Fusion Energy Division
American Nuclear Society
June 2002 Newsletter

Letter from the Chair: James Stubbins, Department of Nuclear, Plasma and Radiological Engineering, University of Illinois at Urbana-Champaign

I would like to begin this letter with congratulations and best wishes to the incoming ANS-FED Officers and Executive Committee Members and in particular, thank Wayne Meier, incoming Chair; René Raffray, incoming Vice Chair /Chair Elect, and Jake Blanchard, incoming Secretary/Treasurer. The coming year will be a busy one for them and we appreciate their willingness to serve our collective interests. Wayne, René, and Jake, I wish you luck.

FESAC Activities

The Fusion Energy Science Advisory Committee (FESAC) met again on February 28 and 29 in Gaithersburg, Maryland. The ANS-FED Chair is an ex-officio member of FESAC. The major topic of discussion was plans for the Summer Study at Snowmass (July 8-19, 2002) to provide a venue for an open discussion to a path forward for a US lead or participation in a "burning plasma experiment" (see http://web.gat.com/snowmass/). This two-week meeting will provide a setting in which the major burning plasma options can be discussed and compared. Following the Summer Study, FESAC will act as a committee to distill the options and recommend a path forward. By the time of the Summer Study, Wayne Meier will be firmly seated in the Chair position, and a participant in the FESAC process.

The FESAC meeting in February was notable for a number of other reasons. There was an extended discussion of the evolving mechanisms for rating federal science (and other) programs to ensure their quality and effectiveness. This performance rating system has been applied selectively to a few select DOE operations with mixed outcomes. The DOE Office of Science, where the Office of Fusion Energy and Science (OFES) functions out of, was part of the recent review process. The marks for the Office of Science were high, but the process will continue to focus new attention on program quality and value. The means to do this in a fair and effective manner is still in question.

Dr. Anne Davies reviewed the status of the OFES, then discussed the budget situation. Following the remarks above, DOE and other government agency budgets will be tied even more closely to performance than in the past. A major theme in Dr. Davies' presentation was the need for OFES supported facilities to perform up to and beyond expectations.

Several of the presentations from the February 2002 FESAC meeting are available online at: http://wwwofe.er.doe.gov/more_html/FESAC/Presentations.2.02.html.

ANS Fusion Energy Division News

This year will be an active one for ANS-FED because it is the year we hold the 15th Topical Meeting on Technology of Fusion Energy (TOFE), which is a major event. The 15th TOFE will be held as an embedded topical at the national ANS winter meeting

November 17-21, 2002 in Washington, D.C. The Program Chair is Roger Stoller, ORNL and Vice Chairs are Akira Kohyama, University of Kyoto, and John Sethian, NRL. The Topical Technical Chair is Lance Snead, ORNL; and Technical Vice-Chairs are Masahiro Seki, JAERI and Dai-Kai Sze, UCSD. Summaries are due no later than June 21, 2002. This year's meeting will be particularly interesting due to its location in an election year for the U.S. Congress. The 15th TOFE will cover all aspects of fusion science and engineering, but will concentrate particularly on similarities and contrasts between magnetic and inertial fusion energies, and on the interfaces between materials performance research and design issues and needs. You can find further detailed information regarding the Symposium at http://www.ans.org/meetings/pdfs/2002/wm2002-15fusion-cfp.pdf.

The ANS-FED will also have a strong showing at the upcoming ANS Annual Meeting in Hollywood, Florida (June 9-13, 2002). The FED will host nine sessions. Some of these sessions on Fusion Space Propulsion are shared with the Aerospace Nuclear Science and Technology Working Group. Others include a number of sessions that are associated with ongoing University Nuclear Engineering Education Research (NEER) programs and other DOE sponsored student work. These sessions, in addition to their technical value, have a large financial impact on the Division since ANS shares meeting revenues with the Divisions based on the Divisions meeting certain goals for number of sessions at each meeting in a given year. This year, the 15th TOFE will be a large event at the Washington winter meeting. We needed to secure sufficient sessions at the Hollywood summer meeting to meet the financial sharing agreements.

The FED will also make a presentation to the ANS Board of Directors at the June meeting. The Board has increased the frequency of Division reports so that most Divisions will report at every third or fourth ANS meeting, about every 18-24 months, rather than the three-year cycle currently used.

