Tritium Focus Group Meeting
@INL 2014.9.23

Overview of tritium activity in Japan

Yasuhisa Oya
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Shizuoka University

Research Subjects and Institutes for Tritium Issues

Research Subjects

- Fusion
  (Processing, Blanket, First Wall, Safety, Licensing)
- Fission Reactor (Heavy Water Reactor)
- Waste Management
- Environmental Behavior
- Biological Effects
- Fundamental Science

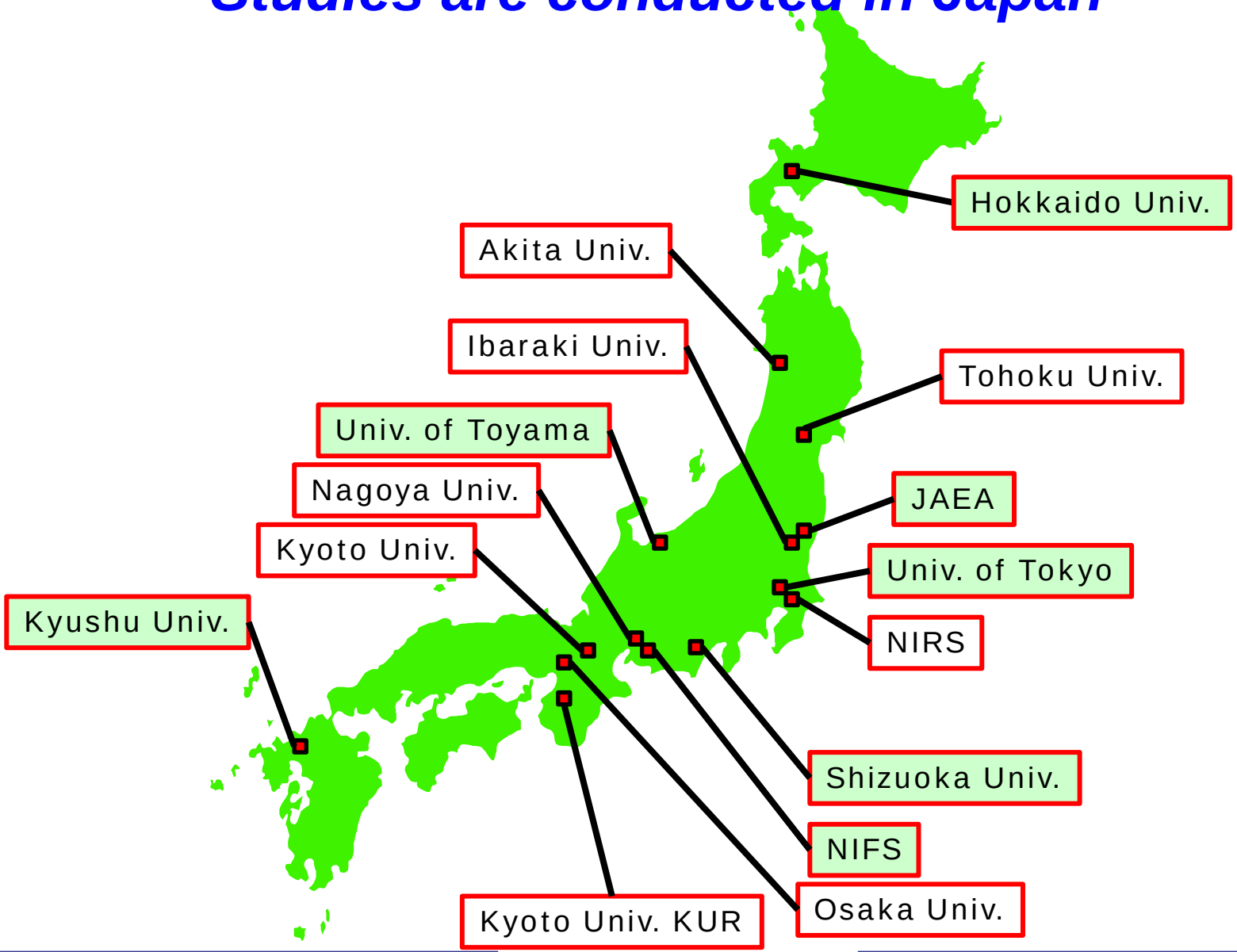
Institutes

- Universities
- Japan Atomic Energy Agency
- National Institute for Fusion Science (NIFS)
- National Institute of Radiological Sciences (NIRS)

Key tritium issue for Fusion Engineering Researches

- Tritium/Material Interaction
  - Plasma Facing Materials
  - Structural Materials
- Blanket Engineering
  - Breeding Materials
  - Tritium Breeding Ratio
  - Tritium Recovery
  - Tritium Permeation
- Tritium Processing and Safety
- Tritium Behavior in Environment

Institutes and Universities where Tritium Related Studies are conducted in Japan



Tritium Network in Japan

NIFS collaboration program

BA collaboration

Universities NIFS

JAEA

Tritium

National Institutes

Industries

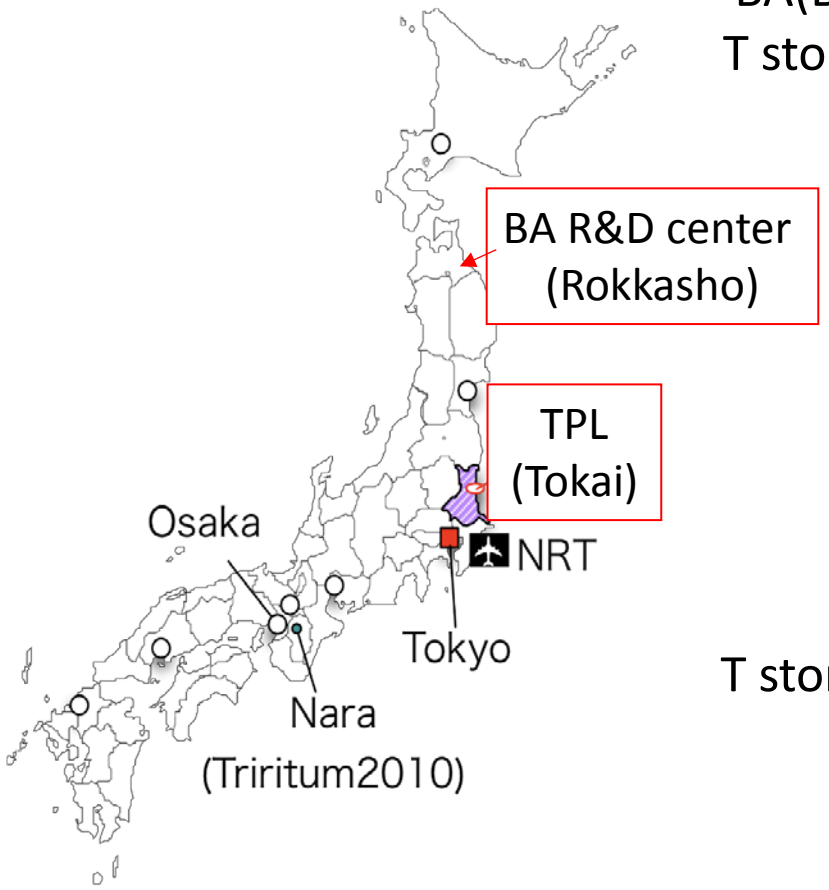
Academic Societies

- Atomic Energy Society of Japan
- The Japan Society of Plasma Science and Nuclear Fusion Research
- The Japan Radiation Research Society

Conferences (International and Domestic)

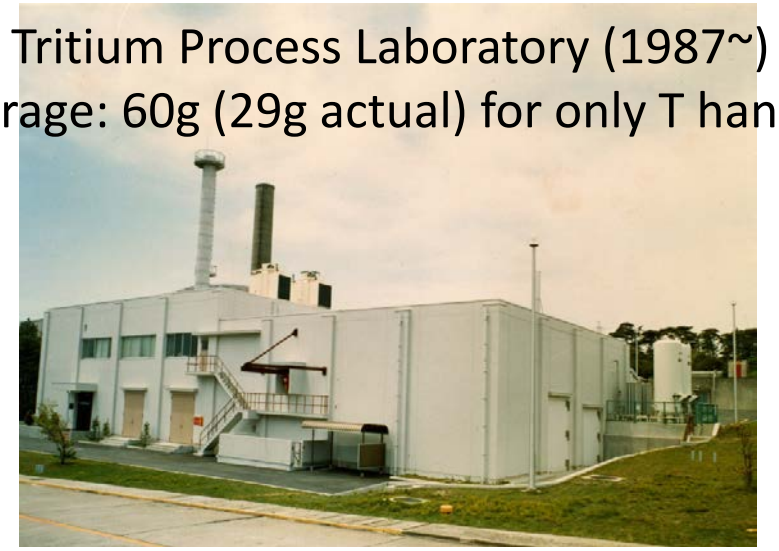
- Tritium Science and Technology
- ISFNT, TOFE, PSI, SOFT
- Joint Symposium, ・・・・・
- Pacific-Asia T WS (J-C T WS)

