American Nuclear Society
Fusion Energy Division
June 2008 Newsletter

Letter from the Chairman, Roger E. Stoller, Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, TN.

In this my second (and final) note as FED Chairman, I hope to provide a brief update on Division and other fusion relevant business over the last six months. Additional details on Division elections and finances will be provided in articles by Jeff Latkowski and Lee Cadwallader below.

First, I would like to thank the outgoing members of the FED Executive Committee for their service to the Division. They are: Neil Morley (UCLA), Paul Wilson (UW-Madison), and Minami Yoda (GT).

Two specific action items from the November 2007 ANS meeting are the ANS Policy Statement on Fusion Energy (PS-12) and the new standardized bylaws for ANS professional divisions. PS-12 was revised and approved by letter ballot of the FED Executive Committee and then submitted to the ANS Public Policy Committee for their approval. A couple of modest wording changes requested by the PPC for clarification were made. The final version will be submitted to the ANS Board of Directors for approval in June. In November of last year, I received a copy of FED bylaws in a newly standardized format adopted by ANS. Discussion of FED-specific items in the standard format apparently preceded my tenure as Chairman. The primary thing I was asked to do was verify that the Division objectives had been accurately transferred to the new format. At the June ANS meeting, I will be delivering a presentation to the ANS Board of Directors on the status of the FED.

18th TOFE

The 18th Topical Meeting on the Technology of Fusion Energy will be held 28 September to 2 October, 2008, at the Stanford Court Hotel in San Francisco, CA. More information on TOFE is provided below by Latkowski/Meier (the General and Technical Program Chairmen for the meeting) and the meeting website: http://www.18th-tofe.com.

News from FESAC

I attended the 19-20 February meeting of the DOE Fusion Energy Sciences Advisory Committee (FESAC) as an ex-officio member. Raymond Fonck, Associate Director for the DOE Office of Fusion Energy Sciences (OFES), provided an update of the current budget status for the Office's programs, and Ray Orbach, the Undersecretary for Science discussed his view of the future for OFES. Congressional budget action featured prominently in both their presentations.

In spite of initial optimism, budgets for the Office of Science have not seen significant growth. The decision to withhold funding for the FY08 US contribution to ITER was particularly troubling and surprising in the face of what was perceived as bi-partisan support. The "rolloff" from the US ITER spending profile had been expected to support new domestic facilities and capabilities to maintain US leadership in future years. This scenario may appear too optimistic at this point, although DOE and OFES remain strongly supportive of fusion. Based on the expected FY09 budget, OFES expects to initiate the Fusion Simulation Project, enhance the high energy density laboratory physics (HEDLP) program, and initiate a strategic planning exercise. As part of this last item, a new charge was issued to the FESAC to evaluate the scientific issues and opportunities associated with alternate fusion confinement concepts, specifically stellarators, spherical tori, reversed-field pinches, and compact tori (Field Reversed Configuration and spheromak). In addition, a subsequent charge letter was sent to FESAC regarding HEDLP. FESAC was charged to work with the HEDLP community to provide information to the Department that will form part of the basis for the development of a scientific roadmap for the HEDLP program during the coming decade. An HEDLP program that is jointly funded by the Office of Science and the National Nuclear Security Administration is envisioned. Additional details on FESAC activities, including charge letters and presentations can be found at http://www.science.doe.gov/ofes/fesac.shtml.

ITER Status

Although ITER is an active international project, the budgetary issues mentioned above have impacted the US participation in the current fiscal year. In addition, the US has decided to minimize its financial commitment to participation in the development of ITER test blanket modules, while maintaining the option for future increased participation once the financial situation *vis a vis* ITER is clear. ITER itself is in the process of developing a new baseline design and budget. Negotiations are underway on the difficult issue of developing an international program management structure that is agreeable to all parties. Additional information on ITER is contained in this issue in an article by Ned Sauthoff, project manager of the US Contributions to ITER Project.

List of Officers and Executive Committee Members, Jeff Latkowski, Lawrence Livermore National Laboratory, Livermore, CA.

The FED election was held in the spring of 2008, with voting being closed by April 8. Our FED Chair, Dr. Roger Stoller (ORNL), completes his term of office this month and Prof. Farrokh Najmabadi (UCSD) becomes FED Chair. Dr. Lance Snead was elected to the position of Vice-Chair/Chair-Elect. Lee Cadwallader (INL) continues his term as secretary/treasurer. The persons elected to three-year terms as FED committee seats are Arthur Nobile, Jr. (LANL), Wayne Reiersen (ORNL), and Alice Ying (UCLA). We thank the outgoing committee members Neil Morley (UCLA), Paul Wilson (UW-Madison), and Minami Yoda (Georgia Tech) for their service and look forward to working with the newly elected members.