As the current year ends, the FED is in solid financial shape and has a steady and slightly growing membership. We remain an effective participant in ANS and continue to have impact both within the Society and on the national level. I'm certain that we will build on these strengths in the coming years.

Officers and Executive Committee List: Kathryn McCarthy, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho

The following Executive Committee members (begin their term after the June 2002 ANS meeting) were elected:

Vice Chair/Chair Elect: A. René Raffray
Sect/Treas: James P. Blanchard
Executive Committee - 3 year terms: Susana Reyes, Lance Snead, and Paul Wilson

Wayne Meier assumes the position of Chair after serving as Vice Chair for the 2001-2002 year.

The Executive Committee as well as committee chair are listed below for your information. Please join me in supporting the new executive committee as well as those serving as committee chairs in the upcoming year!

Chair:	Wayne Meier (LLNL)	(02-03)	meier5@llnl.gov
VC/Chair-Elect:	René Raffray (UCSD)	(02-03)	raffray@fusion.ucsd.edu
Secy/Treas:	James Blanchard (UW)	(02-03)	blanchard@engr.wisc.edu
Exec Committee:	Chris Hamilton (GA)	(00-03)	hamiltonc@gat.com
	Jeffery Latkowski (LLNL)	(00-03)	latkowski@llnl.gov
	Susana Reyes (LLNL)	(02-05)	reyessuarez1@llnl.gov
	Akio Sagara (Japan)	(01-04)	sagara@LHD.nifs.ac.jp
	Lance Snead (ORNL)	(02-05)	sneadll@ornl.gov
	Roger Stoller (ORNL)	(01-04)	stollerre@ornl.gov
	Neill Taylor (England)	(01-04)	neill.taylor@ukaea.org.uk
	Paul Wilson (UW)	(02-05)	wilsonp@engr.wisc.edu
	Dennis Youchison (SNL)	(00-03)	dlyouch@sandia.gov

FED Standing Committee Chairs:		
	Nominating	James Stubbins (UIUC) - Chair
	Honors and Awards	Gerald Kulcinski (UW) - Chair
	Program	Steve Herring (INEEL) - Chair
FED Special Committee Chairs:	Membership	Ken Schultz (GA)
FED Representatives on National Committees:		
	ANS Publications	Ken Schultz (GA)
	ANS Public Policy	Bill Hogan (LLNL)
	ANS Public Information	Julie Van Fleet (Van Fleet & Associates)
Editors:	Newsletter	Laila El-Guebaly (UW) Sue Ann Hubanks (UW)
	Fusion Science and Technology Journal	Nermin Uckan (ORNL)
Liaisons to other ANS divisions and organizations:		
	ANS Board	Gary Gates (Omaha Public Power District)
	AAD	Jim Anderson (DOE)
	MS&T	Ken Schultz (GA)
	IEEE	George Miley (UIUC)
FED web master:		Mark Tillack (UCSD)

Treasurer's Report: René Raffray, University of California, San Diego, CA

As of December 2001, our division has a balance of $10,049. Income in 2001 included:
- $709 from membership
- $2,342 carry forward from 1999
- $7,644 income from 10/2000 Topical

Expenses in 2001 included:
- $250 for setting up room and telephone for FED EC meetings
- $396 for conference call expenses of FED EC meetings

For 2002, our income will include approximately:
- $600 from membership
- $10,049 carry forward from 2001

Anticipated expenses in 2001 include:
- $1,600 for awards (Student, Technical, Achievement)
- $600 for FED EC meeting expenses (conference calls)
- $1,400 for student travel support
- $300 for NEED scholarship.

The projected balance at the end of 2002 is approximately $6,749.

Joint Fusion Energy Division and Aerospace Nuclear Science and Technology Working Group Session at ANS Meeting in Hollywood, Florida: G. Miley, University of Illinois, Urbana, IL

Members are encouraged to attend two special sessions on Fusion Space Propulsion during the June 2002 ANS Meeting. The FED and ANSTWG Executive Committees agreed to sponsor both sessions in order to acquaint ANS members with developments in issues related to fusion propulsion. There is a general agreement that a high specific impulse thruster such as a fusion rocket will be essential for future deep space missions. This would provide a way to reduce the trip times to values that would be acceptable from a radiation and health hazard view point while still allowing for a reasonable cargo weight. The special session will include presentations that cover a wide range of possible approaches to the fusion reactor ranging from a spherical tokamak to magnetized target ICF. Fortunately, we were able to obtain number of outstanding speakers for this special invited session. A tentative list of speakers and their topics follows:

<u>TUESDAY, June 11, 2002, 10 a.m.</u>
- Fusion Space Propulsion: Terry Kammash
- Fusion for Space Propulsion: Francis Thio, George Schmidt, John Cole, John Santarius, Peter Turchi and Richard Siemon
- Integrating Emerging Technologies: Walter Hammond

- Combining Fusion with Other Promising Propulsion Technologies for Missions to Earth-Orbit and Beyond: H. David Froning Jr.

THURSDAY, June 13, 2002, 8:30 a.m.

- Issues Related to Advanced High Specific-Power Fusion Propulsion Units: George Miley
- Nuclear Fusion Space Propulsion System Design: Craig Williams and Charles Orth
- Relative Safety and Environmental Impacts of Fission and Fusion Energy Sources for Space Power and Propulsion Systems: J. Reece Roth
- System Description of the Gas Dynamic Mirror Propulsion System: William Emrich, Jr.
- Approach to Assessing a Space Fusion Transportation System: Scott Carpenter

If there are questions about this session, please contact:
George H. Miley (g-miley@uiuc.edu) or Jim Stubbin (jstubbin@uiuc.edu).

ANS-FED Awards: Call for Nominations: Gerald Kulcinski, Fusion Technology Institute, University of Wisconsin-Madison

This is a repeat announcement for 3 awards to be given at the 15th ANS Fusion Topical Meeting in Washington, DC, November 17-21, 2002. These awards are:

* 2002 Outstanding Technical Accomplishments Award
* 2002 Outstanding Achievement Award
* 2002 FED Student Award for Fusion Science and Engineering

Descriptions of the selection criteria and deadlines for the nominations are posted on the ANS-FED Web site: http://fed.ans.org/ under the Call for Nominations.

Nomination deadline is July 30, 2002.

Please make this announcement known to your colleagues and students. Thank you for your cooperation and I am looking forward to your submissions.

Mail nominations to: Professor Gerald L. Kulcinski
Chair FED Honors and Awards Committee
University of Wisconsin-Madison
Department of Engineering Physics
1500 Engineering Drive, #443
Madison WI 53706-1687

Award for Best Student Paper Presented at 15th Topical: Roger Stoller, Oak Ridge National Laboratory, Oak Ridge, Tennessee

Students are encouraged to submit their work for presentation at the 15th Topical Meeting on the Technology of Fusion Energy. The Technical Program Committee will review all student-authored papers and select the best student paper presented at the meeting. The author of the best student paper will receive a cash award and a plaque signifying their accomplishment.

ONGOING FUSION RESEARCH:

Development of Nanocomposited Ferritic Alloys for High Performance Fusion First Wall and Blanket Structures: G. Robert Odette, University of California Santa Barbara, and David T. Hoelzer, Oak Ridge National Laboratory

"We physicists can dream up and work out all the details of power reactors based on dozens of essentials, but it is only a paper reactor until the metallurgist tells us whether it can be built and from what. Then only can one figure out whether there is any hope that they can provide power."

Dr. Norman Hillberry, former Director of Argonne National Laboratory

Has the quest for fusion energy been offered the magic bullet or do we once again face the truism that "the best thing you will ever hear about a new material is the first thing you hear?" Only time and hard work will tell, but we do know that the feasibility of fusion as a safe, environmentally attractive and economically viable energy source hinges on the development of new high performance structural materials, coupled with their effective exploitation in innovative designs. The materials/structures challenge to the feasibility of fusion power is not simply a matter of an orderly effort to characterize and extend existing material performance limits. Ultimately, entirely new materials systems will be needed. This article will highlight the progress on an emerging class of ferritic alloys that appear to be enormously promising, which have been dubbed nano-composited ferritics (NCFs).

