DIDPA with DTPA)</td>
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<tr>
<td></td>
<td>Solvent extraction (TPEN, TPA, PDA, BTP etc.)</td>
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<td>Extraction chromatography (PDA)</td>
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<td>Ion exchange (Tertiary Pyridine Resin-HCl-MeOH)</td>
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<tr>
<td>Am/Cm separation</td>
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<td></td>
<td>Ion exchange (Tertiary Pyridine Resin-HNO₃-MeOH)</td>
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<tr>
<td>Sr-Cs separation</td>
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<td>Novel inorganic adsorbent (cation exchanger)</td>
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<td>Extraction chromatography</td>
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*Fast reactor cycle technology development (FaCT) project
Transmutation by ADS
- LBE Target/Cooled Concept -

**Function of ADS**
- Effective acceleration of high intensity proton by superconducting LINAC
- Protons are injected into spallation target through beam duct & window
- Pb-Bi acts both spallation target and subcritical core coolant
- Fuel mainly composed of MAs
- Proton generates many neutrons by spallation reaction with Pb-Bi
- MA-loaded subcritical core is driven by spallation neutrons
- Fission neutron also transmute MA by trailing fission reactions
- Neutrons are multiplied 20 times by fission chain reaction
- Generate electricity from fission reaction to operate own accelerator

**Advantages of ADS**
- Chain reaction immediately stop by aborting accelerator
- Wide margin for selection of safety parameter (Doppler coefficient, temperature coefficient etc.) than that of critical reactor
- Pb-Bi is chemically stable
Transmutation by ADS
- Liquid Fuelled Concept -

- Molten-salt fuel to avoid fuel incompatibility and heat release limitation of Am/Cm
- Designed as modular target and core unit with small cyclotron
- Possible to return converted Pu to power reactor cycle for effective fuel usage
  - Lower influence of heat/neutron release than those of homogeneous MA recycling
  - Complicated reprocessing process to isolate Pu than dedicated MA transmutation with dry reprocessing is required

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Target Radius/Height [cm]</td>
<td>12.0/60.0</td>
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<tr>
<td>Target Material/Coolant</td>
<td>W / Water</td>
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<td>Fuel Zone Radius/Height [cm]</td>
<td>18-38/~120</td>
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<tr>
<td>Fuel Density [g/cm³]</td>
<td>3.80</td>
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<td>MA Fraction (Am:Cm)</td>
<td>88:12</td>
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<tr>
<td>Fuel Fraction (MACl₃:NaCl)</td>
<td>30:70</td>
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<tr>
<td>Proton Energy [MeV]</td>
<td>600</td>
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<tr>
<td>Proton Beam Power [MW]</td>
<td>5</td>
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<tr>
<td>Reactor Power [MWth]</td>
<td>320</td>
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<tr>
<td>Initial k-effective</td>
<td>~0.98</td>
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Current Status of J-PARC

Jan. 28, 2008

Hadron Facility

Material and Life Science Facility

50 GeV Synchrotron

3 GeV Ring

Control Bldg.

Site for Transmutation Experimental Facility

LINAC

Neutrino
Transmutation Physics Experimental Facility (TEF-P)
Constructed at 1st Phase with 30kW Beam Dump
Study critical/subcritical core neutronics using MA-bearing fuel
Main Device: Critical Assembly, Remote Systems for MA fuel
Power: 500W by fission with 600MeV-10W proton beam

ADS Target Test Facility (TEF-T)
Constructed in 2nd phase with Super-Conducting LINAC
Prepare material irradiation database to design future ADS
Main Device: 600MeV-200kW Pb-Bi Target Unit
Critical Assembly in TEF-P

- Designed referring FCA facility located at JAEA Tokai-site
  - Effective use of existing fuels and experimental experiences (data, knowledge, equipment, …)
- Simulate both Na-cooled core (FBR) and Pb-Bi cooled core (ADS)
- $10^{12}$ n/s of neutron source strength is available by 600MeV-10W (25Hz) proton beam
- By replacing central 5 x 5 matrix tubes with pin-type assembly, MA fuel can be used with extra cooling circuits and remote handling.
Preliminary Letter of Intent for TEF

Research Field and Items of Proposals (Total: 38 at 2008.10)
1. ADS (Accelerator coupling, Multi-region core, Subcriticality measurements, etc.) 11
2. Innovative Reactors (MA Neutronics, Heavy Metal Reactor, FP Transmutation) 10
3. Nuclear Data Measurements (TOF Threshold Reaction) 6
4. Shielding, Safety 5
5. Particle Physics (Ultra Cold Neutron, Neutrino) 3
6. Pb-Bi Target Development (Irradiation) 2
7. Medical Application (Boron Neutron Capture Therapy) 1

Overseas
- EUROTRANS
- PSI (Swiss)
- CIAE (China)
- Seoul Univ. (Korea)
- MINT (Malaysia)
- NTI (Serbia)

Universities
- Hokkaido Univ.
- Tokyo Tech.
- Nagoya Univ.
- Kyoto Univ.
- Kyushu Univ.
- Tohoku Univ.
- Niigata Univ.
- Osaka Univ.
- Kinki Univ.

Company
- Engineering Development inc.
- JAEA, KEK: 26

Researchers 113 (Except EUROTRANS)
- JAEA, KEK: 26
- University: 30
- Abroad: 56

Company: 1

JAENA
- Quantum Beam Sci. Dir.
- Nucl. Sci. and Eng. Dir.
- Advanced Nucl. System R&D Dir.
- J-PARC Center
Asia ADS Network Initiative

- Started from 2003 and held meetings annually
- Exchange R&D information for national programs, accelerator, neutronics, nuclear data, material issues
- From 2007, topics extended to innovative systems including HLM system

Next Meeting
Xian, China
Dec. 3 - 5, 2008
## Summary

### Impact of P-T technology introduction
- Waste and waste repository can be reduced by P-T Technology
- Prolong lifetime of waste repository 5 to 8 times or more

### Partitioning and Transmutation system studies at JAEA
- Various partitioning methods for U, Np/Pu, Am, Cm, Sr, Cs, etc. are studied
- Design of dedicated ADS optimized for minor actinide transmutation is underway
- R&D needs and experimental equipments to satisfy the requirements are discussed under research committee organized by Atomic Energy Society of Japan
- Progress of last 8 years is reviewed by Atomic Energy Commission of Japan

### International collaboration in Asian region
- Asia ADS Network Initiative was established since 2003
- Keep contact with extended research fields
Long-term radiotoxicity can be reduced by two orders, if 99.5% of transmutation efficiency is achieved.

- The time period to reduce the radiotoxicity below the level of natural uranium used as raw material:
  - 50000 years by current national scenario
  - 500 years by the case with P-T