FED Officers:

Farrokh Najmabadi (UCSD)	Chair (08-09) najmabadi@fusion.ucsd.edu
Lance Snead (ORNL)	Vice Chair/Chair-elect (08-09) sneadll@ornl.gov
Lee Cadwallader (INL)	Secretary/Treasurer (07-09) lee.cadwallader@inl.gov

Executive Committee:

Mark Anderson (UW)	(06-09)	manderson@engr.wisc.edu
Pattrick Calderoni (INL)	(07-10)	Pattrick.Calderoni@inl.gov

Brad Nelson (ORNL)	(06-09)	nelsonbe@ornl.gov
Arthur Nobile, Jr. (LANL)	(08-11)	anobile@lanl.gov
Wayne Reiersen (ORNL)	(08-11)	reiersenwt@ornl.gov
Mohamed Sawan (UW)	(07-10)	sawan@engr.wisc.edu
John Sethian (NRL)	(07-10)	sethian@this.nrl.navy.mil
Brian Wirth (UCB)	(06-09)	bdwirth@nuc.berkeley.edu
Alice Ying (UCLA)	(08-11)	ying@fusion.ucla.edu

Past Chair:

Roger Stoller (ORNL)	(08-09)	stollerre@ornl.gov

FED Standing Committee Chairs:
Nominating: Roger Stoller (ORNL)
Honors and Awards: Neil Morley (UCLA) - Chair
Program Committee: Jake Blanchard (UW) - Chair

FED Representatives on National Committees:
ANS Publications: Ken Schultz (GA)
ANS Public Policy: Said Abdel-Khalik (Georgia Tech)

Editors:
Newsletter: Laila El-Guebaly (UW), Dennis Bruggink (UW)
Fusion Science and Technology Journal: Nermin Uckan (ORNL)

Liaisons to other organizations and ANS divisions:
ANS Board: Kathryn McCarthy (INL)
MS&T: Ken Schultz (GA)
IEEE: George Miley (UIUC)
RPS: Ham Hunter (ORNL)

Webmasters:
Mark Tillack (UCSD) – FED website
Dennis Bruggink (UW) – UW website

Treasurer's Report, Lee Cadwallader, Idaho National Laboratory, Idaho Falls, ID.

As of December 31, 2007, the Fusion Energy Division had a balance of $18,236. Expenses in 2007 included $350 to support a teacher education workshop at the 2007 ANS summer meeting (which was credited by ANS headquarters as a Landis Challenge II contribution), $150 in general nuclear student travel support to ANS national meetings, a $500 cash prize for the Best Student paper from the 17th TOFE held in November 2006, a $500 contribution to the Nuclear Engineering Education for the Disadvantaged (NEED) fund, a $500 contribution to the 2008 ANS Student Conference that was held at TAMU in March 2008, and $512 in telephone costs for conference calls during division meetings. Income in 2007 included $801 from the typical $1/division member allocation from ANS headquarters.

As of March 31, 2008, the division balance is $19,846. Projected expenses in 2008 include $3,000 in student travel assistance to the 18th TOFE, $500 contribution to the upcoming 2009 ANS Student Conference, $150 in general nuclear student support for travel to ANS national meetings, $600 for telephone charges at two division meetings held during national ANS meetings, $500 contribution to the NEED fund, and up to $1,500 in cash prizes for up to three professional awards to be conferred at the 18th TOFE. Income in 2008 includes an increased member allocation from ANS HQ to $2/division member, for a total of $1,610. Income in the form of division profits from the 18th TOFE, to be held at the end of September 2008, will not be realized until 2009.

18th ANS Topical Meeting on the Technology of Fusion Energy, Jeff Latkowski and Wayne Meier, Lawrence Livermore National Laboratory, Livermore, CA.

The 18th Technology of Fusion Energy (TOFE) meeting will be held in San Francisco September 28-October 2, 2008. By all indications, we are headed for a very interesting and successful meeting. Abstract submissions were due April 1, and we received over 280 with more than half coming from international colleagues. As expected, many contributions are from those working on various aspects of ITER. Like past TOFE meetings, however, a broad range of other fusion related research will be covered, with significant contributions in the areas of first wall, blanket, and shielding; materials development and testing; next steps and power plants; safety; IFE related talks; divertor and high heat flux components; and alternate concepts. We have notified the authors and are currently working to complete the preliminary program. Highlights of the program will include talks by Norbert Holtkamp on ITER and Ed Moses on the National Ignition Facility. On Wednesday afternoon, Oct. 1, we will have a tour of NIF followed by the conference banquet at Wente Cellars winery in Livermore. Due to the larger than expected turn-out, attendees are encouraged to make their hotel reservations early.

Call for Nominations, ANS-FED Awards, Neil B. Morley, University of California-Los Angeles, Los Angeles, CA.

The Honors and Awards Committee of FED/ANS is seeking nominations for Fusion Energy Division of ANS Awards:

1) **Outstanding Achievement Awards:** This award is for recognition of a continued history of exemplary individual achievement requiring professional excellence and leadership of a high caliber in the fusion science and engineering area.

2) **Technical Accomplishment Award:** This award is for recognition of a specific exemplary individual technical accomplishment requiring

professional excellence and leadership of a high caliber in the fusion science and engineering area.

Detailed descriptions of the awards and past recipients can be found at http://fed.ans.org/awards.shtml. Note that the nominees should be ANS members.

The deadline for nominations is July 1, 2008 for the awards to be presented at the 18th ANS Topical Meeting on the Technology of Fusion Energy, to be held 28 September to 2 October 2008 in San Francisco, CA. Nominations from the 2006 ANS TOFE in Albuquerque will automatically be considered.

Nominations can be made by individuals and submitted anytime to the FED Honors and Awards Committee Chair (N. Morley). The nomination package should include:

a) Nominee's CV
b) A description of exemplary achievements
c) Support letters (and/or co-signature on the nomination form).

Details are available at http://fed.ans.org/awards.shtml.