Tritium facilities in Japan Atomic Energy Agency



BA(Broader Approach) R&D center (2012~)
T storage: 7.4TBq w/ radioisotopes handling

Tritium Process Laboratory (1987~)
T storage: 60g (29g actual) for only T handling



Tritium Facilities for Fusion Research
in Japan Atomic Energy Agency

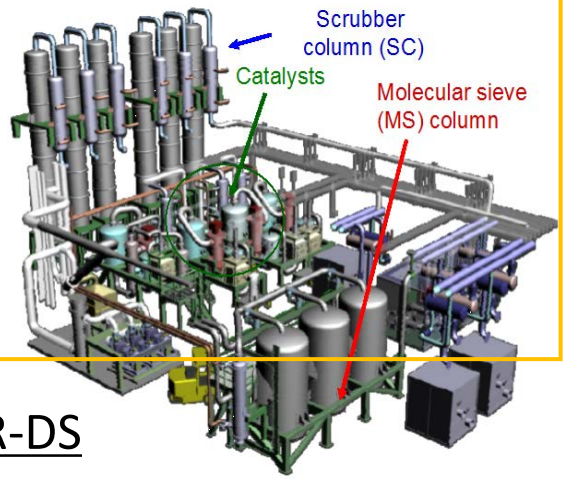
Research activities in T Facilities of JAEA

In Tritium Process Laboratory

Main Purposes are to develop
1) fuel cycle technology for fusion reactor, and 2) tritium safety handling technology.
Now, we focus to the ITER Detritiation System (DS) Procurement

Activities

1. **Pilot scale Wet Scrubber Column (SC) performance test for DS** (completed)
2. **Procurement of DS**
3. **Qualification test of DS**



ITER-DS

In BA(Broader Approach)-R&D center

Main Purpose is to implement
Tritium R&D for DEMO under BA

Activities

1. **Tritium accountancy development**
2. **Tritium-material interaction study including JET tile/dust analysis**
3. **Tritium durability test**

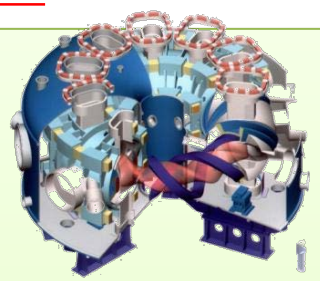
Many Japanese Universities (Hokkaido, Toyama, Tokyo, Shizuoka, NIFS, Osaka, Kyushu, etc.) participate in this program under the collaboration with JAEA

In this center, not only tritium study but also material development (RAFM, SiC/SiC, Blanket materials : Li & Be) are carried out under BA.

National Institute for Fusion Science [NIFS]

Staff : Masa Tanaka, Naofumi Akata, Takuya Saze, Takao Kawano, Kiyohiko Nisimura

Study of tritium safety control and environmental tritium



Research Topics

- **Large Helical Device [LHD] research project**
  - **Tritium removal system [TRS] for LHD exhaust gas**
    - Application of polymer permeable membrane to recovery tritiated water
    - Exhaust gas analysis under deuterium plasma experiment for tritium mass balance study
  - **Environmental tritium, radioactivity and radiation monitoring**
    - Fallout, aerosol, atmosphere, river water, precipitation, soil, organic sample, etc
    - Development of environmental radiation [neutron, gamma ray] monitoring system

- **Fusion Engineering Research project** [Collaboration with universities]
  - **Development of fuel cycle and tritium safety system**
    - Feasibility study of fuel cycle system [EXPRESS] and proposal of new fuel cycle concept
    - Cryogenic pressure swing adsorption [PSA] process for ISS
    - Advanced combined electrolysis and catalytic exchange [CECE] process for WDS
    - Advanced tritium oxidation and regeneration of absorbent for TRS
  - **Environmental impacts and biological effects of tritium**
    - Development of a code to simulate tritium transfer in the environment
    - Study of the biological effects of tritium at the cellular level and by using genetically engineered animals

Multi column PSA system "PSMAP"

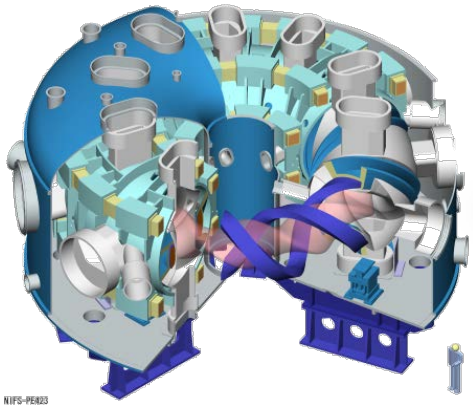
Advanced CECE system "DTDP-CECE"

LHD deuterium plasma experiment

~ for public consent ~

Tritium system in NIFS

- Tritium removal system for LHD exhaust gas
  - Molecular sieves type for deuterium plasma exhaust gas
  - Polymer membrane type for LHD maintenance period
- Aqueous and gaseous effluent tritium monitor
- Environmental tritium/radioactivity monitoring



Large Helical Device
D plasma experiment: 2016-

Annual tritium production by DD reaction
Max: 55.5 GBq/y [1.5 Ci/y]

Exhaust gas

NBI system,
cryopump for closed divertor,
ice pellet injection system,
gas puff system,
plasma diagnostics, etc

Gas analysis[2012-]:
Micro-gaschro, qRGA
Tritium monitoring:
Water babbler system
Proportional counter

Under construction
Commissioning by 2015
Operation: 2016-

Tritium removal system

Molecular sieves type
Process flow: << 1 Nm^3/h

Polymer membrane type
Process flow: 300 Nm^3/h

Stack

Environmental monitoring
- ✓ River water [1982-]
- ✓ Precipitation [1990-]
- ✓ Organic sample [1998-]
- ✓ Atmosphere [2004-]
- ✓ Soil [2012-]
- ✓ Fallout [2014-]
- ✓ Aerosol [2014-]

Large volume [30L] ionization chamber

Active tritium sampler for stack monitor [2012-]

Low background type LSC [LSC-LB-7/1220 Quantulus]

Continuous tritiated water measurement system by a plastic scintillator

Low concentration tritium waste water [< 20 kBq/cm^3]

The University of Tokyo

Staff : Takayuki TERAI & Akihiro SUZUKI

http://lohas.t.u-tokyo.ac.jp/yunen/index.html https://www.facebook.com/terailab

The approach to the energy and environmental issues from the viewpoint of materials science & the research and the development of elemental technology for new energy system

