IAEA Projects on Radiation Effects Modelling and Experiments for Fission and Fusion Power Plants

Joint ICTP-IAEA Workshop on the Training in Basic Radiation Materials Science and its Applications to Radiation Effects Studies and Development of Advanced Radiation-Resistant Materials

G. Mank
IAEA, Physics Section

21 November 2008, ICTP, Trieste
Outline

1. Introduction

2. Materials Research
   1. Research Reactors
   2. Fusion
   3. Accelerators

3. IAEA activities on Materials Research (Physics Section)
The Demand

- New fuel for the next generation of NPP
- Simulation and modelling of radiation effects (using accelerators and research reactors)
- Synergies related to fission and future fusion power plants
The Challenge

• Materials Research at Research Reactors (overbooking – under-utilization)

• Accelerators (tool for materials research)

• ITER and the fusion demo reactor

• Next Generation Power Plants
The Challenge - Fission

Increasing demands on materials

- Operating temperature (°C)
- Trend in burn-up (MWd/t)
- Ingestible radioactivity index

IAEA Scientific Forum 2005,
http://www-pub.iaea.org/MTCD/Meetings/Announcements.asp?ConflID=138
This workshop
Number of Research Reactors

Number of research reactors in industrialized and developing countries

- Total
- Industrialized
- Developing

Fuel and Material Irradiation
- Neutron Radiography
- Neutron Scattering Exp.
- Neutron Activation Analysis

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Number of Research Reactors
Number of Research Reactors

Number of reactors

Number of research reactors in industrialized and developing countries
The Challenge - Fusion

Specific aspects of status of fusion research and materials needs

See also ➔ Talk by Dudarev
Confinement

Magnetic Confinement

Gravitational Confinement in the Sun and Stars

Inertial Confinement Using Lasers

General Atomics

Energy - Fusion
Main route to ignition: indirect laser drive with central hot-spot ignition

Baseline target and driver designs for NIF have been worked out more than 10 years ago.

- Laser light creates a "bath" of thermal X-rays in a cylindrical hohlraum, which then drive spherical implosion of a DT capsule.
- The compressed DT is ignited from a central hot spot, which is naturally formed in the process of implosion provided that the implosion velocity \( \geq (2-3) \times 10^7 \) cm/s.

What have been the latest new developments?
Fast Ignition Realization Experiment (FIREX) Project

FIREX I & II

Principle of Fast Ignition will be Proved with the FIREX Project
Progress in IFE

- GEKKO XII
  - High density compression
  - '88-89

- Fast ignition
  - '02

- Nova

- GEKKO MII
  - '80

- GEKKO IV
  - '80-81

- LHART
  - '85-86

- NIF
  - High gain

- Ignition

- Fusion parameter (sec/cm²)
  - High gain
Magnetic Fusion is most advanced

Today: JET, JT60-U

Fusion Reactor

ITER

IAEA

Energy - Fusion
Heat load – long pulses
Achievements and Fusion Needs

Progress in controlled magnetic fusion since the first research at the beginning of the 1960s. Fusion reactor conditions will be touched by the new international ITER device.
ITER Performance, pulse length up to 1000 s

B. Spears, FPA 2003, Washington

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Energy - Fusion
Objective: The specific requirements associated with the theory, construction and steady state operation of new machines are addressed. These meetings bring experts from the fields of steady state operation, energetic particles, transport and data acquisition together to present their results and discuss physical and technological aspects of new long-pulse machines.

- Technical Meetings on Steady State Operation, Energetic Particles, H-mode Physics and Transport Barriers, Fusion Power Plants and Data Acquisition
Dust and Irradiation

1. Tritium (total site inventory)
2. Tokamak dust (Beryllium, Carbon, Tungsten)
3. Activated Corrosion Products
4. Activated Wall and Blanket

Principle: Safety ALARA
## Problem: Radioactive Waste

<table>
<thead>
<tr>
<th>Power Source</th>
<th>Total Waste (cubic meters)</th>
<th>High-Level RAD Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>10,000 (ashes)</td>
<td>0</td>
</tr>
<tr>
<td>Fission</td>
<td>440</td>
<td>120</td>
</tr>
<tr>
<td>Fusion:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Today’s Materials</td>
<td>2000</td>
<td>30</td>
</tr>
<tr>
<td>Advanced Materials</td>
<td>2000</td>
<td>0</td>
</tr>
</tbody>
</table>