Please send nominations to:

Neil B. Morley
43-133 Engineering IV
Mechanical and Aerospace Engineering, UCLA
Los Angeles, CA 90095-1597
morley@fusion.ucla.edu

Electronic submission via email is encouraged.

Fusion Award Recipients, Laila El-Guebaly, University of Wisconsin-Madison, Madison, WI.

Fusion awards have been established to formally recognize outstanding contributions to fusion development made by members of the fusion community. The following awards (listed in alphabetical order) were available to the newsletter editor at the time of publishing this newsletter. We encourage all members of the fusion community to submit information on future honorees to the editor (elguebaly@engr.wisc.edu) to be included in future issues. The ANS-FED officers and executive committee members congratulate the honored recipients of the 2007/2008 fusion awards on this well-deserved recognition and our kudos to all of them.

EPS Award

The Board of the Plasma Physics Division of the European Physical Society announced the award of the 2008 Hannes Alfvén Prize to: Prof. **Liu Chen**, Professor of Physics and Astronomy in the School of Physical Sciences, University of California at Irvine, USA. The award is made "for his many seminal works on Alfvén wave physics in laboratory and space plasmas and his continuing contribution of new ideas, including: the theories of geomagnetic pulsations, Alfvén wave heating, fishbone oscillations, the formulation of the nonlinear gyrokinetic equations and fundamental contributions to drift wave instabilities and turbulence." Prof. **Chen** will receive the award and present a lecture during the opening session of the 35th EPS conference on Plasma Physics, to be held June 9-13, 2008 at Hersonissos, Crete.

Hungarian Nuclear Society Award

At its annual meeting November 29, 2007 in Budapest, the Hungarian Nuclear Society awarded the Karoly Simony Memorial Plaque and Prize to Prof. **Miklos Porkolab,** director of the Plasma Science and Fusion Center (PSFC) at the Massachusetts Institute of Technology (MIT). The award was given in recognition of "outstanding achievements and contributions to plasma physics and fusion research." This is a newly established award and Prof. **Porkolab** is the first recipient.

Nuclear Fusion Award

The International Atomic Energy Agency has awarded, for the second time, a prize called "Nuclear Fusion award" to honor exceptional work published in the journal Nuclear Fusion. The winner of the 2007 Nuclear Fusion award is **C. Angioni (**Max-Planck-Institut für Plasmaphysik, IPP-EURATOM Association) for the paper "Density Response to Central Electron Heating: Theoretical Investigations and Experimental Observations in ASDEX Upgrade" (Nuclear Fusion 44 (8) pp. 827-845). Each year, ten papers are short-listed for the Nuclear Fusion award. These are papers of the highest scientific standard, published in the journal volume from two years previous to the award year. Nominations are based on citation record and recommendation by the Board of Editors. The Board votes by secret ballot to determine which of these papers has made the largest scientific impact. The winning paper is freely available to read online until July 31, 2008: http://www.iop.org/EJ/abstract/0029-5515/44/8/003.

News from Fusion Science and Technology (FS&T) Journal, Nermin A. Uckan, FS&T Editor, Oak Ridge National Laboratory, Oak Ridge, TN.

During the past twelve months (May 1, 2007 – April 30, 2008), FS&T received 262 manuscripts for FS&T regular issues, plus 47 camera-ready papers for FS&T Transactions [Transactions are FS&T supplements and not fully refereed in the same sense as the journal issues.]

During the first half of 2008, FS&T published two long-awaited special issues: MFE Diagnostics and Joint European Torus (JET).

- FS&T February 2008 issue was devoted to high-temperature plasma diagnostics on magnetic fusion energy research. Alan Costley (ITER Organization) and David Johnson (PPPL) were the guest editors for the issue. Writing in the preface, Alan Costley notes, "This is the fruit of the labor of many researchers over a period of two and a half years. It is the most comprehensive collection of articles ever published on plasma diagnostics. The articles were written by established experts, all practitioners in the field, and through them this edition is connected directly to the cutting edge of research in plasma diagnostics."

– As part of the tokamak special issue series, FS&T May 2008 issue was devoted to JET. This issue provides an overview of the physics research program carried out at JET since the beginning of its exploitation in 1983, covering the periods of JET operation under JET Joint Undertaking and EFDA-JET phases. Claude Gormezano (former member of JET Joint Undertaking) is the guest editor for the issue and the preface is written by Francesco Romanelli (EFDA-JET Director). FS&T has been working with the international tokamak groups to contribute to a series of special issues to recognize and highlight the science and technology contributions to ITER. The JET issue is the eighth in this series. The other tokamak issues published before include Alcator C-Mod, ASDEX-U, DIII-D, FTU, JFT-2M, JT60-U, and TEXTOR.

These two issues will serve as a comprehensive resource for new and experienced fusion researchers and are expected to be of long-lasting value to the fusion community.

The following dedicated issues have been published or scheduled for 2008:

- EC Wave Physics, Technology and Applications (Part 2) – FS&T Jan08 (24 papers)
- MFE Diagnostics (EU, JA, RF, US) – FS&T Feb08 (13 papers)
- 8th Carolus Magnus Summer School – FS&T Transactions Feb08 (47 papers)
- JET Tokamak (EU) – FS&T May08 (12 papers)
- 8th Tritium Science & Technology 2007 – FS&T July/Aug08 (140 papers)
- ARIES Compact Stellarator Study – FS&T Oct08 (12 papers).