RESEARCH SUBJECTS

[1] Material chemistry research for nuclear fusion reactors

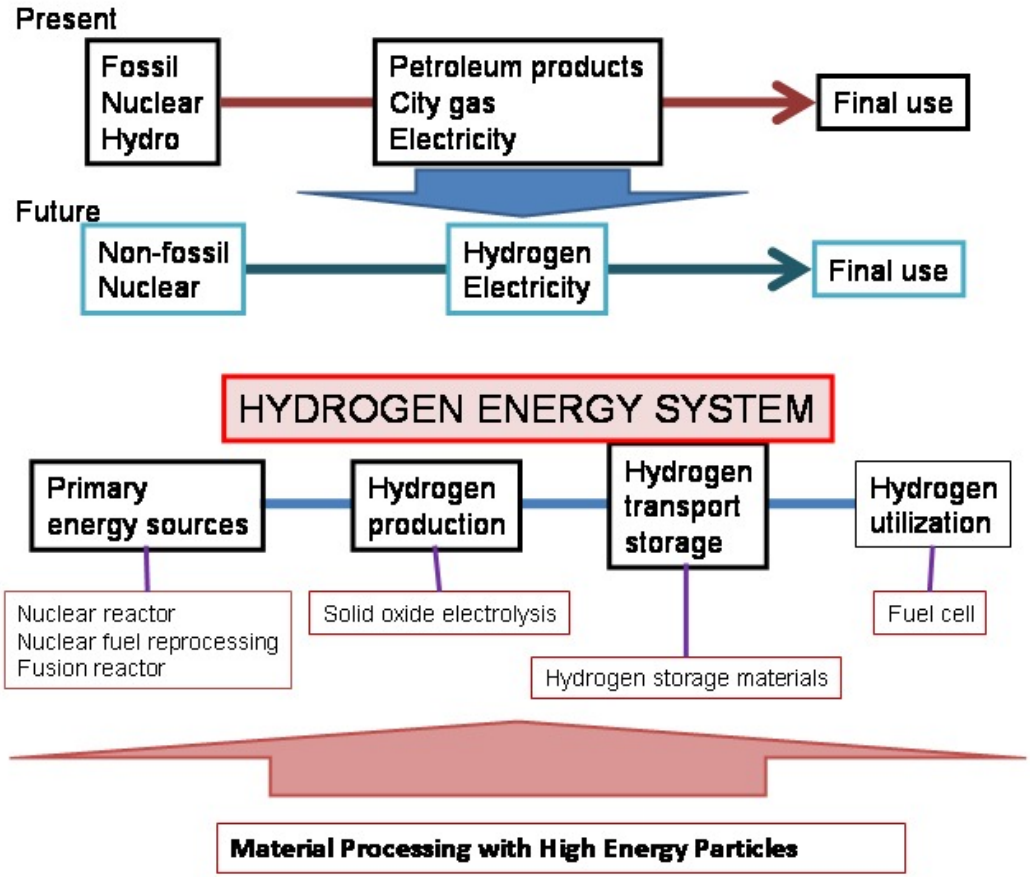
→Chemical reactivity & tritium behavior of solid breeder Li_2TiO_{3+x}

→Behavior of tritium and non-metallic impurities in liquid breeders (Li, Li-Pb, Flibe, etc.)

→H isotope behavior in permeation reduction coatings

[2] Material research for advanced energy systems and energy & environmental problems

[3] Material processing with high-energy particles



Impurity recovery from liquid lithium

Improvement of hydrogen recovery efficiency by nitrogen removal

Two step nitrogen removal system in Li flow of IFMIF

Li（N concentration 400wt.ppm~）

↓

Short-term purification by pure Ti (once through)

↓

Li（N concentration 100wt.ppm~）

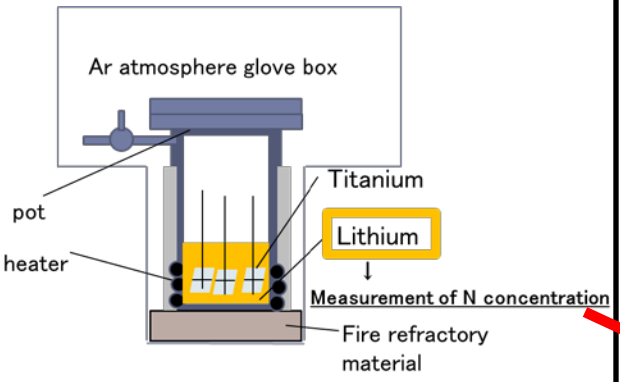
↓

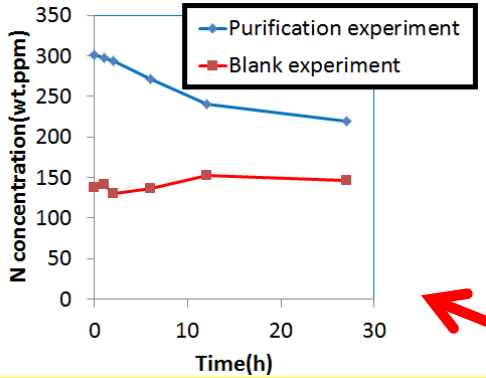
Further purification by Fe-Ti alloy

↓

Li(N concentration **~10wt.ppm)**

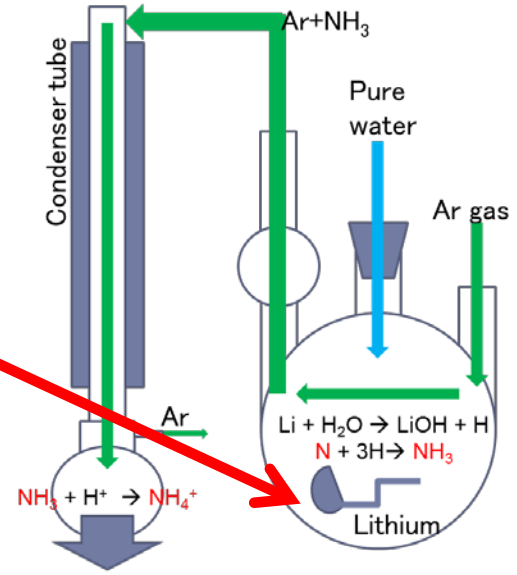
Nitrogen hot trapping by pure Ti in Li at 773K





In the experiment, purification by pure Ti was confirmed in 27 hours.

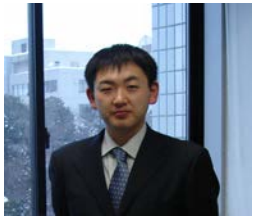
Nitrogen measuring method



Measurement with an ammonia sensor

Measurement of ammonia concentration gives the nitrogen concentration in lithium indirectly.

Shizuoka University

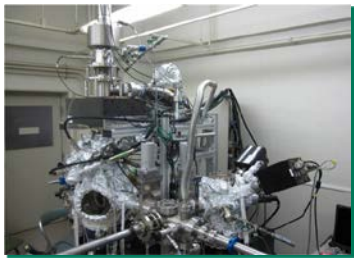


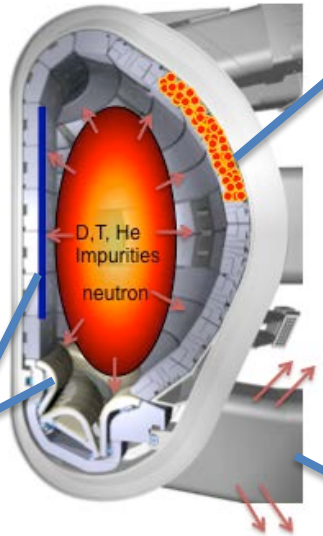
Staff : Yasuhisa Oya & Takumi Chikada

Tritium behavior in fusion related materials based on radiochemical aspects

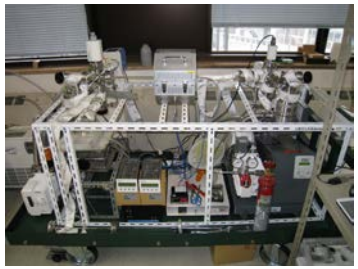
Research Topics

- Correlation of D retention with irradiation damages in W
- Development of tritium permeation barrier
- T retention enhancement in W by LHD plasma exposure
- Behavior of ^{137}Cs & T in tea leaf





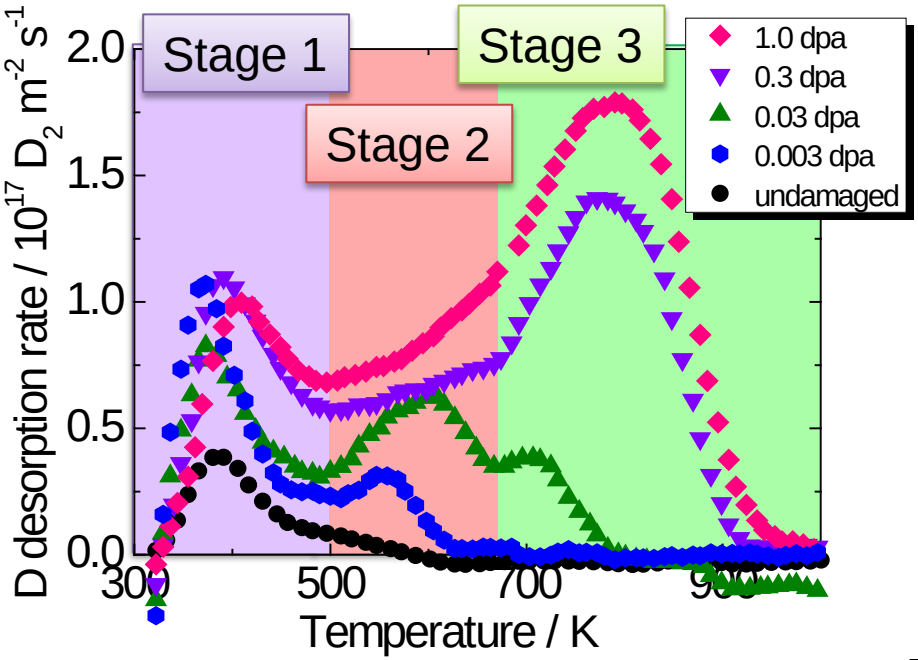
Blanket issues
- Tritium recovery from lithium oxides
- Behavior of irradiation damages