1000 MW(e) Power Plant - 30 year Lifetime

ITER: 6100 t remaining after 100 years

General Atomics

IAEA

Energy - Fusion
Schematic Reactor – Tritium breeding

Plasma

Helium

Lithium

Tritium

Deutrium

Neutron

Blanket

Heat Removal

Tritium Recovery

Energy - Fusion
The Way to a Fusion Power Plant

![Diagram showing the relationship between radiation dose (dpa) and operating temperature (°C) for different reactor materials. The chart includes regions for HTR Materials, Fusion Materials, Fast Reactor Materials, and ITER.](image-url)
New Materials for Fusion

Necessity of Blanket & Material Development for Fusion Power Generation

- Core plasma technology: High plasma fusion power gain (Q = 10), extended DT burn - steady state (Q = 5) ultimate goal.
- Fusion Technology: Fabrication of SC coil, plasma facing components, shielding, heating and current drive, tritium handling, remote handling, establish technology integration

Blanket & Material development is the major technology task not covered by ITER

In addition to TBM tests in ITER, material development and its database construction is essential.

Target Material Performance for DEMO Plant

- Reduced Activation Ferritic Steel (RAFS)
- (Target Performance)
- DEMO

ITER Operation region

Neutron Dose (MWe/m² ~10 dpa)

Material Temperature, C

0 500 1000

Matsui, IEA Paris, 2005
**EUROFER 97:**
- Recycling dose rate level of 10 mSv/h is achieved after 50-100 years
- Hands-on dose rate level of 10 μSv/h is achieved after $10^5$ years

Public Demand:
- Assumptions:
  - HCLL PPCS reactor model B
  - Fusion power: 3.3 GW
  - First wall made of EUROFER 97
  - Neutron flux: $1.53 \times 10^{16}$ cm$^{-2}$s$^{-1}$
  - 5 full power year irradiation
### Fusion Material

#### Plasma Facing Components

<table>
<thead>
<tr>
<th>Function</th>
<th>First wall</th>
<th>Breeding blanket</th>
<th>Divertor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armour material</td>
<td>W-base alloy, W-coated ODS steel, flowing liquid metal: Li</td>
<td>-</td>
<td>W-base alloy, W-coated SiC/SiC, flowing liquid metal: Li, Ga, Sn, SnLi</td>
</tr>
<tr>
<td>Coolant</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Functional Material

<table>
<thead>
<tr>
<th>Function</th>
<th>First wall</th>
<th>Breeding blanket</th>
<th>Divertor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutron multiplier material</td>
<td>-</td>
<td>Be, Be$<em>{12}$Ti, Be$</em>{12}$V, Pb</td>
<td>-</td>
</tr>
<tr>
<td>Tritium breeding material</td>
<td>-</td>
<td>Li, eutectic Pb-Li, Li-base ceramic materials</td>
<td>-</td>
</tr>
<tr>
<td>Coolant</td>
<td>-</td>
<td>Water, helium, eutectic Pb-Li, Li</td>
<td>Water, helium</td>
</tr>
</tbody>
</table>

#### Structural Material

<table>
<thead>
<tr>
<th>Function</th>
<th>First wall</th>
<th>Breeding blanket</th>
<th>Divertor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural material</td>
<td>RAFM steel, ODS steel, V-base alloy, SiC/SiC</td>
<td>RAFM steel, ODS steel, V-base alloy, SiC/SiC</td>
<td>ODS steel, W-base alloy</td>
</tr>
<tr>
<td>Coolant</td>
<td>-</td>
<td>Water, helium, eutectic Pb-Li, Li</td>
<td>Water, helium</td>
</tr>
</tbody>
</table>

N. Baluc et al., Fusion Energy Conf. 2006, China
The Test Blanket Module

Functional Material

<table>
<thead>
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<th>Divertor</th>
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<tr>
<td>Coolant</td>
<td>-</td>
<td>Water, helium, eutectic Pb-Li, Li</td>
<td>Water, helium</td>
</tr>
</tbody>
</table>

N. Baluc et al. , Fusion Energy Conf. 2006, China
A wide use of pure lead, as well as its alloys (such as lead-bismuth, lead-lithium), is foreseen in several nuclear-related fields: it is studied as coolant in critical and sub-critical nuclear reactors, as spallation target for neutron generation in several applications and for tritium generation in fusion systems.