The following issues are under consideration/planning for 2009 and beyond:

- ECH/ECE – FS&T regular issue (papers due mid-2008)
- Tore Supra Tokamak – FS&T regular issue (papers due late 2008)
- 18th TOFE08 – FS&T regular issue/Proceedings (papers due early 2009)
- IFE Target Fabrication – FS&T regular issue (papers due early 2009)
- KSTAR (Korea) – FS&T regular issue (under discussion/in planning)
- W7-X (Germany) – FS&T regular issue (under discussion/in planning)
- JT-60SA (JA-EU Broader Approach) – FS&T regular issue (in planning/on hold)
- DEMO Studies (EU, JA) – FS&T regular issue (in planning/on hold)
- Test Blankets (EU, JA, RF, US) – FS&T regular issue (under discussion/on hold)

FS&T has been offering color print for special issues for the past several years and recently started offering a color option to all FS&T issues. Also, all (regular/special) FS&T issues are now color online.

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Please send your comments on FS&T contents and coverage as well as suggestions for potential future topical areas that are timely and of interest to fst@ans.org.

ONGOING FUSION RESEARCH:

Materials Challenges in the US Fusion Program, Richard Kurtz, Pacific Northwest National Laboratory, Richland, WA.

Fusion reactor materials will be required to function in an extraordinarily demanding environment that includes various combinations of high temperatures, chemical interactions, time-dependent thermal and mechanical loads, and intense neutron fluxes. This environment produces atomic displacement damage ultimately equivalent to displacing every atom in the material up to about 200 times during its expected service life, as well as changes in chemical composition by transmutation reactions, including the introduction of damaging concentrations of reactive and insoluble gases. Radiation damage degrades materials properties through processes that include hardening, embrittlement, phase instabilities, segregation, precipitation, irradiation creep, volumetric swelling, He embrittlement, and radiation-induced conductivity. A long-standing feasibility issue is the development of structural materials that can tolerate the intense fusion neutron environment.

The US Fusion Materials Program is engaged in a science-based effort to develop the scientific understanding of the damage mechanisms controlling performance-limiting phenomena of materials for fusion power systems. The program employs the full suite of experimental and computational tools to explore life limiting materials degradation phenomena in the fusion neutron environment. Our overarching goal is to develop experimentally validated, physics-based, predictive models of complex material behavior that can be used to improve existing materials or to design better ones.

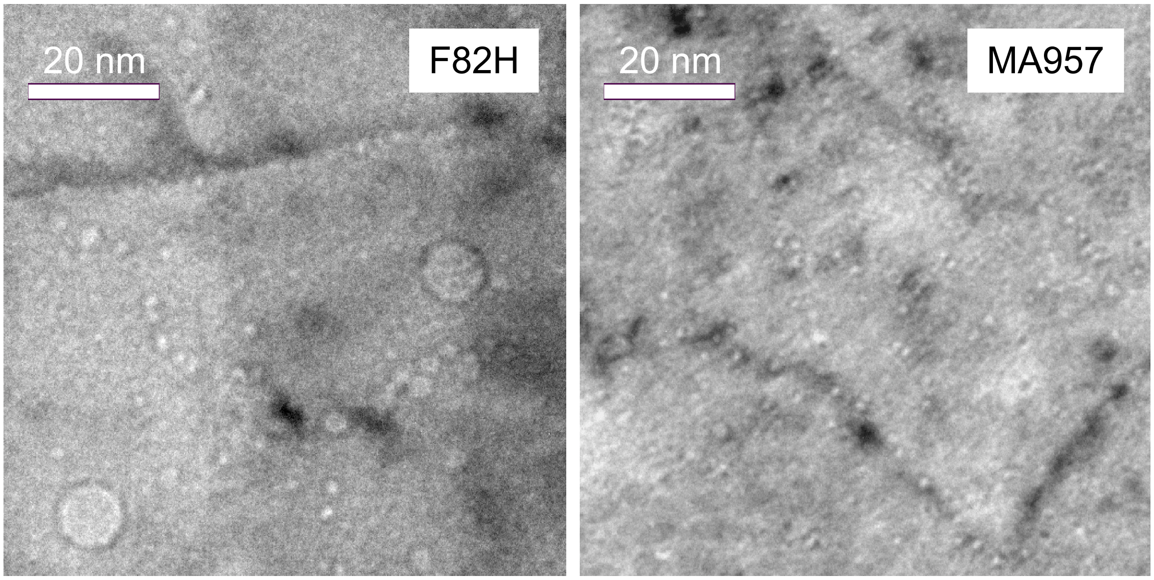
To a large extent, structural materials in the fusion blanket region most strongly impact the technical feasibility, economic attractiveness and environmental acceptability of fusion power systems. Therefore research on structural materials is the main focus of the US program. To produce an economically attractive fusion reactor, while simultaneously achieving safety and environmental acceptability goals, the program is developing low or reduced activation materials so that when they are removed from service they will not require long-term deep geological disposal and may be recyclable and/or clearable. Only a limited number of materials possess the physical, mechanical, and low-activation characteristics required: reduced activation steels, vanadium alloys, and SiC/SiC composites. In the recent past, the fusion materials research emphasis was on defect production and migration mechanisms, low-to-intermediate temperature deformation and fracture behavior of these materials, as well as the fundamental effects of irradiation on the electrical and thermal properties of SiC. In the future, the program focus will be on investigating the synergistic effects of He, tritium and neutron irradiation on the properties of bonded materials, as well as developing a mechanistic understanding of damage evolution at high-temperatures due to creep, fatigue and creep-fatigue interaction. In this article highlights of recent and ongoing experimental and computational efforts to characterize and understand the effects of He on microstructural evolution in ferritic/martensitic steels, and an important revolutionary class of materials, nanostructured ferritic alloys (NFA), is presented.