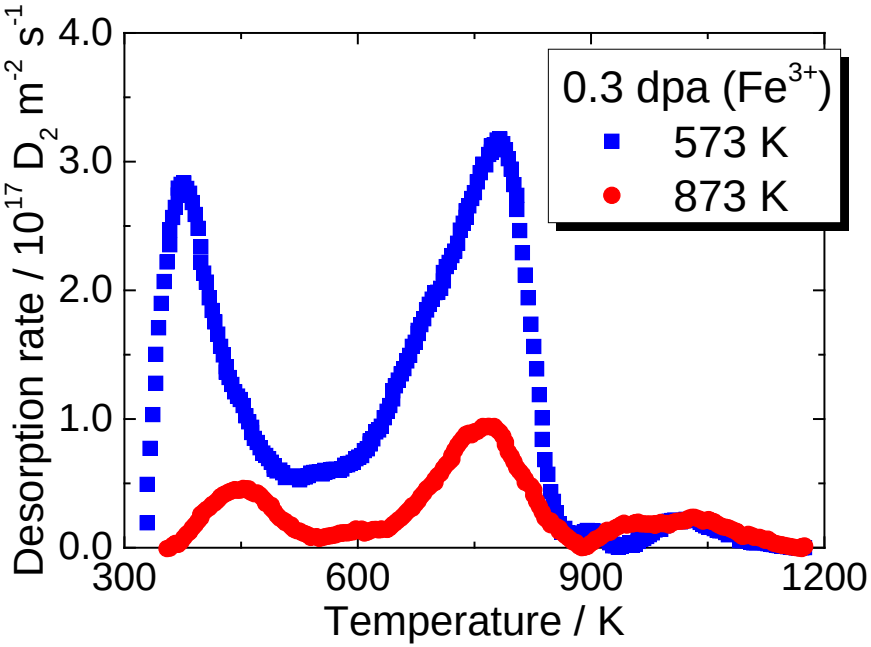
Plasma Wall Interaction (PWI) issues
Simultaneous ion implantation
(D, T, He, C) & Neutron irradiation
effects on fuel retention

Tritium recovery and cooling system issues
Tritium permeation behaviors through
structural materials

Correlation of D retention with irradiation damages



D_2 TDS spectra for Fe^{2+} irradiated W with various ion fluence.



D_2 TDS spectra for Fe^{3+} implanted W

D retention and desorption behavior for ion-damaged W and comparison by simulation.

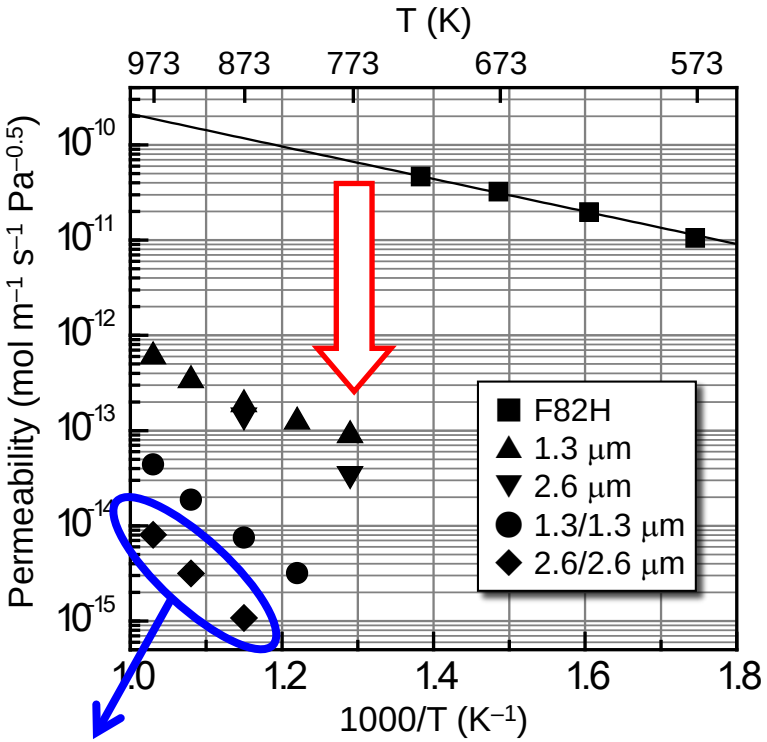
Most of D was desorbed at higher temperature of ~750 K, indicating that D was trapped by voids. The D retention was clearly changed by the implantation temperature.

Development of tritium permeation barrier

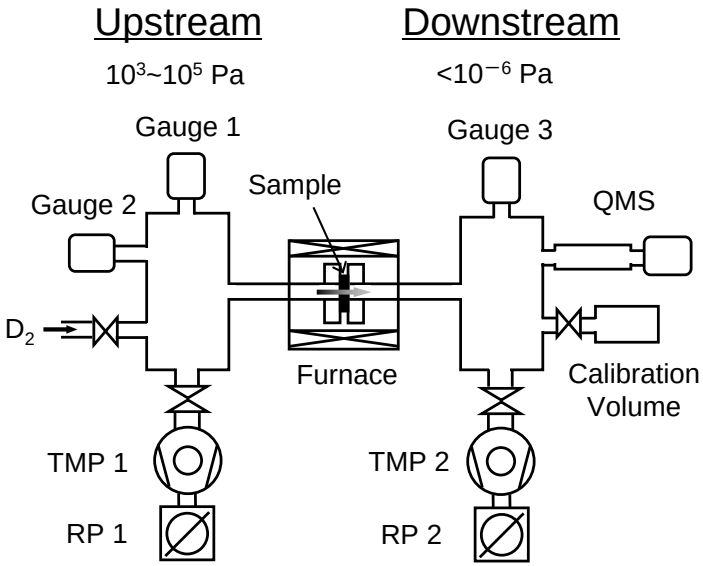
Permeation reduction: up to $1/10^5$

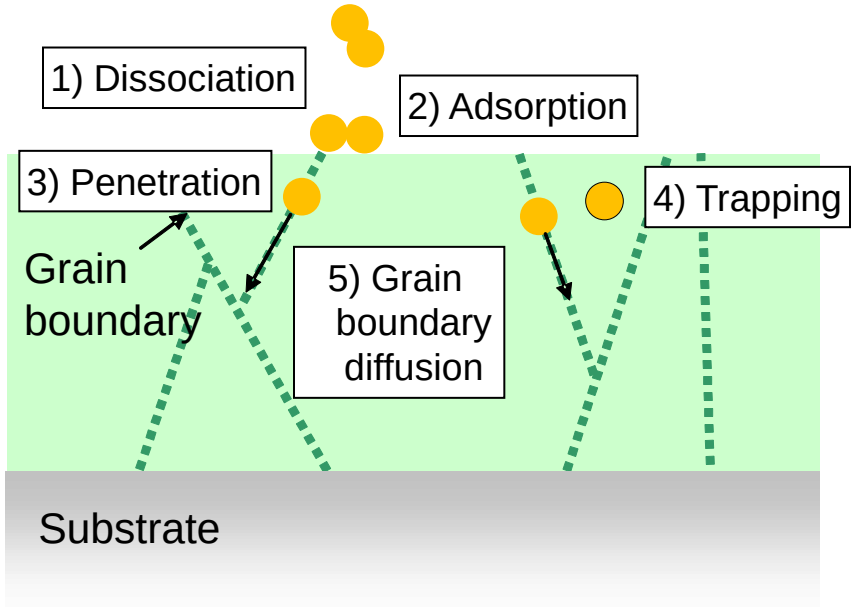
→ Er_2O_3 coating has a high potential as hydrogen permeation barrier

Permeation mechanism in the coatings has been investigated through experiments and computer simulations



New world record!!