Nowadays, the possibility to use Heavy Liquid Metals (HLM) both as spallation target and coolant of the sub-critical part of the Accelerator Driven Systems (ADS) seems very attractive, the ADS being proposed as a viable solution to burn nuclear waste.

The use of lead as coolant appears as an appealing choice also for critical reactors. In the generation IV nuclear reactors technology evaluation, in fact, lead fast reactors (LFR) appear as a promising technology, top ranked both in sustainability because of the closed fuel cycle and in proliferation resistance and physical protection due to the long life core.

Slowly flowing lead lithium alloy in eutectic composition (Li 15.7%at) is the tritium breeder and neutron multiplier for one of the two EU blanket concepts to be tested in ITER.
Lack of intense neutron source emphasizes the need for co-ordinated experiment, modeling & theory to develop fundamental understanding of radiation damage
Multiscale Modeling of Radiation Damage in Fusion Reactor Materials Brian D. Wirth et al presented at DOE, March 12, 2002
## Spallation Source for Fusion Research: IFMIF

<table>
<thead>
<tr>
<th>Issue</th>
<th>Today's expts</th>
<th>ITER</th>
<th>IFMIF</th>
<th>DEMO Phase 1</th>
<th>DEMO Phase 2</th>
<th>Power Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disruption avoidance</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>R</td>
<td>R</td>
<td>R</td>
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<td>Steady-state operation</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>r</td>
<td>r</td>
<td>R</td>
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<tr>
<td>Divertor performance</td>
<td>2</td>
<td>3</td>
<td></td>
<td>R</td>
<td>R</td>
<td>R</td>
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<tr>
<td>Burning plasma Q&gt;10</td>
<td></td>
<td>3</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
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<tr>
<td>Power plant plasma performance</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>R</td>
<td>R</td>
<td>R</td>
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<tr>
<td>T self-sufficiency</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>R</td>
<td>R</td>
<td>R</td>
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<tr>
<td>Materials characterisation</td>
<td>3</td>
<td></td>
<td></td>
<td>R</td>
<td>R</td>
<td>R</td>
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<tr>
<td>Plasma-facing surface lifetime</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>FW/blanket materials lifetime</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>FW/blanket components lifetime</td>
<td>1</td>
<td></td>
<td>1</td>
<td>3</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Divertor materials lifetime</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>NB/RF heating systems performance</td>
<td>1</td>
<td>3</td>
<td></td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Electricity generation at high availability</td>
<td></td>
<td>1</td>
<td>3</td>
<td>R</td>
<td>R</td>
<td>R</td>
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<tr>
<td>Superconducting machine</td>
<td>1</td>
<td>3</td>
<td></td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Tritium issues</td>
<td>1</td>
<td>3</td>
<td></td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>

**Key:**
- 1: Will help to resolve the issue
- 2: May resolve the issue
- 3: Should resolve the issue
- r: Solution is desirable
- R: Solution is essential
Fusion Needs: Materials and Wall

Objective: The choice of wall and blanket is crucial for the success of magnetic and inertial fusion. Data analysis as well as dedicated experiments are supported.

- Technical Meetings on Fusion Power Plants, Atomic and Molecular data and on codes as well as 4 Coordinated Research Projects e.g. on molecular processes, spectral features, tritium inventory and wall studies in small tokamaks are supported. A school on pulsed neutrons: enhancing the capacity for materials science will discuss materials research under very high neutron peak fluxes.
Next Steps in Fusion Research

From Physics Studies to a Power Reactor

Present Generation of Large Tokamaks

Experimental Reactor

ITER

Demonstration Reactor

DEMO

Commercial Power Reactor

Optimisation of Tokamak Reactor Design
Availability of Electrical Power
Evaluation of Economics

