IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Vapour Shielding CRP

Kalle Heinola
fusion-data@iaea.org

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Vapour Shielding CRP

“Atomic Data for Vapour Shielding in Fusion Devices”

Duration: 2019 – 2022

CRP: Vapour Shielding

https://amdis.iaea.org/CRP/vapour-shielding

Background

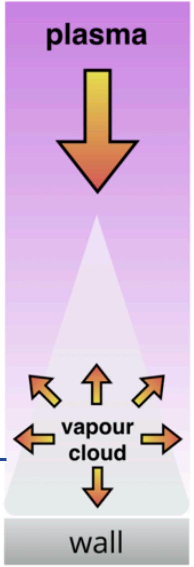
- Plasma transient events and disruptions may induce rapid evaporation or ablation of the PFC surface layers. This may result in a dense expanding plasma cloud in front of the surface.
- In the formed plasma cloud, or vapour, the incoming energy from the hydrogen plasma can be converted into radiation, thereby shielding the PFC surface from further PWIs.

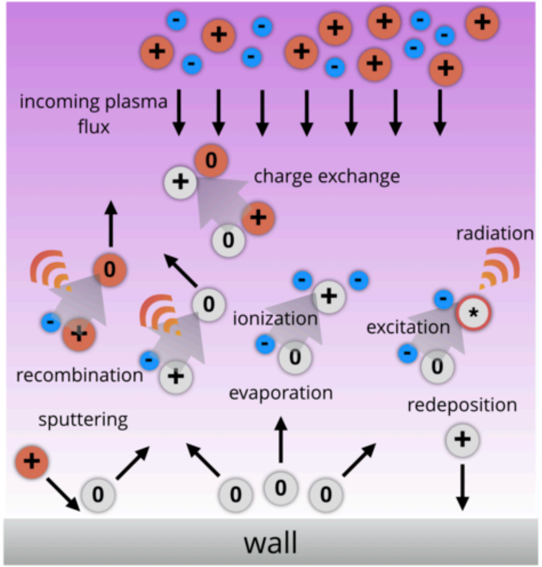
Objectives

- Provide an authoritative and evaluated set of **data relevant to vapour shielding** with particular emphasis on *liquid metals*.

Data needs

- Data relevant to liquid metals including **Li, Sn, LiSn mixture**. Impact of impurities, such as O, N, and C.
- **CR properties** of relevant atoms, ions and molecules
- Effect of **surface chemistry**. Especially: effect of H/D/T co-deposition on sputtering and evaporation





CRP: Vapour Shielding

https://amdis.iaea.org/CRP/vapour-shielding

IAEA

Participants		Methodologies (exper., comput., both)
Mohamad AKEL	AECS (Syria)	Plasma-focus device exposure of Sn targets; A+M data
Igor BRAY	Curtin Univ. (Australia)	CCC applied to p + H, e + Li and p + Li
Roberto CELIBERTO	Univ. Bari (Italy)	QM ro-vibrational properties $e + Li_2$ and e + LiH
Ronnie HOEKSTRA	Univ. Groningen (Netherland)	Structure and interactions of Sn^{q+}; $q<20$
Ratko JANEV (†)	MASA (Macedonia) ***in memoriam***	TC-AOCC on $p + Li^{+}$ and $p + Sn^{+}$
Predrag KRSTIĆ	PPPL (USA)	Classical MD of Li surfaces with O & C impurities
Narendra SINGH	Univ. Delhi (India)	Atomic data for $Sn^{3\text{-}4+}$ and W^{11+}, W^{13+}
Francisco TABARÉS	CIEMAT (Spain)	LM (Li, Sn, LiSn) targets at TJ-11 (OLMAT project)
Ling LIU G	IAPCM (China)	AOCC and MOCC on p + Be, $Ne^{1,2+}$, $Ar^{1,2+}$

CRP: Vapour Shielding

https://amdis.iaea.org/CRP/vapour-shielding

IAEA

Research Coordination Meetings

1st RCM from 13 – 15 March 2019 (IAEA HQ)