Hydrogen Isotope Research Center (HRC), University of Toyama

HRC is one of the largest tritium research facilities in Japanese universities and licensed to handle 8 TBq (217 Ci) tritium per day and 555 TBq (15 kCi) per year.

Research Staffs: 3 Professor, 3 Associate Professor, 1 Assistant Professor
1 Research Fellow, 1 Foreign Researcher (Guest Professor)

Education: Department of New Energy Science (Ph. D. course)
Department of Chemistry (Master course)

Main Directions of Research

(1) Development of safe handling techniques of tritium for fusion reactors

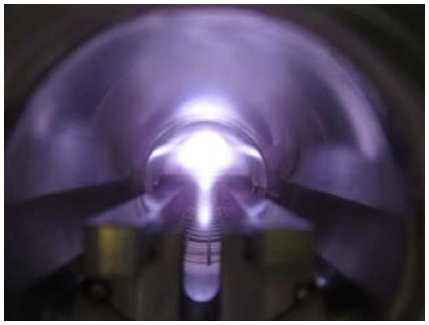
(2) Hydrogen isotope behaviors in fusion reactor materials

(3) Development of functional materials for hydrogen energy system (catalysis, separation membrane etc.)

Uniqueness of Tritium Facility

(1) Handling of tritium in any chemical/physical form

- ✓ Tritium gas exposure
- ✓ Tritium ion implantation (~keV)
- ✓ Tritium glow discharge
- ✓ HTO vapor exposure



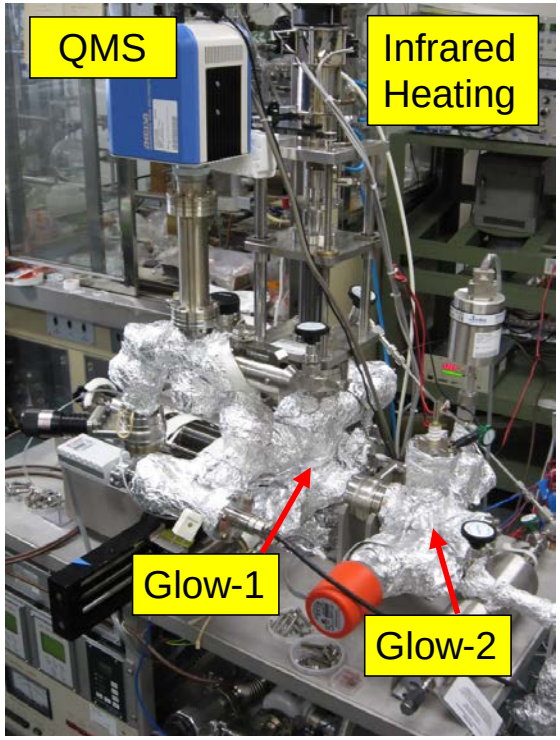
(Glow Discharge)

(2) Various instruments for tritium measurements

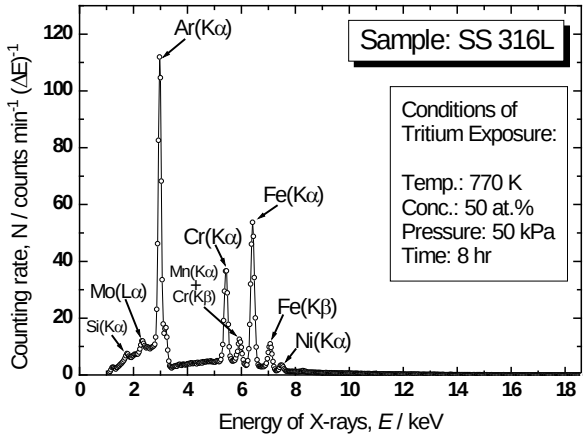
- ✓ β-ray-induced X-ray spectrometry (BIXS)
- ✓ Imaging plate (IP)
- ✓ High sensitivity calorimeter

(3) Various tools for characterization of tritium-containing materials.

- ✓ X-ray photoelectron spectroscopy
- ✓ Field-emission scanning electron microscope
- ✓ X-ray diffraction



(Apparatus)

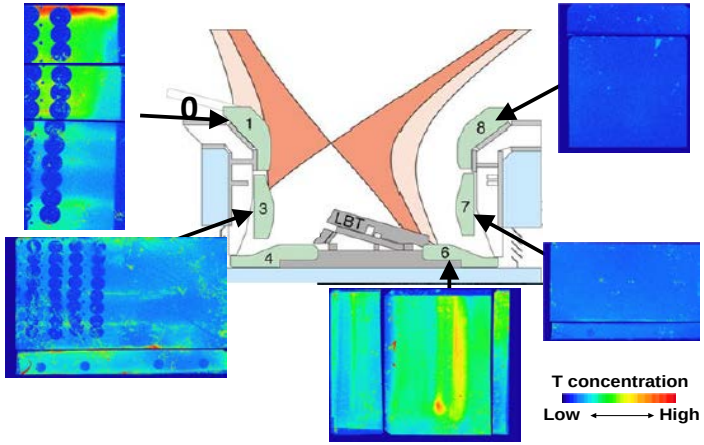


BIXS spectra of stainless steel

Current Tritium-Related Research

(1) Tritium measurements

- ✓ T distributions on JET ITER-like wall tiles with IP and BIXS (collaboration with EUROfusion)
- ✓ Near-infrared spectroscopy for HTO detection with non-hygroscopic windows



(2) Tritium/hydrogen isotope behaviors in fusion materials *including neutron-irradiated materials*

- ✓ Hydrogen isotope retention in neutron-irradiated tungsten (Japan-US collaboration TITAN and PHENIX, collaboration with IMR, Tohoku U.)
- ✓ Detritiation of fusion reactor materials

(3) Application of tritium to materials science (e. g. visualization of hydrogen isotopes in solids by autoradiography)

HRC plays a role of national user facility through collaboration program of NIFS.

International collaboration is also welcome.

Kyushu University

Interdisciplinary Graduate School of Engineering Sciences,
Department of Advanced Energy Engineering Science,
Energy Chemical Engineering

ECHE Fukada Lab.


Satoshi Fukada


Kazunari Katayama


Toshiharu Takeishi

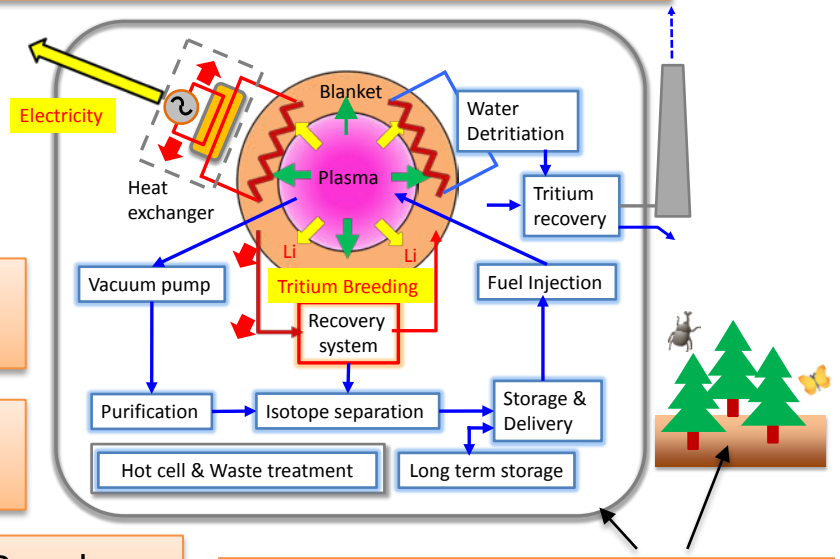

Takako Kimura

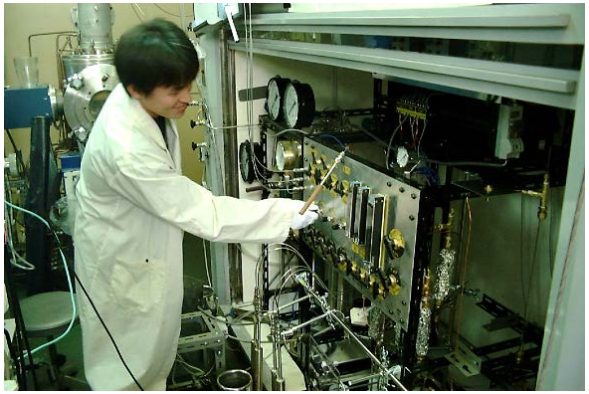

Students

Research Topics

- Tritium recovery in Liquid blanket system
- Tritium behavior in solid breeder materials
- Plasma wall interaction
- Tritium penetration in concrete materials
- Tritium behavior in soil