Demonstration of Technologies essential for a power reactor
- Superconducting coils
- Plasma power and particle exhaust component
- Remote maintenance
- Reactor-relevant tritium-breeding blankets

Confirmation of physics basis
- Confinement
- Alpha particle physics
- Steady state operation

Physics basis for extrapolations and predictions of performances of next step machines
Time frame magnetic fusion
## Overview of Demands

<table>
<thead>
<tr>
<th>Reactor Type</th>
<th>Inlet Temp (°C)</th>
<th>Outlet Temp (°C)</th>
<th>Maximum Dose (dpa)</th>
<th>Pressure (MPa)</th>
<th>Coolant</th>
<th>Structural Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR</td>
<td>290</td>
<td>320</td>
<td>100</td>
<td>16</td>
<td>Water</td>
<td>FM Steel, SS</td>
</tr>
<tr>
<td>SCWR*</td>
<td>290</td>
<td>500</td>
<td>15-67</td>
<td>25</td>
<td>Water</td>
<td>FM steel, SS</td>
</tr>
<tr>
<td>VHTR*</td>
<td>600</td>
<td>1000</td>
<td>1-10</td>
<td>7</td>
<td>Helium</td>
<td>Ni alloys, Graphite, ceramics</td>
</tr>
<tr>
<td>SFR*</td>
<td>370</td>
<td>550</td>
<td>200</td>
<td>0.1</td>
<td>Sodium</td>
<td>(ODS) FM steel, SS</td>
</tr>
<tr>
<td>LFR*</td>
<td>600</td>
<td>800</td>
<td>200</td>
<td>0.1</td>
<td>Lead</td>
<td>(ODS) FM steel, SS</td>
</tr>
<tr>
<td>GFR*</td>
<td>600</td>
<td>850</td>
<td>80</td>
<td>7</td>
<td>Helium SC CO₂</td>
<td>(ODS) FM steel, SS, Ni alloys, ceramics</td>
</tr>
<tr>
<td>Fusion DEMO EU, Model C</td>
<td>480</td>
<td>700</td>
<td>150</td>
<td>8</td>
<td>Helium</td>
<td>(ODS) FM steel, ceramics, refract.</td>
</tr>
<tr>
<td>Spallation MYRRHA, XT-ADS</td>
<td>300</td>
<td>400</td>
<td>~60</td>
<td>0.1</td>
<td>Pb-Bi</td>
<td>FM-steel, SS</td>
</tr>
</tbody>
</table>

* Gen IV Rod Map 2002

Th. Walter Tromm OECD/NEA SMINS- Workshop 04-06/06/2007
Main Emphasis

Drivers of fusion future programme:

- Support Member States on the move towards a fusion power plant

- Materials research for nuclear power plants (fission and fusion)
Materials Research at / for Accelerators
Neutron Production:

Peak Neutron Flux Limited
Neutron Production using Spallation:
Spallation Accelerator:

Simplest idea: Can it be done with a linear accelerator alone??

Ion source → ion beam → target

Linear accelerator to 1 GeV (87% of the speed of light)

(courtesy: K. Herwig, SNS)
Spallation Accelerator (SNS): (courtesy: K. Herwig, SNS)
Final Design

1) Produce $H^+$ beam pulse in source
2) Accelerate beam pulse in linear accelerator to 1 GeV
3) Accumulate 1060 pulses in the accumulator ring
4) Extract and fire the accumulated beam at the target
5) Do this 60 times per second!

(courtesy: K. Herwig, SNS)
Spallation target:

- E.g. Mercury
- Proton beam
- Beam line
- Moderator
- Reflector
### Spallation Neutron Sources worldwide:

<table>
<thead>
<tr>
<th>Source</th>
<th>Primary Acceleration</th>
<th>Pulse Rate (Hz)</th>
<th>Final Energy (MeV)</th>
<th>Power (kW)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSI</td>
<td>Cyclotron</td>
<td>CW</td>
<td>800</td>
<td>1100</td>
</tr>
<tr>
<td>ISIS</td>
<td>RCS</td>
<td>50</td>
<td>800</td>
<td>160</td>
</tr>
<tr>
<td>PSR (Lujan)</td>
<td>Linac</td>
<td>20</td>
<td>800</td>
<td>100</td>
</tr>
<tr>
<td>IPNS</td>
<td>RCS</td>
<td>30</td>
<td>450</td>
<td>7.5</td>
</tr>
<tr>
<td>SNS (Achieved)</td>
<td>Linac</td>
<td>30</td>
<td>880</td>
<td>180</td>
</tr>
<tr>
<td>SNS (Design)</td>
<td>Linac</td>
<td>60</td>
<td>1000</td>
<td>1400</td>
</tr>
<tr>
<td>J-PARC (Design)</td>
<td>RCS</td>
<td>25</td>
<td>3000</td>
<td>1000 **</td>
</tr>
</tbody>
</table>

* Operational level during neutron production
** After linac upgrade
Figure 8. The IFMIF design concept
Data for neutron cross sections (> 20 MeV) needed:

Nuclear Data Section has been asked to support

Readiness of Technical Status of IFMIF for EVEDA (3)

- Test Cell
  - Detailed conceptual designs of “High Flux Test Module” and their performance analyses have been made with satisfactory results.
  - Small Specimen Test Technology has been developed in order to fit many specimens in the relatively small IFMIF irradiation volume.
The IAEA’s action

1. Fission

2. Fusion

3. Accelerators and Materials
The IAEA’s action

**International Conferences**
(as supported by Physics Section):

- Research Reactor Conference (next 2011)
- Fusion Energy Conference (next 2010)
- Accelerator Conference (next 2009)
- Workshop on Structural Materials for Innovative Nuclear Systems SMINS (together with NEA. next 2009)
Coordinated Research Projects (CRP)  
Fission: FUMEX I – III (NE-Department)

Objective I:
The major objective of the CRP was to improve the predictive capabilities of codes used in fuel behaviour modelling for extended burn-up. The focus was on the topics:

• Thermal performance
• Fission gas release
• Pellet to clad interaction (PCI) at extended burn-up above 50 MWd/kg.

Objective II:
In addition, the CRP addressed the performance of codes used for transient analysis such as RIA and LOCA at extended burn-up.
The IAEA’s action

Fission: FUMEX (I – III)

Significant improvements in the capability to model fuel temperature, fission gas release and dimensional change have been achieved, and with the recently completed FUMEX-2, the range of fuel burnup that is capable of being analysed accurately has increased to around 60,000 MWd/tU in support of the extended burnups in modern LWR fuel cycles.

Objective III:
FUMEX-3 will address concerns with high burnup transient behaviour, consequences of the rim effect observed at high burnup and will also consider fuel behaviour in advanced PHWR fuel cycles with high ratings and extended burnup.

→ Killeen, Inomzentsev

Extend understanding of the basic physics of accelerator irradiation under operational conditions in fission reactors, and through synergy with other nuclear concepts such as fusion and spallation systems.

That goal will bridge from micro- to macroscopic behaviour of materials through modelling validated by specific detailed experiments.
The IAEA’s action

Fission: SMoRE (2008-2011)

The CRP will give a special emphasis to following phenomena:

- Primary damage, cascade and sub-cascade formation
- Irradiation activated kinetic processes
- Void and gaseous swelling, including He + H synergisms
- Phase stability and self-organization under irradiation
- Irradiation effects on mechanical properties
- Corrosion processes under irradiation
- Role of impurities (e.g. transmutation, fabrication)

Following alloys/steels will be considered primarily for further studies of above-mentioned phenomena, in particular,

- Zr alloys
- Austenitic and ferritic-martensitic steels
- ODS materials

Structural materials related to other nuclear systems which contribute to the specific research objectives can be considered too.
The IAEA’s action

Fission: Technical Meetings

The overall objective of a Technical Meeting is to provide a forum to exchange ideas and information through scientific presentations and brainstorming discussions, it is anticipated that this meeting will achieve overall objectives.
The IAEA’s action

Fission:

Technical Meeting on “Accelerator Simulation and Theoretical Modelling of Radiation Effect” June 2008

To demonstrate how experimental accelerator simulation methods and theoretical modelling tools could be applied for investigation of irradiation phenomena, which degrade physical and mechanical properties and induce dimensional changes.
Fission:

