Measurement of Displacement Cross Section of Window and Target Materials at J-PARC

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2) Material and Life Science Division J-PARC/JAEA
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- Summary
ADS Proposed by JAEA - LBE Target/Cooled Concept -

- Proton beam: 1.5GeV ~20MW
- Spallation target: Pb-Bi
- Coolant: Pb-Bi
- Subcriticality: $k_{eff} = 0.97$
- Thermal output: 800MWe
- Core height: 1,000mm
- MA initial inventory: 2.5t
- Fuel composition:
  - (60%MA + 40%Pu) Mono-nitride
- Transmutation rate:
  - 10%MA/Year (10 units of LWR)
- Burn-up reactivity swing: 1.8%Δk/k
Neutron beam lines (23)

Bird's eye photo

Transmutation Facility (TEF) (Phase II)

Hadron Experiment Facility

Neutrino Exp. Facility (294km to Super KAMIOKANDE)

Materials & Life Science Facility (MLF)

3GeV Synchrotron RCS (25Hz, 1MW)

JRR-3M 800m to MLF

30GeV Synchrotron MR (0.75MW)

J-PARC = Japan Proton Accelerator Research Complex

JFY2007 Beam

JFY2008 Beam

JFY2009 Beam
Transmutation Experimental Facility (TEF) in J-PARC

**TEF-P: Transmutation Physics Experimental Facility**

- **Purpose:** Reactor Physics
- **Category:** Critical Assembly
- **Proton Power:** 400MeV-10W
- **Thermal Output:** Less than 500W

**TEF-T: ADS Target Test Facility**

- **Purpose:** Material Irradiation
- **Category:** Radiation Application
- **Proton Power:** 400MeV-250kW
- **Target Material:** Lead-Bismuth

For R&D of ADS, 0.4 GeV beam by LINAC will be delivered to TEF.
Beam transport from RCS to MLF

Length of BT: 314m
Partial of 25 Hz beam goes to MR
FX: 2.48 s, SX: 5.5 s

Ep: 3GeV
Power: 1MW
Already demonstrated
Rep.: 25Hz

Material and Life
Science Experimental
Facility (MLF)

3NBT

3-GeV
RCS

Dump

road to
coast

3-50BT

Muon
target

Neutron
target
1st target ST (TS-1): 24 Hz: 1MW
2nd target ST (TS-2) 1Hz: 42kW (Designed to accept 1 MW)
Lifetime of Proton Beam Window

- Lifetime estimation based on Post Irradiation Examination (PIE) for safety shroud (AlMg3) at SINQ in PSI
- Considering difference of proton energy, to predict lifetime of the PBW with high accuracy for validation of calculation

Result at SINQ/PSI for 0.6GeV

Lifetime of PBW: Determined by He gas production (2000 appm) 2 years

By recent PIE result of the SINQ (3300 apmm), the lifetime may be applicable to 3 years.

Height: 3.8m
Weight: 10t
Inspection replaced PBW

PBW#1 (obs. 2013 Oct) 1916 MWh (1.4x10^{22} POT)

PBW#2 (obs. 2017 Aug) 2510 MWh (1.9x10^{22} POT)
Measurement of activation of aluminum

- Foil (45x25mm, 0.5mmt) placed at beam dump line with linear guide for control beam irradiation
- Projectile: 3-GeV and 400 MeV proton
  - RCS injection energy: 400 MeV
  - RCS extraction energy with acceleration: 3 GeV
  - Changing extraction timing, the energy can be varied 0.4〜3 GeV.
Obtained activation cross section

- Due to well calibrate monitor and beam control, good accuracy of incident protons number
- Frequently 0.4 and 3 GeV protons used for accelerator tuning
- DPA cross section of 3 GeV will be measured at first.
DPA (Displacement per Atom) is estimated by calculation based on PKA.
Please see last night presentation.
Although DPA is widely utilized for estimation of target material damage, DPA cross section has not been enough validated.

- \( \text{DPA} = \text{flux} \times \text{DPA cross section} \)
- DPA cross section has been measured only Cu and W for a few energies of protons (5 experimental data above 20 MeV!)
- DPA cross section with calculation showing large discrepancies among models.