Novel Experiments to Characterize He Transport and Fate

A unique aspect of the DT fusion environment is the substantial production of gaseous transmutation products, particularly He. Helium is essentially insoluble in materials, and this insolubility is ultimately the reason for its detrimental effects on mechanical properties. Low solubility is equivalent to a very strong tendency for He to precipitate into clusters or bubbles, and significant accumulation of He can have major consequences for the integrity of fusion structural materials. At high temperatures the effects of He can result in significant degradation of the tensile, creep, and fatigue properties. These effects are caused by He bubbles at grain boundaries that lead to initiation of cracks and premature failure under stress. At intermediate temperatures, He affects the incubation time for onset of swelling due to enhancement in the stability of cavity nuclei. At low temperatures, He may also influence irradiation hardening and fatigue life by interfering with plastic deformation processes.

Because He can substantially affect properties, it is essential to carefully quantify its effects in order to develop a safe and reliable fusion power system. Currently, it is difficult to properly explore the effects of He under prototypic conditions due to a lack of appropriate neutron irradiation sources. To design, develop, and validate He resistant microstructures, appropriate experimental methods are needed to introduce He into a material at fusion relevant ratios of He atoms to displacements per atom (dpa). A novel technique [1,2] has been developed to inject He into a substrate while under neutron irradiation. A Ni bearing coating on any substrate causes production of energetic He atoms due to a two-step thermal neutron reaction sequence under mixed spectrum neutron irradiation conditions, and the He is injected into the substrate. With this approach it is possible to explore the effects of He on microstructural development by implanting He at almost any desired He-to-dpa ratio to a uniform depth of a few microns. It is not possible to obtain bulk mechanical property information by this technique so it does not eliminate the need for a fusion-like neutron source. Figure 1 gives two examples of microstructures that are obtained by this method [3]. Figure 1-a shows a transmission electron microscope image of F82H, a reduced activation ferritic/martensitic steel, and Fig. 1-b displays a similar image for MA957, an NFA. Both specimens were irradiated at 500°C in the High Flux Isotope Reactor (HFIR) to about 9 dpa and 380 appm He. Preliminary analysis of these images indicates that the bubble density in F82H ($\sim 1 \times 10^{23}$ /m^3) is about one third that in MA957 ($\sim 3 \times 10^{23}/m^3$), while the mean bubble radius is larger in F82H (~2 nm) than in MA957 (≤1 nm). There is also evidence of polyhedral void formation in the F82H, but not in MA957.

Helium is prevented from forming large bubbles in MA957 because this material contains $\sim 10^{24}$ /m^3 of ~5 nm diameter Y-Ti-O particles. The high number density of these particles provides many sites to benignly trap He and substantially reduce bubble formation at grain boundaries. These particles, in conjunction with a high dislocation density, also impart resistance to radiation damage in these alloys. A significant additional advantage of NFAs is that they can potentially operate at ~800°C, which is above the displacement damage-swelling regime [4]. At this temperature the primary irradiation damage concern is creep embrittlement due to accumulation of He on grain boundaries. These studies are just beginning and will emphasize quantitative characterization of the irradiated microstructures, including additional alloys and irradiation conditions.



(a) (b)

Figure 1. Bubble and cavity microstructures for F82H (a) and MA957 (b) neutron irradiated in the HFIR at 500°C to about 9 dpa and 380 appm He. Note the mean bubble size is larger and number density smaller in F82H compared to MA957.

Computational Modeling of He Effects

A comprehensive effort is underway to develop a multiscale model of He transport and fate in ferritic/martensitic alloys [5]. The model will be used to predict the performance of irradiated reduced activation ferritic/martensitic steels and NFAs. Atomistic simulations are being performed to determine the binding and migration of He at defects such as dislocations, grain boundaries, and particle-matrix interfaces [6]. The goal is to identify generic properties of these defects that control the binding and migration of He. A variety of atomic-level computational tools are employed to investigate the effects of dislocation character, grain boundary structure, and particle/matrix elastic properties on the binding and migration of He in and near these defects. The information obtained from these simulations is incorporated in higher scale spatial and temporal models to describe the effect of He on microstructural evolution.

A significant result from the atomic-level simulations is that binding of He to defects correlates strongly with defect excess volume. Thus, edge dislocations are more effective traps for He than screw dislocations because of the much larger excess volume available in an edge dislocation compared with a screw dislocation. Helium trapping at grain boundaries is somewhat greater to somewhat less than for dislocations depending on the type of grain boundary. Coherent, positive misfit, nanoparticles also efficiently trap He, but semi-coherent particles may be more efficient traps because of the excess volume associated with the array of misfit dislocations needed to accommodate the lattice parameter mismatch between the particle and matrix.

Summary

The US Fusion Materials Program is engaged in a long-term, science-based effort to develop structural materials for fusion power system applications. Significant challenges are faced because of the extremely demanding conditions under which these materials must safely perform their function. The principal focus of the program is on determining the underlying physical mechanisms controlling the performance of materials in the harsh fusion environment. Illustrated here is some of the exciting recent progress being made by implementation of a novel experimental technique coupled with state-of-the-art computational modeling to explore the effects of He on microstructural evolution in reduced activation ferritic/martensitic steels, and a new class of material, NFA, that offers the potential to operate at considerably higher temperatures and to be much more radiation tolerant.