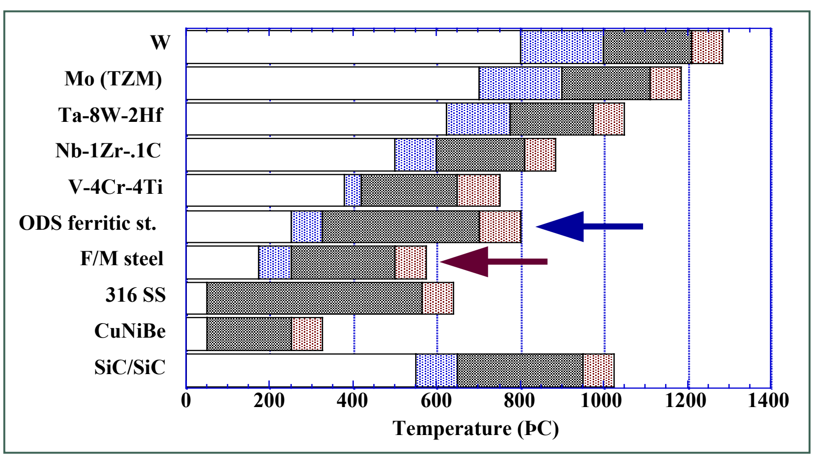
The use of ferritic alloys in innovative first wall and blanket designs is currently being explored by the Advanced Power Extraction (APEX) chamber technology team led by M. Abdou (UCLA). A major objective of the APEX study is to explore the broad technical issues and potential cost advantages of high temperature, high thermal efficiency dry wall concepts. Motivated by this activity, a host of issues related to the use of NCFs and advanced reduced activation martensitic steels (RAMS) were discussed at the highly successful International Energy Agency's Workshop on Advanced Ferritic Steels held in Del Mar, California April 15-16, 2002. The materials-design interface theme of this meeting of the materials and chamber technology communities produced a number of specific recommendations for enhanced international collaborations that offer the promise of accelerated progress in the future. Following a brief background, we will summarize the status of NCF development.

Background

Fusion structures must withstand large time-varying thermal-mechanical stresses, elevated temperatures, corrosive chemicals and intense high-energy neutron radiation fields. These severe environmental conditions lead to the degradation of a host of performance and life limiting mechanical properties, dimensional changes, internal damage and macroscopic cracking. So, developing long-lived and reliable first wall and blankets arguably represents the single greatest structural and materials engineering challenge of all time.

The U.S. DOE sponsored fusion materials research focuses on accomplishing this objective through an integrated science-based program of theory, experiment, and modeling. Emphasis is on cross cutting issues, such as embrittlement, that are pertinent to essentially all material systems under consideration. Three major model systems are leading candidates, each representing significant potential advantages and each manifesting severe limits. They include vanadium alloys, RAMS, and SiC/SiC composites.

A simplified, but useful perspective on the potential role of these and other material systems is shown in the temperature window limits for various candidates shown in Figure 1 prepared by Zinkle (ORNL) and Ghoniem (UCLA). Such windows are established by considering potential show-stopping phenomena, such as severe irradiation embrittlement and low toughness that often sets the lower temperature limit, and thermal creep and oxidation-corrosion that often control the maximum temperature.



S.J. Zinkle and N.M. Ghoniem (2000)

Figure 1. Estimated potential temperature ranges for various materials systems based on a minimum fracture toughness ≥ 30 MPa√m and ≤ 1% thermal creep strain at 150 MPa and 1000 h.

Of course such estimates represent only snapshots of our current knowledge and ignore many complexities and unknowns. For example, refractory alloys may also have a role in high-temperature applications, but since they inherently suffer enormous sensitivity to both irradiation and impurity embrittlement, they are not likely to emerge as viable candidates in the near future. Systems level issues are also important. For example, it is clear that vanadium based alloys that can be used in liquid Li-cooled structures will require a robust and, perhaps, self-healing electrically insulating coating, presenting an enormous materials-system challenge. The SiC/SiC composites are at an even earlier state of development and face a myriad of issues, ranging from the feasibility of large and complex thermo-mechanically loaded structures made of an inherently brittle material, to irradiation induced degradation of thermal conductivity. However, their potential long-term attractiveness, both vanadium alloys and SiC/SiC merit serious consideration, and both represent very useful model systems for building a knowledge base. Indeed, unexplored effects, such as fatigue and high levels of displacement damage and helium, will likely shrink these design windows for all existing materials.