Technical Meeting on “Accelerator Simulation and Theoretical Modelling of Radiation Effect” June 2008

To demonstrate how experimental accelerator simulation methods and theoretical modelling tools could be applied for investigation of irradiation phenomena, which degrade physical and mechanical properties and induce dimensional changes.
Schemes of triple beam accelerators
The IAEA’s action

Fission:

Technical Meeting on “Research Reactor Applications for Materials under High Neutron Fluence” November 2008

Specific objectives:

• Available irradiation facilities and recent development of Irradiation devices
• New material irradiation programmes and their implementation
• Radiation damage at high doses
• Effective and optimal operation procedures
• Information exchange
Accelerator Conference AccApp

Topics to be addressed at the conference:

• Applications
  • Simulation of radiation damage and testing of materials for nuclear systems;
  • Research and development of applications for advanced materials;
  • Different aspects of industrial accelerator applications;
  • Interdisciplinary endeavours.

• Accelerator technology
  • Operation, instrumentation and control;
  • New acceleration techniques;
  • Research and development.

• Accelerator Driven Systems (ADS)
  • Innovative nuclear systems;
  • ADS experiments and test facilities;
  • Nuclear data.

http://www-pub.iaea.org/MTCD/Meetings/Announcements.asp?ConflID=173
IMPROVED PRODUCTION AND UTILIZATION OF SHORT PULSED, COLD NEUTRONS AT LOW-MEDIUM ENERGY SPALLATION NEUTRON SOURCES

- Improvement of spallation source by development of cryogenic moderators
- Increase of potential usage of beam lines by contributing to improve micro-focusing small angle neutron scattering
- Enhance capability for strain determination by improving data extraction and evaluation from high resolution transmission measurements

25 MeV e LINAC, CENTRO ATOMICO BARILOCHE - ARGENTINA
Spallation Modelling Benchmarking

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Joint ICTP-IAEA Advanced Workshop on Model Codes for Spallation Reactions
Schools on Accelerators:

School on Pulsed Neutron Sources: Enhancing the Capacity for Material Science
17 - 28 October 2005, ICTP, Trieste, Italy

School on Ion Beam Analysis and Accelerator Applications,
13-24 March 2005, ICTP, Trieste, Italy

School on Pulsed Neutrons: Characterization of Materials
15 - 26 October 2007, ICTP, Trieste - Italy
Joint ICTP/IAEA Workshop on
Advanced Simulation
and
Modelling for Ion Beam Analysis
23 - 27 February 2009
Miramare - Trieste, Italy

Joint ICTP/IAEA Advanced Workshop on
Development of Radiation Resistant Materials
20 – 24 April 2009
(Miramare – Trieste, Italy)

Joint ICTP/IAEA School on
NOVEL SYNCHROTRON RADIATION
APPLICATIONS
16-20 March 2009
ICTP, Miramare - Trieste, Italy

Joint ICTP/IAEA School on Physics and Technology
of Fast Reactors Systems
9 November - 20 November 2009
The IAEA’s action

Fusion:

Technical Meetings

Physics and Technology of Inertial Fusion Energy Targets and Chambers (2009)
Steady State Operation of Magnetic Fusion Devices (2009)
First Generation of Fusion power Plants: Design and Technology (2009)
Fusion:

Coordinated Research Projects:

Integrated approach to dense plasma applications in nuclear fusion technology
Pathways to Energy from Inertial Fusion – An integrated approach
Investigations on Materials under High Repetition Intense Fusion Pulses (2011)
Dense Plasmas technology and applications for main steam fusion research (2010)
Summary I

Material Research at research reactors, neutron sources and accelerators is important for future projects on:

NPP, Gen IV reactors, *transmutation*

Fusion (magnetic and inertial)

Material Research has to be complementary using:

New neutron sources and their capabilities

Including different investigation technologies
The IAEA takes action on urgent issues related to materials for energy.

The new programme and budget 2010/11 includes many new activities on materials research, which need support from the Physics Section, the Fuel Section, and the Research Reactor Cross-coordination.
Take care of materials!

In 1943 the T2 tanker Schenectady broke in two due to brittle metal and bad welding. Finally sold to Trieste. (from Wikipedia).