2nd RCM from 7 – 9 October 2020 (online event)

3rd RCM from 19 – 21 October 2022 (IAEA HQ)

Data provided for A+M Unit databases

https://db-amdis.org/collisiondb *new database*

Heavy particle collisional processes: $p + Be^{1,3+}$, p + Li, Be^{3+} + Li and H + $Ne^{(6-10)+}$ (AOCC, MOCC)

p + H (CCC)

Electron-molecule collisional: e + LiH, e + Li_2

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Thank you!

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Hydrogen Permeation CRP

Kalle Heinola
fusion-data@iaea.org

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Hydrogen Permeation CRP

"Hydrogen Permeation in Fusion-Relevant Materials"

Duration: 2020 – 2025

CRP: Hydrogen Permeation

https://amdis.iaea.org/CRP/hydrogen-permeation

Background

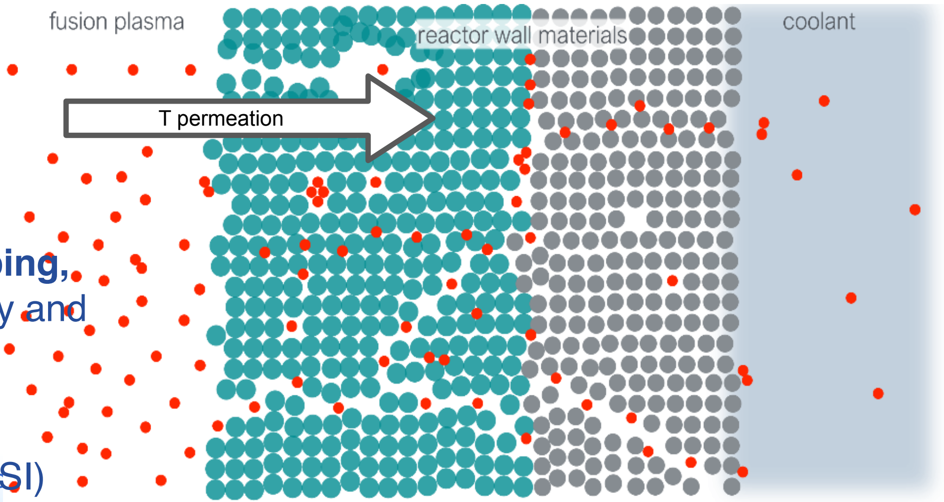
Hydrogen permeation in fusion reactor materials plays a crucial role since the radioactive **T behaviour in materials determines the *in-vessel source term*, and the *ex-vessel release term*** used in the *reactor safety assessments* for licensing future fusion facilities.

Objectives

To *enhance the knowledge base* and *reduce uncertainties* in data concerning the migration of hydrogen in materials (ITER, DEMO and FPPs)

Data needs

- divertor and main chamber: W, RAFM
  joining materials: Cu and its alloys (CuCr1Zr0.1)
- parameters affecting hydrogen **permeation, trapping, retention, release**, scrutinized both experimentally and computationally (*ab initio*, multi-scale simulations).
- **effect of *n*-induced damage** and defect evolution
- **effect of surface chemistry**, surface evolution (PSI)



CRP: Hydrogen Permeation

https://amdis.iaea.org/CRP/hydrogen-permeation

Participants

- 22 participants, 15 Member States

Experimental

- 16 proposals
  - ✓ Permeation: gas-driven, ion-driven, plasma-driven
  - ✓ TDS, NRA, PAS, plasma devices, SEM, EDX, XPS, GDOES
  - ✓ Materials: Be, W, Cu, CrZr, RAFMs
  - ✓ Bulk material, thin films, ITER W mono-block

Modelling/computational

- ~all proposals
  - ✓ DFT, MD, Rate Theories (TMAP, TESSIM, advanced RE, MHIMS, …)