References:

[1] T. Yamamoto, G. R. Odette, P. Miao, D.T. Hoelzer, J. Bentley, "The Transport and Fate of Helium in Nanostructured Ferritic Alloys at Fusion Relevant He/dpa Ratios and dpa Rates," J. Nucl. Mater. **367-370**, 399 (2007).

[2] R.J. Kurtz, G.R. Odette, T. Yamamoto, D.S. Gelles, P. Miao, B.M. Oliver, "The Transport and Fate of Helium in Martensitic Steels at Fusion Relevant He/dpa Ratios and dpa Rates," J. Nucl. Mater. **367-370**, 417 (2007).

[3] G.R. Odette, P. Miao, D.J. Edwards, T. Yamamoto, H. Tanagawa, R.J. Kurtz, "A Comparison of Cavity Formation in Neutron Irradiated Nanostructured Ferritic Alloys and Tempered Martensitic Steels at High He/dpa Ratio," Trans. American Nuclear Society **98** (2008).

[4] G.R. Odette, M.J. Alinger, B.D. Wirth, "Recent Developments in Irradiation Resistant Steels," Annual Reviews of Materials Research (to be published).

[5] B.D. Wirth, G.R. Odette, J. Marian, L. Ventelon, J.A. Young-Vandersall, L.A. Zepeda-Ruiz, "Multiscale Modeling of Radiation Damage in Fe-Based Alloys in the Fusion Environment," J. Nucl. Mater. **329-333**, 103 (2004).

[6] R.J. Kurtz, H.L. Heinisch, F. Gao, "Modeling of He – Defect Interactions in Ferritic Alloys for Fusion," J. Nucl. Mater. in press.

INTERNATIONAL ACTIVITIES:

ITER Update, Ned Sauthoff, US ITER Project Office, Oak Ridge National Laboratory, Oak Ridge, TN.

Since the last report in the December 2007 Newsletter, the worldwide ITER team as well as the fusion community as a whole has focused on a set of issues that emerged from the Design Review that was concluded in September 2007 and on the recommendations of the ITER Science and Technology Advisory Committee (STAC). These issues were judged to be real, to have significant consequences on ITER performance, and to have scientific and technological solutions that should be considered for incorporation into the ITER design.

The US team has played a strong role in these considerations of the options for addressing these issues and in performing design actions that could improve ITER's performance and its capabilities as a scientific and technological research instrument. Many groups dedicated effort to research on the scientific bases and to the development of design concepts. Members the US delegation on the STAC, the participants in the Burning Plasma Organization, the Virtual Laboratory for Technology, contributors to the International Tokamak Physics Activity, DOE program managers, and many others played essential roles.

Among the issues were:

- Vertical Stability, Plasma Shape Control, and Flux Swing
- Edge Localized Mode (ELM) control
- Vacuum Vessel/Blanket Loading Conditions
- Remote Handling
- Blanket Manifold/Remote Handling
- First Wall Material
- Capacity of 17 MA Discharge
- Magnet Cold Coil Test
- Test Blanket Modules (TBM) Strategy
- Hot Cell Design
- Heating and Current Drive Strategy (H&CD), Diagnostics, and Research Plan.

In late-March/early-April, the ITER Organization and the Domestic Agencies met to review the results of the intense studies and to decide on the recommendations and directions for near-term work. The STAC met in April and May to review the material and to make a recommendation to the ITER Council in September. Also advising the Council will be the Management Advisory Committee, which will address cost, schedule, and management plans and issues.

Following action by the Council in June, outcomes of these efforts will be available to the worldwide fusion community and the governments.

Thanks to all of you who continue to contribute so effectively.

EVEDA, the New Phase of the IFMIF Project in the Broader Approach,

Pascal Garin, Commissariat à l'énergie atomique (CEA), France.

The Broader Approach, an agreement signed between the European Union and Japan on February 5, 2007 (but open to other ITER Parties), aims at enhancing the fusion program by proposing, in complement to ITER, several projects to speed up the design of DEMO. Because of its experimental nature and its pulsed operation, ITER will not produce a significant amount of neutrons compared to what DEMO's structural materials will face (3 dpa during its entire life, compared to about 30 dpa per year in a power plant). The International Fusion Materials Irradiation Facility (IFMIF) proposes irradiation and characterization of materials with a production of neutrons of the same order of magnitude as DEMO. After several conceptual phases (the last one being conducted under the IEA's auspices [1]), the Engineering Validation and Engineering Design Activities (EVEDA) of IFMIF will lead to the delivery in 2013 of the detailed design file of the facility, enabling its construction.

The organization of the project is the following: a Project Team, located at Rokkasho, Japan, coordinates the work carried out in several Institutes and Universities in Japan and in Europe. It is assisted by a Project Committee and reports to the Steering Committee of the Broader Approach.