Recovery of H isotopes from fluidized molten salts such as Flibe, Flinabe and liquid metal eutectic Li17Pb83





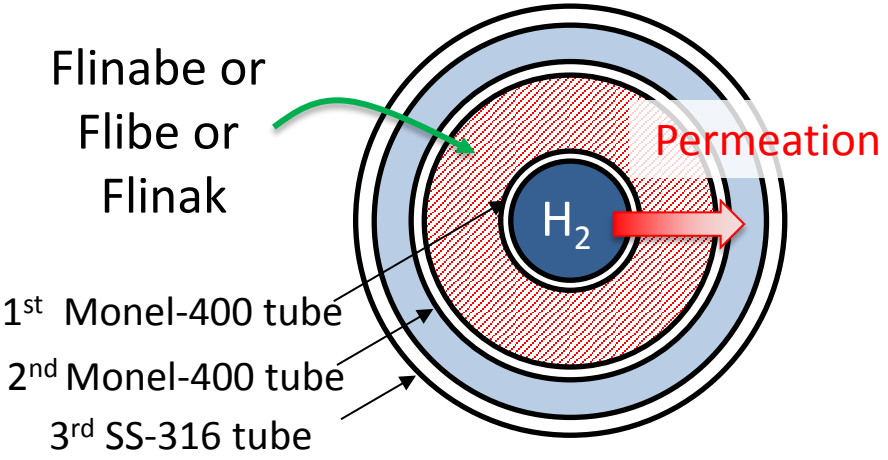
H isotopes retention in W deposition layer

Li mass loss and T behavior in Li2TiO3

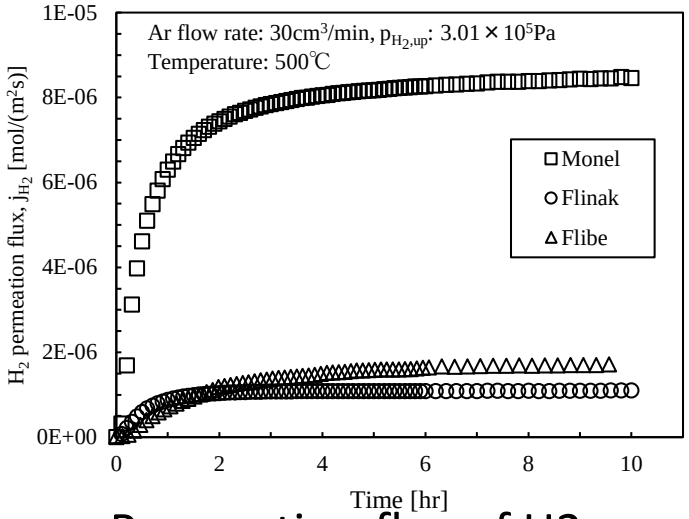
T permeation in Solid Breeder-Water coolant blanket system

HTO behavior in concrete and soil

Tritium recovery from liquid blanket loop

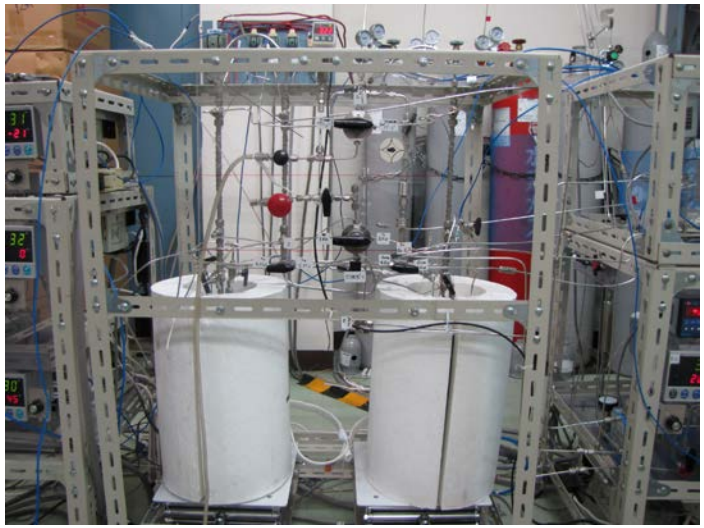


Sectional view of sample tubes

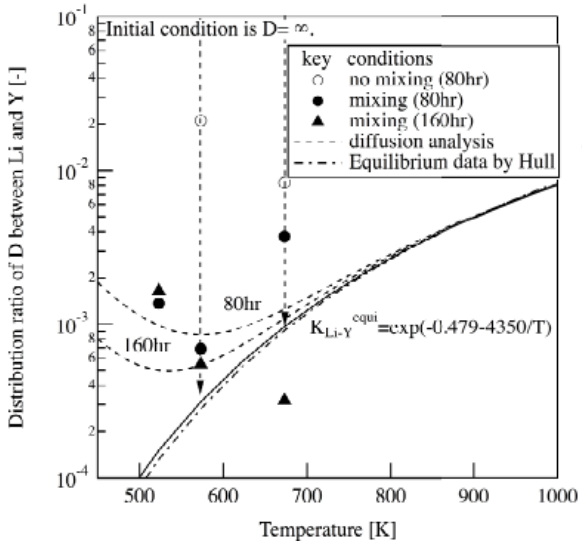


Permeation flux of H2

Tritium recovery from fluidized Li by Y



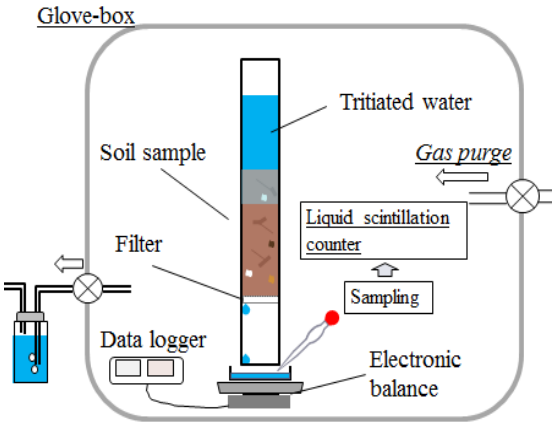
Overview of the Li loop with Y trap

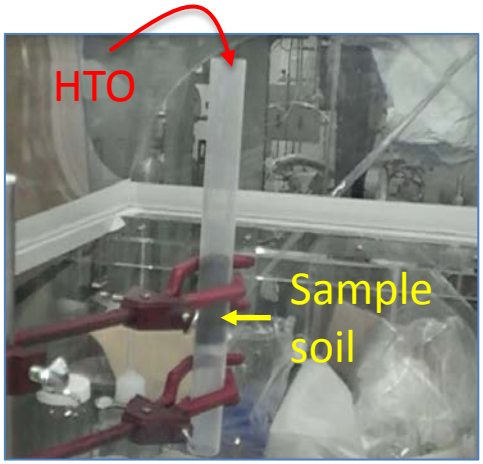


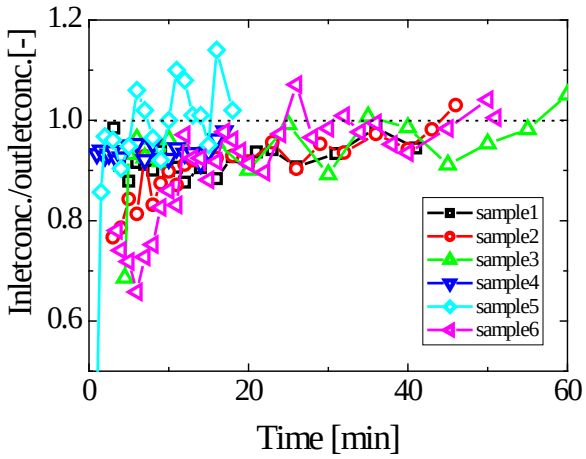
Distribution factor between Li and Y

99.9% D recovery is achieved.