Vapour Shiel

Tommy AHLGREN	Department of Physics, University of Helsinki, Finland
Sk. Musharaf ALI	Bhabha Atomic Research Centre, India
Pablo BRUZZONI	National Atomic Energy Commission, Argentina
Long CHENG	Beihang University, China
Sergei DANILCHENKO	Institute of Applied Physics, The National Academy of Sciences, Ukraine
Yves FERRO	Physique des Interactions Ioniques et Moléculaires (PIIM), Aix-Marseille Université (AMU), France
Anna GOLUBEVA	Kurchatov Institute, Russia
Anne HOUBEN	Forschungszentrum Jülich (FZJ), Germany
Wolfgang JACOB	Max Planck Institute for Plasma Physics, Garching, Germany
Mikhail Yu. LAVRENTIEV	Culham Centre for Fusion Energy, United Kingdom
Floriane LEBLOND	Centre d'Etudes Nucleaires de Cadarache, Association EURATOM-CEA, France
Byeongchan LEE	Kyung Hee University, South Korea
Sabina MARKELJ	Jožef Stefan Institute, Slovenia
Olga OGORODNIKOVA	National Research Nuclear University MEPhI, Russia
OYA Yasuhisa	Shizuoka University, Japan
Daniel PRIMETZHOFER	Uppsala University, Sweden
Li QIAO	Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, China
Masashi SHIMADA	Idaho National Laboratory, United States of America
Dmitry TERENTYEV	SCK•CEN, Belgium
Brian WIRTH	Department of Nuclear Engineering, University of Tennessee, United States of America
Anže ZALOŽNIK	Center for Energy Research, UCSD, United States of America
Haishan ZHOU	Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP), China

CRP: Hydrogen Permeation

https://amdis.iaea.org/CRP/hydrogen-permeation

IAEA

Research Coordination Meetings & other meetings

- **1st RCM** from 23 – 25 November 2020 (online event)
  - 51 participants, 15 Member States
- Technical Meeting on "*Nuclear Fusion Fuel Permeation in Reactor First Wall Components*", planned for 4 – 6 October 2021 (IAEA HQ/hybrid event)
  - CRP PIs added with external experts (52 participants, 15 Member States)
- **2nd RCM** from 28 – 30 November 2022 (IAEA HQ)

CRP subtasks ongoing

- Round-robin with **GDP** (Anne Houben, FZJ)
- Permeation and defect evolution analysis of **Neutron-irradiated samples** (IAEA)

planned
- Round-robin for **TDS** (IAEA) and **Rate Theory codes** (*tbc*)

CRP: Hydrogen Permeation

https://amdis.iaea.org/CRP/hydrogen-permeation

IAEA

Subtask: Round-robin activity *GDP for fusion materials* (GDPFM)

- Samples EUROFER97 (batch 2) from same source.
  - ✓ IPP Garching: raw material
  - ✓ FZ Jülich: sample preparation – polish, anneal, pre-characterization, sample distribution, coordination of the activity
- Participants: CEA (France), FZ Jülich (Germany), "Kurchatov Institute" (Russia), ASIPP (China), CNEA (Argentina), IPP Garching (Germany)

Floriane Leblond (CEA)	diameter 20 mm	T: 150°C - 400°C (>500°C) p: 10 mbar - 1000 mbar
Anne Houben (FZ Jülich)	diameter 24-25 mm	T: 300°C - 550°C (750°C) p: 25 mbar - 800 mbar
Anna V. Golubeva (NRC)	diameter 30-35 mm	T: 200°C-400°C (750°C) p: 1-800 mbar (1500 mbar)
Hao-Dong Liu (ASIPP)	diameter 20 mm	T: 327°C - 627°C p: 10 mbar - 1000 mbar

Pablo Bruzzoni (CNEA)	diameter 30-35 mm	T: 30°C - 90°C p: 1000 mbar
Rodrigo Arredondo (IPP)	diameter 20-21 mm	T: RT - 727°C (750°C) p: < 10 mbar (gas) Ion: E: 50 eV - keV Ion: Flux: 1e18 - 1e19 D/m2/s