Principles of IFMIF

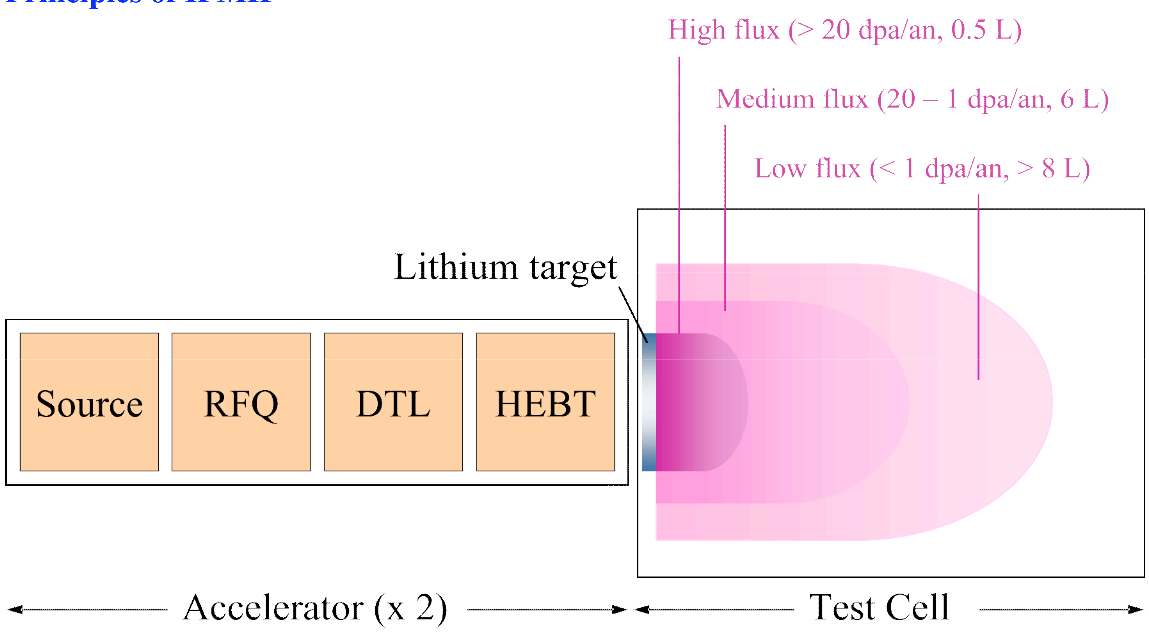


Figure 1. Principles of IFMIF.

Two deuteron accelerators, each carrying a current of 125 mA, bring the energy of the particles to 40 MeV. The beams, which have at the output of the accelerator a rectangular footprint of 20 x 5 cm^2, interact with a curtain of 2.5 cm thick liquid lithium flowing at about 15 m/s. The interaction between the deuterons and lithium generates a high flux of neutrons of typically 10^{18} n/m^2s with a broad energy peaked at 14 MeV, which irradiate three main volumes in the Test Cell (refer to Fig. 1):

- High Flux Test Module (> 20 dpa per year);
- Medium Flux Test Volume, which hosts 3 elements:
  - Creep Fatigue Module
  - Tritium Release Module
  - Liquid Breeder Validation Module

- Vertical Irradiation Tubes, with a lower neutron flux (< 1 dpa/year).

Post Irradiation Experiment cells complete the facility, as well as Remote Handling tools, enabling the characterization and replacement of the samples inside the facility.

IFMIF/EVEDA Project Plan

The main objective of EVEDA, as mentioned above, is to deliver the detailed design file of IFMIF in a 6 year framework. The work is broken down into four main areas, in addition to the management and QA general activities:

- The Test Facilities
- The Lithium Target Facility
- The Accelerator Facility
- The Conventional Facilities

Because of the advanced nature of the three first systems, their validation through prototypes is foreseen during EVEDA.

A. Test Facilities

The reference design for the High Flux Test Module consists of an arrangement of 12 vertical capsules, containing a total of about 1000 samples. The temperature monitoring is ensured by a proper mix of helium cooling and heating by means of wire brazed in a groove of the capsule. The irradiation of a full rig will be made in a European reactor, in relevant conditions comparable to the actual ones. The hydrodynamics of the helium flow will be fully characterized by means of a specific loop built at the Forschungszentrum Karlsruhe.

With respect to the Medium Flux Test Modules, the characterization of the Creep Fatigue Module is also foreseen, in particular to check the reliability of the actuators, submitted to a rather high flux of neutrons.

B. Lithium Target Facility

This challenging and very innovative system raises the following issues in particular:

- Purification (down to a few ppm) of the lithium, pollutants as hydrogen, oxygen and nitrogen leading to a very high erosion and corrosion rate
- Hydraulic stability of the flow: its thickness should be kept within ±1 mm, to avoid any risk of hitting the backplate by the deuteron beam
- Easy exchange of the backplate, the latter suffering the highest neutron flux, and thus its exchange must occur probably every year.

These three main points, plus safety handling, etc. will be tackled in an experimental loop built at Oarai, Japan with the contribution of ENEA, Italy. This loop will have all characteristics of the IFMIF's ones, except the width of the lithium flow, reduced to 1/3.

C. Accelerator Facility

The acceleration of a 125 mA deuteron current in continuous wave (CW) has never been achieved. The validation activities of IFMIF thus foresee the construction of the full low energy part (up to 9 MeV) of the first of the two accelerators and its tests in a dedicated building at Rokkasho, Japan. More particularly:

- The injector (electron cyclotron resonance source with 140 mA at 100 keV)
- The RadioFrequency Quadrupole, bunching and accelerating the beam to 5 MeV
- The first section of the Drift Tube Linac, up to 9 MeV (a half wave resonator superconducting technology is contemplated)
- The full RF system (amplifier units of 60, 105 or 220 kW at 175 MHz)
- All associated instrumentation, beam dump, etc. will be designed, built, and tested during the project.