Percolation behavior of HTO into a soil packed bed





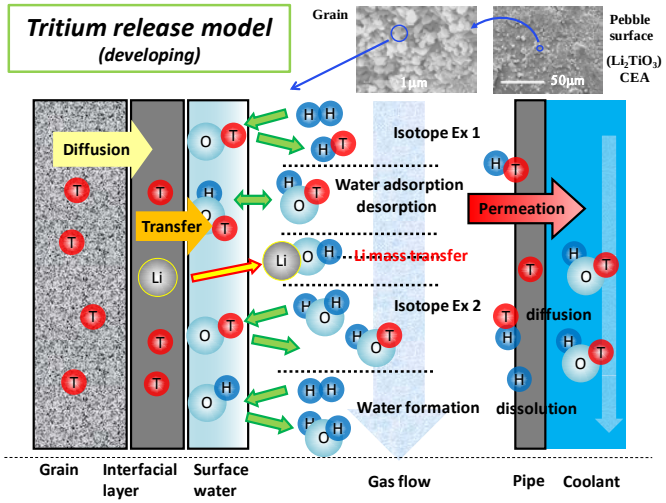


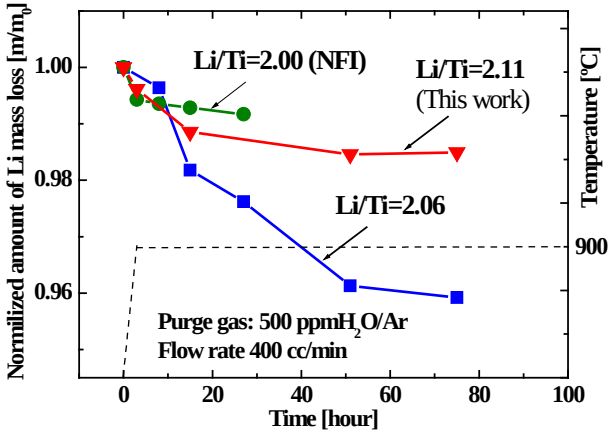
Percolation experimental system & Soil packed bed

T conc. in effluent water

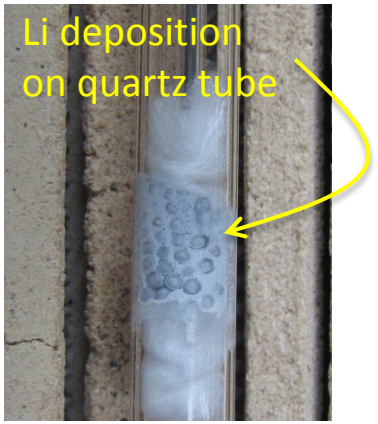
- T retention is larger than water retention because of T trap by isotope exchange reaction of T with structural water.

Li mass loss & T behavior in solid breeder materials





Li mass loss at 900°C.



1%H_2at 900°C

- Li mass loss from Li_2TiO_3 is not negligible at 900 °C.

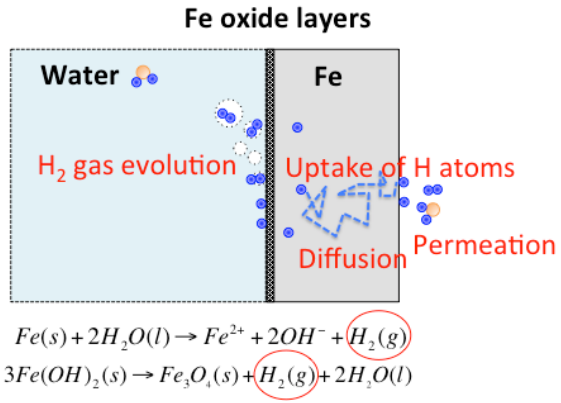
Current Activities of the Laboratory of Materials Science in Extremely Severe Conditions (Nuclear Materials), Kyushu University.

Laboratory members: K. Hashizume and T. Otsuka

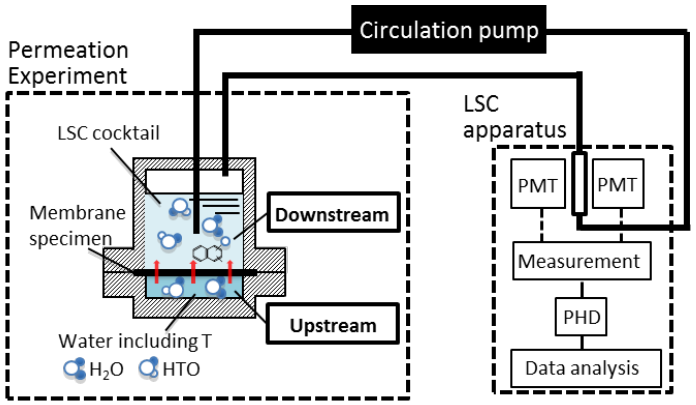
Our laboratory has been devoted to the studies on the hydrogen isotope (tritium) behavior in fusion, fission and other energy-related materials using tritium tracer methods (liquid scintillation counting method, imaging plate technique and autoradiography).

(1) Tritium permeation induced by water corrosion of metals

Issues on tritium permeation leakage from storage tanks of tritium contaminated water

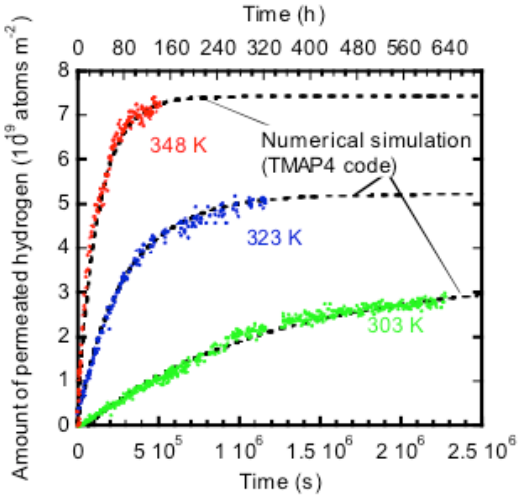


Schematics of automated long-term permeation exp. apparatus



LSC: Liquid scintillation counting
PMT: Photomultiplier, PHD: Pulse-Height discriminator

Successful observation of tritium permeation induced by water corrosion of pure iron

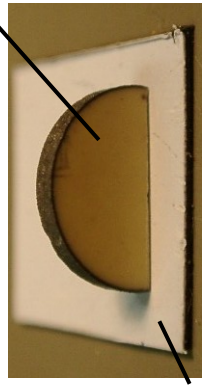


(2) Visualization of Tritium Distribution

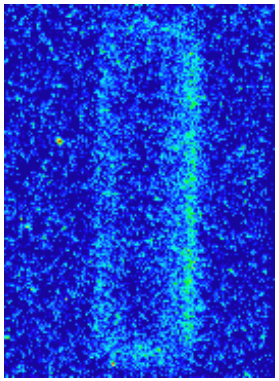
2-1. Tritium Diffusion Behavior in Zr-contented $BaInO_{2.5}$ (Proton conducting Ceramics) using Tritium Imaging Plate: Tritium Solubility and Diffusivity Dependences on Zr Content

Exposure to HT gas at 873K for 1 h

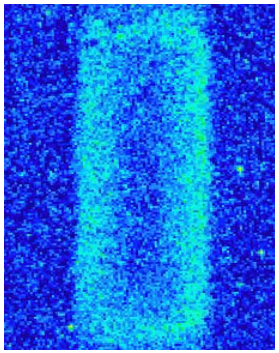
Specimen (cut in halves)