The RAMS offer the most promise for use in a demonstration reactor, following engineering studies as a blanket module in ITER or its progeny. The current generation of RAMS, such as F82H and Eurofer, emerged from earlier studies of 8-12 Cr ferritic-martensitic steels for breeder and fossil fuel technologies and are the direct descendent of the T91 alloy originally developed by Klueh (ORNL). They typically contain 7-9%Cr along with smaller amounts of C and other alloying elements. The key to their reduced activation status is the reduction or elimination of some impurity and alloying elements, such as Nb and the replacement of Mo with W, which behaves metallurgically in an almost identical fashion.

The advantages of RAMS include a well-developed manufacturing, fabrication and joining technology base as well as resistance to swelling and helium embrittlement. Similar alloys are also of interest to many other energy technologies. RAMS are the focus of materials research and development activities in Japan and Europe. The U.S. program is more science based with an emphasis on the fundamentals of deformation and fracture of irradiated alloys, advanced structural integrity assessment methods, and extensive international collaborations. The major known limitations of RAMS are irradiation hardening and embrittlement coupled with loss of uniform strain capacity at lower irradiation temperatures and relatively low thermal creep strength at higher temperatures. Service at higher temperatures may also be accompanied by the precipitation of brittle phases as well as microstructural instabilities and softening. In addition, swelling and helium embrittlement resistance has not been confirmed in a fusion type neutron spectrum at high displacement dose and helium levels. Depending on the coolant, component lifetimes also may be limited by corrosion-oxidation. More complex degradation processes and failure paths such as low to high-cycle fatigue and fatigue crack growth are issues in RAMS that soften under cyclic loads. Others such as creep fatigue and creep crack growth may suffer from high levels of helium.

Finally, we note that there are other approaches to developing higher temperature capabilities in iron-based alloys. Klueh (ORNL) and coworkers are developing advanced age hardening tempered martensitic steels strengthened by a high density of fine-scale TiC phases for fossil energy applications. These alloys are broadly consistent with conventional steel processing practices. With appropriate composition modifications, they could provide an increase in operating temperatures of RAMS up to about 650°C. The flexibility provided by an evolutionary approach to developing ferritic-martensitic steels for fusion applications is an important advantage and emphasizes the cross-cutting nature of materials research challenges.

NCF Alloys

The ultimate attractiveness of 'conventional' RAMS may be most limited by the impact of thermal efficiency on the cost of electricity. In contrast, NCF alloys have demonstrated outstanding high temperature tensile and creep strength as illustrated in Figures 2 and 3. To date, the highest strength is observed in a Japanese 12Cr-3W-0.5Ti-0.25Y_2O_3 NCF, dubbed 12YWT. This alloy resulted from an intense, decade-long development effort by Ukai (PNC) and Okuda (Kobe Steel) and their co-workers. The test data of Maziasz (ORNL) and coworkers in Figure 2 demonstrates the marked superiority of the yield stress of 12YWT over other alloys up to temperatures in excess of 800°C. The corresponding results of creep testing shown in Figure 3, represented in Larson Miller plots that combine the effects of stress and temperature on creep strains and rupture life, demonstrate even larger advantages of the 12YWT. The strength advantage coupled with the corrosion resistance provided by high chromium levels offers great promise for elevated temperature fusion applications.

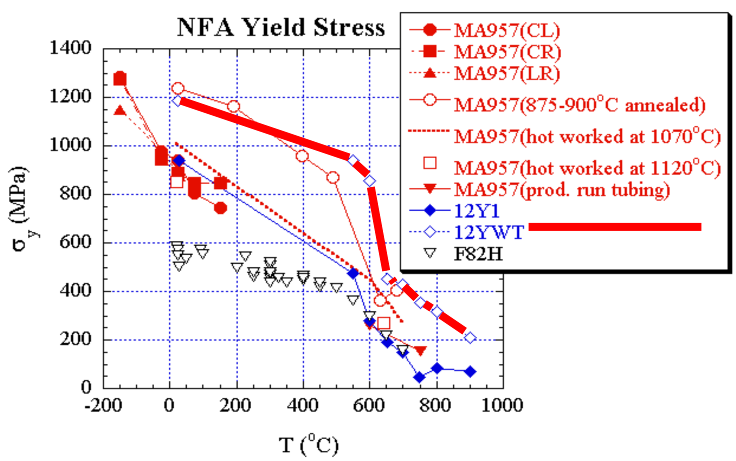


Figure 2. Yield stress as a function of temperature for 12YWT and other mechanically alloyed ferritic alloys as well as the F82H RAMS.