Conclusion

After the necessary initial phase of organization of the project, which was officially launched in June 2007, several results have been already achieved:

- Welding of austenitic and martensitic steels has been demonstrated for the lithium backplate
- Purification of hydrogen by means of yttrium trap and nitrogen (iron/titanium hot trap) seems achievable, thanks to the experimental work conducted in Kyushu and Tokyo Universities
- Erosion and corrosion of austenitic and martensitic steels show significant differences (ENEA Lifus 3 loop; a high Li purity is also clearly mandatory)
- The design of the accelerator systems (focused on the prototype) did not raise any showstopper: thermal loads can be spread, with a reasonable electric field
- A first capsule of the High Flux Test Module has been manufactured.

The ordering of the major systems and infrastructure will start this year (accelerator main components and the building at Rokkasho, the HELOKA loop in Karlsruhe, the Lithium Test Loop in Oarai, etc.).

Reference

[1] Comprehensive Design Report, an Activity of the International Energy Agency (IEA) Implementing Agreement for a Program of Research and Development on Fusion Materials, January 2004.

Calendar of Upcoming Conferences on Fusion Technology

2008:

35th EPS Conference on Plasma Physics
June 9-13, 2008, Hersonissos (Crete), Greece
http://eps2008.iesl.forth.gr/

ANS Annual Meeting
June 8-12, 2008, Anaheim, CA, U.S.A.
http://www.ans.org/

Innovative Confinement Concepts Workshop (ICC-2008)
June 24-27, 2008, Reno, Nevada, U.S.A.
http://www.iccworkshops.org/icc2008/

17th International Symposium on Heavy Ion Inertial Fusion – HIF2008
August 3-8, 2008, Tokyo, Japan
http://www.nr.titech.ac.jp/hif2008/

25th Symposium on Fusion Technology - SOFT-2008
September 15-19 2008, Rostock, Germany
http://soft2008.ipp.mpg.de

ANS 18th Topical Meeting on the Technology of Fusion Energy – TOFE-2008
September 28-October 2, 2008, San Francisco, CA, U.S.A.
http://www.18th-tofe.com/

22nd IAEA Fusion Energy Conference - 50th Anniversary of Controlled Nuclear Fusion Research
October 13-18, 2008, Geneva, Switzerland
http://www-pub.iaea.org/MTCD/Meetings/Announcements.asp?ConfID=165

2008 Joint Symposium on Molten Salts
October 19-23, 2008, Kobe, Japan
http://msc.electrochem.jp/ms8/

ANS Winter Meeting
November 9-13, 2008, Reno, NV, U.S.A.
http://www.ans.org/

50th American Physical Society - Division of Plasma Physics (APS-DPP) meeting
November 17-21, 2008, Dallas, TX, U.S.A.
http://www.apsdpp.org

Fusion Power Associates Annual Meeting
December 3-4, 2008, Livermore, CA, U.S.A.
http://fusionpower.org/

18th International Toki Conference (ITC18) on Development of Physics and Technology of Stellarators/Heliotrons en route to DEMO
December 9-12, 2008, Toki City, Japan

2009:

8th IEA International Workshop on SiC/SiC Ceramic Composites for Fusion Applications
January 18-23, 2009, Daytona Beach, FL, U.S.A.
http://cer.ucsd.edu/icopssofe09/

23rd Symposium on Fusion Engineering – SOFE-2009
May 31 - June 5, 2009, San Diego, CA, U.S.A.
http://cer.ucsd.edu/icopssofe09/

ANS Annual Meeting
June 14-18, 2009, Atlanta, GA, U.S.A.
http://www.ans.org/

6th International Conference on Inertial Fusion Sciences and Applications – IFSA-09
September 6-11, 2009, San Francisco, CA, U.S.A.
https://ifsa09.org/

14th International Conference on Fusion Reactor Materials - ICFRM-14
September 7-12, 2009, Sapporo, Japan
http://www.icfrm-14.com/

51st American Physical Society - Division of Plasma Physics (APS-DPP) meeting
November 2-6, 2009, Atlanta, GA, U.S.A.

ANS Winter Meeting
November 8-12, 2009, Washington, DC, U.S.A.
http://www.ans.org/

9th International Symposium on Fusion Nuclear Technology - ISFNT-9
October 11-16, 2008, Dalian, China
http://www.isfnt-9.org/

2010:

ANS Annual Meeting
June 13-17, 2010, San Diego, CA, U.S.A.
http://www.ans.org/

18th International Symposium on Heavy Ion Inertial Fusion

26th Symposium on Fusion Engineering – SOFT-2010

9th International Conference on Tritium Science and Technology
October 24-29, 2010, Nara, Japan

52nd American Physical Society - Division of Plasma Physics (APS-DPP) meeting
November 8-12, 2010, Chicago, IL, U.S.A.
http://www.apsdpp.org

ANS Winter Meeting

November 14-18, 2010, New Orleans, LA, U.S.A.

http://www.ans.org/

ANS 19th Topical Meeting on the Technology of Fusion Energy – TOFE-2010

November 14-18, 2010, New Orleans, LA, U.S.A.

http://www.ans.org/