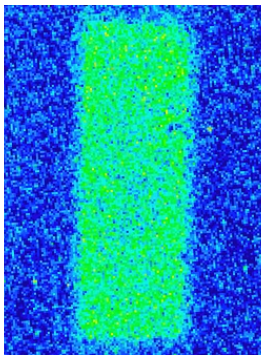
Zr: 0%



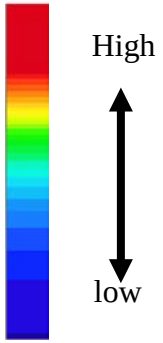
Zr: 5%



Zr: 10%

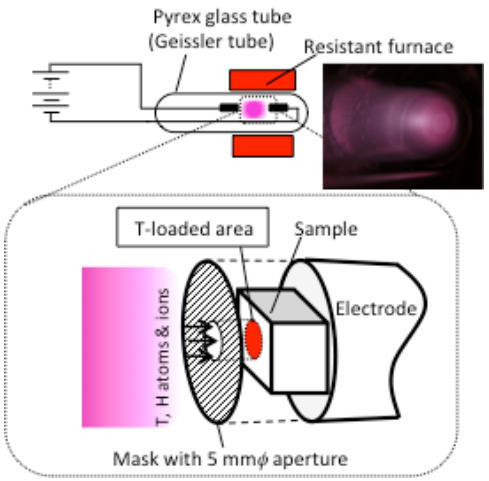


PSL intensity

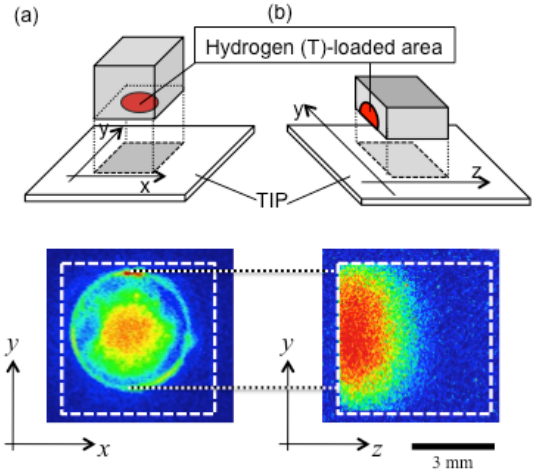


2-2. Tritium depth profiling and its application to determination of hydrogen diffusion coefficients in nuclear fusion materials

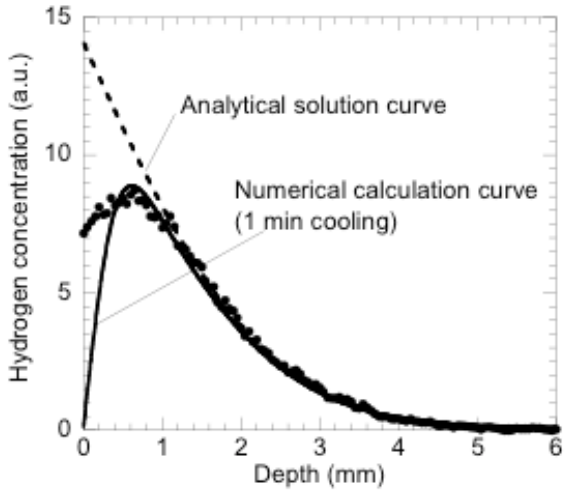
Schematics of tritium implantation exp. by DC glow discharged method



IP measurement on the tritium loaded surface and the cross-section surface



Depth profile of tritium loaded in F82H steel at 573 K for 1 h



Hokkaido University

- Staff : Yuji Yamauchi, Yuji Nobuta

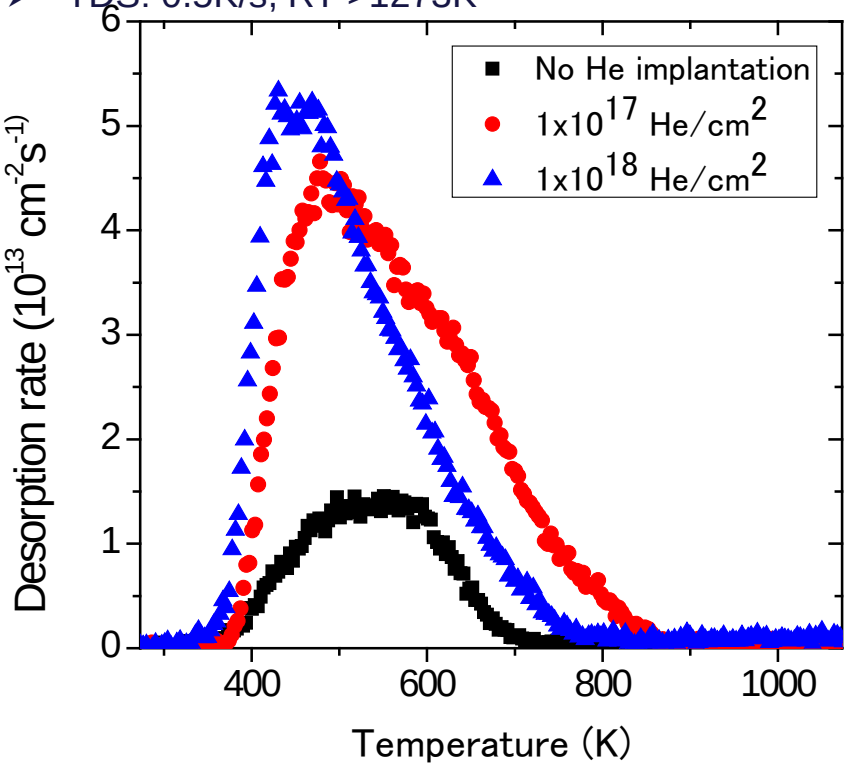
- Main subject
  - Effects of impurity/inert gas/neutron implantation on hydrogen retention and release behavior in fusion related materials.

- Research topics
  - Effect of impurity and inert gas implantation on D retention behavior in W and F82H
  - Deuterium retention property of W-coated F82H
  - Study on plasma-wall interaction in LHD using long-term samples
  - Effect of neutron and helium irradiation on deuterium retention behavior in W and F82H
  - Helium implantation effects on T retention and release behavior in W

(Example of results)

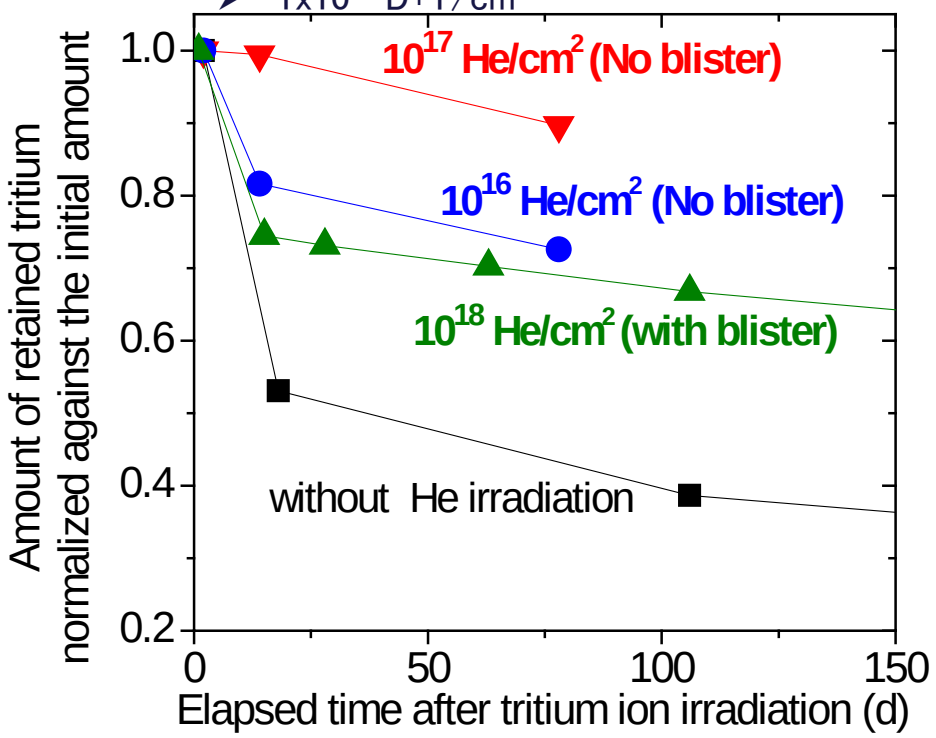
He implantation effect on hydrogen desorption and long-term hydrogen release in W

- D ion (1keV, 1x10^{18}/cm^2) --> He pre-implanted W
- TDS: 0.5K/s, RT->1273K



- Development of desorption rate at high temperatures after He implantation

- 1keV DT$^+$ (0.6 keV T)
- 1x10^{17} D+T/cm^2



- Long-term T release behavior strongly depends on He fluence

He implantation into W influences not only thermal desorption but long-term T release behavior

Summary

This presentation overviews the recent tritium related research activities in Japan. Many researchers involve the tritium research and key collaboration between JAEA, NIFS and universities enhances the tritium science and engineering research activities.

International collaborations with ITER, China, Korea, EU, US and etc. are also good opportunity to exchange the information and technique for tritium handling.

Thank you
for your attention!!

We always welcome you to visit Japan.