➢ Parameters: 30 – 550 °C, 10 – 1000 mbar, E97 samples with identical thickness

CRP: Hydrogen Permeation

https://amdis.iaea.org/CRP/hydrogen-permeation

IAEA

Subtask: *Hydrogen in Neutron-irradiated Materials* (HNIM)

- Participants: Idaho National Lab (USA), MEPhI (Russia), UKAEA (UK), Univ. Helsinki (Finland). Coordination: IAEA
  - ➢ Permeation studies, round-robin experiment and studies of evolution of n-irradiation-induced defects: GDP, PDP, TDS, PAS, NRA
- Two batches of samples:
  1. N-irradiation campaign 2017 – 2019 (samples provided by SCK-CEN)
     - ✓ various W grades: 0.072 – 0.124 dpa (up to 1 dpa), 600 – 1200 °C
     - ✓ IGP W for round-robin: 0.072 – 0.098 dpa, 600 – 1200 °C
  2. N-irradiation campaign **2022**
     - ✓ 85 samples
     - ✓ various W grades, CuCrZr, Mo, Fe, steels: 0.001 – 0.2 dpa and 50 – 1200 °C
     - ✓ Eurofer97 (batch 3) donation: collaboration with **F4E**

FUSION FOR ENERGY

CRP: Hydrogen Permeation

https://amdis.iaea.org/CRP/hydrogen-permeation

Subtask: *Hydrogen in Neutron-irradiated Materials* (HNIM)

- IAEA front page article

  https://www.iaea.org/newscenter/news/neutrons-blast-fusion-materials-in-new-iaea-project

IAEA International Atomic Energy Agency

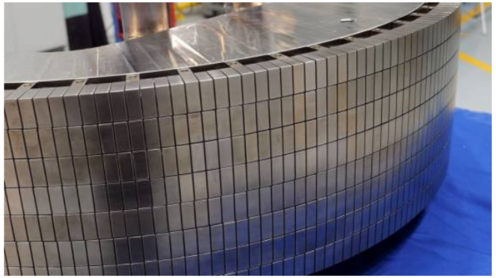
TOPICS SERVICES RESOURCES NEWS & EVENTS ABOUT US Search

Home / News / Neutrons Blast Fusion Materials in New IAEA Project

Neutrons Blast Fusion Materials in New IAEA Project

Michael Amdi Madsen, IAEA Office of Public Information and Communication

APR 4 2022



A prototype plasma-facing part of the ITER divertor. Material made of tungsten, like this, is being studied for fusion hydrogen permeation in the IAEA coordinated research project. (Photo: ITER)

On 21 December 2021, in a facility nine miles south of Oxford's city centre, the Joint European Torus (JET) fusion device fired up. Using powerful magnets to confine and fuse hydrogen, the *tokamak* reactor produced a record-shattering 59-megajoule fusion energy pulse over a period of five seconds. The almost forty-year-old JET was able to make the historic breakthrough, thanks in part

CRP: Hydrogen Permeation

https://amdis.iaea.org/CRP/hydrogen-permeation

IAEA

Subtask: Round-robin for TDS (TDS4F)

Plan:

- Samples (W) from same batch. Three types of sample preparation:
  1. D plasma exposure, pre-irradiated W (IPP Garching)
  2. D high-energy implantation (FZJ)
  3. thermal exposure D_2 gas, pre-irradiated W (Univ. Helsinki)

  - D_2 exposure first trial successful
    - ✓ 0.1 dpa self-damaged W, D_2 gas exposure @ 250°C for 24 hrs
    - ✓ ERDA analysis: retention ~7×10^{15} at./cm^2
      - ➢ Sample mass production still needs to be confirmed (ongoing)
  - **Benefit**: only *known* pre-irradiated damage in the samples

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Thank you!