Recent plasma-surface interaction activities supported by the IAEA

R.E.H. Clark

Nuclear Data Section, IAEA, Vienna, Austria

Oak Ridge, Tennessee, USA

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International Atomic Energy Agency

Outline

- Goals of the IAEA

  Nuclear Data Section (NDS)

  Atomic and Molecular (A+M) Data Unit

- Current PSI Projects

- Future plans

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International Atomic Energy Agency:

- World centre for nuclear cooperation
- Working for the safe, secure and peaceful use of nuclear energy

Mission statements directed towards:

- Safety and Security
- Safeguards and Verification
- Science and Technology

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IAEA Nuclear Data Section (NDS): Mission

- Develop and disseminate atomic and nuclear data for applications
- Assist in technology transfer activities to scientists in developing countries

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Atomic and Molecular Data Unit

Primary objective:

establish and maintain internationally recommended numerical databases of atomic and molecular collision and radiative processes, atomic and molecular structure characteristics, particle-solid surface interaction processes, and physico-chemical and thermo-mechanical material properties for use in fusion energy research and other plasma science and technology applications

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Co-ordinated Research Projects

- Research effort on topic of interest to fusion
- Representatives from approximately 10 research institutes
- Duration of 3-5 years
- Periodic meetings at IAEA Headquarters
- Final results published in *Atomic and Plasma-Material Interaction Data for Fusion (APID)*, and data assembled as an electronic database

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Current CRPs

- Atomic and Molecular Data for Fusion Diagnostics: 12 participants, ends in 2005
- Data for Molecular Processes in Edge Plasmas: 11 participants, ends in 2005
- Tritium Inventory in Fusion Reactors: 11 participants, ends in 2006

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CRP on Tritium Inventory in Fusion Reactors

<u>Overall Objective:</u> gather and generate new data relevant to the overall inventory of tritium in fusion reactors, with special emphasis on the interactions of tritium with plasma-facing components, and methods for tritium removal

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CRP on Tritium Inventory in Fusion Reactors

Participants:

A.A. Haasz (Toronto, Canada)
N. Bekris (Karlsruhe, Germany)
J. Roth (Garching, Germany)
T. Tanabe (Nagoya, Japan)
V.Kh. Alimov (Moscow, Russian Federation)
A. Pisarev (Moscow, Russian Federation)
J.P. Coad (Culham, Oxon, UK)
R.A. Causey (Livermore, USA)
R. Doerner (San Diego, USA)
C.H. Skinner (New Jersey, USA)
S. Artemov (Tashkent, Uzbekistan)

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CRP on Tritium Inventory in Fusion Reactors

- First RCM held 2002 - identified specific topics for study and formulated a work plan
- Important materials include carbon, tungsten and beryllium
- Cannot be assumed that the first wall will be carbon-free
- Effects of dopants are important, and dependent on particle and heat load
- Flux and fluence dependence of chemical erosion important in modelling

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CRP on Tritium Inventory in Fusion Reactors

- Still some question of erosion sources
- Removal of tritium will be an important issue for ITER
- Electron-simulated desorption, glow discharge and laser heating are all being investigated for tritium removal
- Research initiated on all topics

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Results From RCM - 2004

Sintered B_4C:

- Deuterium is solely accumulated in sintered B_4C as D atoms
- At 300 K, implanted deuterium is accumulated mainly in the ion implanted zone
- At temperatures above 600 K and high fluences (above 10^{24} D/m^2), the bulk accumulation plays a major role in D retention
- At temperatures around 900 K and high ion fluences, the maximum D concentration in the bulk (up to a depth of 50 µm) is ~0.1 at.%
- Diffusivity of deuterium in sintered boron carbide is evaluated as $D = 1.4\times10^{-5} \exp\{-(100\pm10 \text{ kJ/mol})/RT\}$ m^2/s

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Results From RCM – 2004

Neutron-induced Elastic Recoil Detection (NERD):

- Determines content and concentration profiles of hydrogen isotopes
- Non-destructive method
- Maximum depth determined by range of recoiled neutrons
- New design of inner element of chamber
- Electronics improved
- Overall performance improved

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Results From RCM - 2004

Carbon flakes:

- Flakes are likely in any carbon machine
- Flakes undergo chronic tritium release
- Nature of purging gas has little influence on rate of tritium release
- Tritium release from flakes enhanced by heating; not affected by gamma irradiation (up to 3.5 Mrads)
- Gamma irradiation has no effect on O_2 but after irradiation amount of water release seems to decrease

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Results From RCM - 2004

Tungsten:

- Hydrogen trapping: diffusivity is rapid, solubility is low, recombination is high
- Trapping occurs at vacancies, dislocations on grain boundaries and in voids
- Calculations and experiments of hydrogen retention indicate small tritium inventory in ITER
- Need more information on reactions of beryllium with tungsten, possible formation of low melting point alloys

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Results From RCM - 2004

Experiments in JET:

- Impurities arriving at inner divertor eroded from main chamber, but not sure from where
- Last step in transport is ablation from powdery deposits at corner of divertor
- ^{13}C tracer experiments provide some insight into SOL drift phenomenon
- Photon cleaning successfully applied *in-situ* in JET to ablate deposits from inner divertor; also being applied to de-tritiate tiles
- Oxy-gas burner used for end-of-life de-tritiation of carbon files

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Results From RCM - 2004

US-EU collaboration on mixed materials:

- Understanding of mechanism for Be-rich layer formation on C at very low impurity Be concentration
- Determine the role of O impurities on retention in Be-rich co-deposits
- Investigate concurrent Be and C injection into D plasma
- Stability of surface layers during ELM conditions
- W-Be alloy formation is a critical issue needing immediate attention (melting temperature, thermal properties, formation rates, etc.)

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Results From RCM - 2004

Study of erosion of carbon tiles due to tritium ions:

- Measured chemical erosion yields by low energy T ions
- Chemical erosion yields of graphite for H, D and T ions are similar in magnitude and temperature dependence
- Absence of isotope effect for H and D ions in 10-200 eV range, and similar yields for H, D and T ions at 200-250eV; reasonable to assume no significant T isotope effect in tens of eV range
- H and D experiments should provide good guidance for carbon erosion from T in fusion machine

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Results From RCM – 2004

Laser de-tritiation:

- High energy laser can lead to ablation of material
- Films can be removed from PFC
- Re-deposition of ablated material is an issue
- Pulsed lasers used to clean by ablation
- Continuous laser to avoid ablation
- Extensive tests have been carried out on TFTR and JET tiles with continuous Nd laser

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Future Plans

- Comprehensive work plan has been formulated for CRP
- Results will appear in issue of *Atomic and Plasma-Material Interaction Data for Fusion*, and will be included in database
- CRP on "Data for surface composition dynamics relevant to erosion processes" to start in 2006 - recommended by IFRC Subcommittee

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Work Plan to 2006

- Identify sources and sinks in tokamaks using ^{13}C puffs
- Transport of hydrocarbon species in tokamaks
- C erosion, and dependence in respect of amounts of impurities

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Work Plan to 2006

- Monitor deposition of eroded material using Quartz Micro Balances (QMBs)
- Analysis of long-term samples (ASDEX-UG, JET, JT-60, NSTX)
- Analysis of JET samples using Neutron-induced Elastic Recoil Detection (NERD)

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Work Plan to 2006

- Use of laser as removal technique, and evaluation of possible re-absorption
- Other in-vessel techniques will also be tested
- Effect of metals impurities with respect to thermal oxidation

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Work Plan to 2006

- Laboratory oxidation studies of DIII-D and JET tiles
- Tritium retention on clean W will be continued and investigated under various conditions
- Diffusion of Be in W as a function of temperature and the formation of a Be-W alloy will be investigated
- Injection of Be into plasma, and retention by W substrate will be studied

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ALADDIN

- Numerical data include wide variety of processes
- User may select process, followed by choice of reactants and specific transitions
- Data displayed in tabular and graphical forms
- GENIE search engine allows retrieval of numerical data from databases at other data centres

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Processes

- Atomic and molecular excitation and ionization through electron and heavy particle impact
- Charge exchange processes
- Molecular formation and destruction processes
- Plasma-material interaction processes, energy and angle dependent

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AMBDAS

- Bibliographic database for fusion-related data
- Search carried out by combination of author, process and reactants
- List of co-authors generated automatically

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Publications

- *Atomic and Plasma-Material Interaction Data for Fusion* (APID)
- *International Bulletin on Atomic and Molecular Data for Fusion* (“the Bulletin")
- Summary reports of meetings

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APID

- Formerly a supplement to *Nuclear Fusion* journal - now a stand-alone publication
- Reports on work from CRPs
- Average of one issue per year
- Articles are refereed
- Priced publication, so not available on-line

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The Bulletin

- Previously two volumes per year, recently changed to once per year
- Bibliographic reference for data relevant to fusion
- Cross referenced by author, process and reactants
- All data in Bulletin are accessed on-line by AMBDAS

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IAEA, Vienna International Centre

http://www-amdis.iaea.org/

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