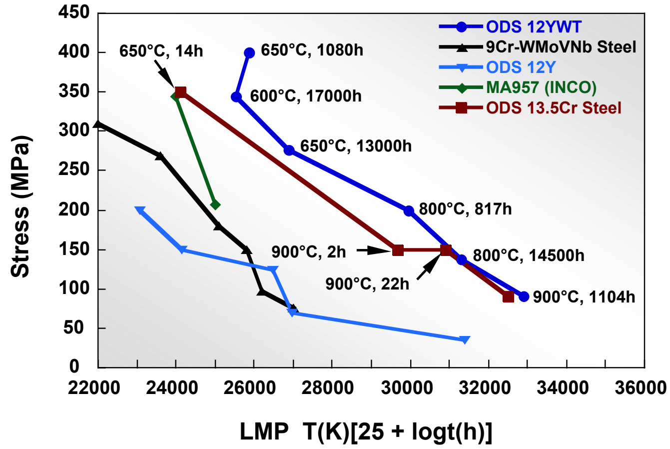


Figure 3. Larson Miller plot of creep rupture for 12YWT and other mechanically alloyed ferritic alloys and an advanced martensitic steel (9Cr-WMoVNb).

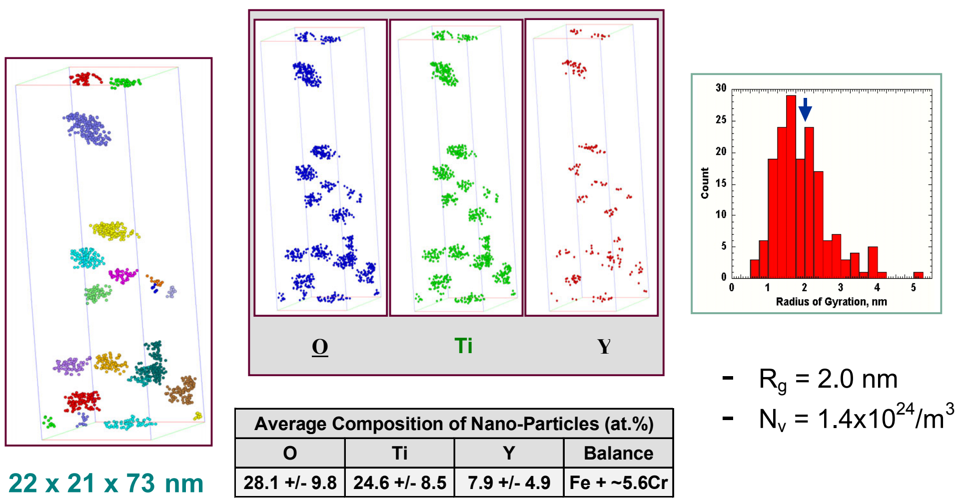
Studies at ORNL and elsewhere have shown that the NCF alloys are strengthened by a unique combination of nano-clusters, composed of Y-O-Ti solute atoms, very small grain sizes, high dislocation densities and possibly, dislocation solute atmospheres. These nano-structures are remarkably stable with recrystallization temperatures of about 1300°C. Because they contain only trace amounts of impurity C, NCFs are not in the alloy category of steels. Due to their high Cr and W and low C content, the body-centered cubic ferrite crystal structure of NCF is unchanged below the melting temperature. In contrast, RAMS are so-called hardenable steels that undergo a solid-state transformation from face centered cubic austenite to martensite, then upon subsequent tempering at intermediate temperatures, manifest the good balance of mechanical properties for intermediate temperature applications.

Typically, NCF alloys are prepared by mechanical alloying (MA) of master Fe-Cr-W-Ti alloy and Y_2O_3 powders by ball milling. Repeated impacts of energetic balls results in a remarkable degree of solid-state mixing and refinement of the various constituents. Indeed, powders can be completely mixed even in multiphase regions not permitted by equilibrium thermodynamics. In the case of NCF, it is believed that most of the Y_2O_3 is almost fully dissolved in the ferrite matrix during MA. The MA also produces very fine-scale grain structures and high dislocation densities. The MA powders are then consolidated at elevated temperature (typically > 1000°C) to nearly full density by hot isostatic pressing (HIPing) and/or hot extrusion.