For validation and improve of calculation model, DPA cross section will be measured in J-PARC. Fund is approved by the MEXT.
Measurement of DPA cross section

- Irradiation on metal at cryogenic temperature with GM cryocooler
- By observing increase of electrical resistance, the cross section can be observed.

Measurement for Cu already performed at Kyoto Univ. for 125 MeV proton

Experiment at J-PARC
- Samples and GM placed at exit of 3-GeV synchrotron for various energy of proton 0.4 to 3 GeV
- Other experiment performed at other sites for energy < 400 MeV
Experimental condition

How much of protons is necessary?

1 nA x 12h = 3x10^{14} protons
Several shots of beam at MLF

Y. Iwamoto et al.

How much of temp rising is allowed?

Temp rising ~20 K will be acceptable.
If time permits, lowest beam is preferable.
However, it makes worse accuracy of beam charge. (Vary 1x10^{10} – 2x10^{13} protons/shot)
Plan for Ep 0.4~3 GeV

- Experiment at 3NBT (0.4~3 GeV) in JFY2017
  - Fabrication chamber (~Sep)
  - Installation (Sept. )
  - Exp. : Cooling ~Nov.
  - Beam test (Dec.)
Plan for 3 ~ 30 GeV

- Using MR beam
  - Difficult to carry out experiment at hadron hall due to expand plan of building.
  - Decided to perform experiment at MR abort dump
  - Approval by PAC will be required, which will be held June 2017.
Estimation radio activity

Particles flux during irradiation

<table>
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<th>Incident energy</th>
<th>4h (μSv/h)</th>
<th>7days (μSv/h)</th>
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<tr>
<td>3 GeV</td>
<td>19</td>
<td>0.01</td>
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<tr>
<td>30 GeV</td>
<td>29</td>
<td>0.02</td>
</tr>
</tbody>
</table>

※ Distance from samples 0.3m

Residual dose: Confirmed enough small for handling
Detail design to obtain good accuracy

- Beam width and intensity can be observed precisely. With the help of calculation, simple fluence can be determined.
- Frenkel-pair resistivity can be obtained by using thin window configuration with additional experiment with low energy proton (Ep<10 MeV).

\[
\sigma_{exp} = \frac{1}{\rho_{FP} \Phi} \left( \Delta \rho_{metal} \right)
\]

\(\Delta \rho_{metal}\): Electrical resistivity change (\(\Omega\)m)

\(\Phi\): Beam fluence (1/m²)

\(\rho_{FP}\): Frenkel-pair resistivity (\(\Omega\)m)

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# Schedule

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<tr>
<td>Exp. DPA x-sec of 0.4～3 GeV (JAEA)</td>
<td>Procurement</td>
<td>Experiment</td>
<td></td>
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<tr>
<td>Exp. DPA x-sec of 4 ～30 GeV (KEK)</td>
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<td>Preparations</td>
<td>Experiment</td>
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<tr>
<td>Revise calculation (JAEA)</td>
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Target: Cu, Al, Fe, Nb, W
Future plan for DPA by spallation neutron

- Neutron spectrum at backward angle of mercury will be also available for DPA x-sec measurement.
  - $1 \times 10^{11} \text{ n/m}^2/\text{s}$ at 1MW
  - Long duration ~1 year available
To obtain DPA cross section, measurement for 0.4〜30 GeV protons will start in J-PARC.

- Procurement finished for GM cryocooler, instruments for resistance, and vacuum chamber
- Experiment for 0.4〜3 GeV protons will start in this JPY after changing license granted by Nuclear Regulatory Agency (NRA).
Collaborators of experiment

- JAEA (Shin-ichiro Meigo)
  - Yosuke Iwamoto
  - Fujio Maekawa
  - Hiroki Iwamoto
  - Hiroki Matsuda
  - Shioichi Hasegawa

- KEK (Makoto Yoshida)
  - Tatsuya Nakamoto
  - Taku Ishida
  - Shunsuke Makimura
  - Tsutomu Mibe

Attending this workshop
Thank you

Question?