It is believed that nm-scale Y-O-Ti clusters form during consolidation. However, the precise sequence of events of alloy mixing and solute clustering as well as the remarkable thermal stability of the clusters are not well understood. Recent insight into the nano-structures comes from sophisticated characterization studies based on x-ray diffraction, electron microscopy and most recently, three-dimensional atom probe tomography (3D-APT) measurements. The latter technique measures the position and isotopic character of atoms field emitted from the tip of needle sample to near atomic resolution. Figure 4 shows the results of APT characterization of Y-O-Ti clusters in the Japanese 12YWT by Miller (ORNL) and his coworkers in a collaborative study with Japanese researchers.

MA can also disperse coarser-scale incoherent Y_2O_3 oxide particles in the ferrite matrix. However, the high-temperature tensile and creep strength of alloys with only oxide dispersion strengthening (ODS) are inferior to NCFs. The powder-processing route for NCFs alloys opens up other opportunities as well. Spatially organized powders pre-forms can be consolidated into functionally graded, near net shape components. For example, functional grading may aim at producing a corrosion resistant or integrally coated surface region coupled with a strong, high toughness, and perhaps fiber reinforced core. Thus the designation as NCF, rather that ODS alloys, owes to their engineered nanostructural architectures produced by MA-powder consolidation processing routes.

Indeed, NCFs cannot be considered to be completely new and have their roots in MA ODS alloys developed for high-temperature aerospace and nuclear applications beginning in the 1970s. A patent for Y_20_3 breeder fuel ODS ferritic alloys cladding was issued in 1978 and a 14Cr MA957 was offered for sale by INCO in 1982 (along with a higher Cr MA956). MA957 was studied extensively in the U.S. breeder program by Gelles (PNNL) and co-workers for the next decade and similar research was carried out in Europe and Japan on MA957 and other ODS steels. The results of the studies of MA957 were encouraging with respect to the creep strength, irradiation stability, ability to fabricate tubes and joining by pulsed magnetic welding.



Average Composition of Nano-Particles (at.%)			
O	Ti	Y	Balance
28.1 +/- 9.8	24.6 +/- 8.5	7.9 +/- 4.9	Fe + ~5.6Cr

Figure 4. 3D-APT shows a ultra high density of Y, O, Ti enriched nano-clusters which contribute to the high temperature strength. Notably, these ATP measurements followed creep testing at 138 MPa and 800°C for more than 14,000h. The nano-clusters have been found to coarsen only slightly even after 10 h anneals at 1300°C.

However, research on MA957 also revealed problems that must be avoided or mitigated in developing new high-performance NCF alloys. The first relates to the highly texturedanisotropic grain structures that occur in extruded product forms. This, in turn, leads to properties with strong orientation dependence and weaker directions. Anisotropy is reduced by HIPing, although this processing path may not always produce sufficient consolidation. An alternative is to use nano-composited RAMS, which are the current focus of high-temperature alloy research in Europe, since the austenite to martensite transformation can be used to reduce the anisotropy in the as-extruded product.

Another potential issue for NCF alloys is low-fracture resistance intrinsically associated with their very high strength levels. Recent studies by Alinger (UCSB) and coworkers of the tensile properties and fracture toughness of MA957 demonstrated a strong orientation dependence related to an even more serious problem of Al_2O_3 impurity inclusions that form extended stringers in the direction of the elongated grains. The ceramic inclusions act as trigger sites for low toughness cleavage fracture and nucleation sites for voids during ductile fracture. However, for orientations in which the effect of the stringers is minimized, reasonable toughness was found with ductile-to-brittle transition temperatures comparable to those in RAMS in spite of the much higher MA957 strength level.

These results suggest that a balanced combination of high strength and toughness will require microstructurally clean alloys in general and the elimination of potential cleavage trigger sites in particular. In this regard, the NCFs offer superior promise compared to nano-composited RAMS since the latter contain cleavage trigger sites in the form of large grain boundary carbide particles. Irrespective of the details, however, the issue of toughness-strength tradeoff and its implications to alloy design illustrates both the research challenges and opportunities presented by NCF alloys.

Indeed, many other issues remain to be resolved for this new class of advanced high-temperature, high-performance materials. These include corrosion and compatibility with coolants and breeding materials and system-structure effects of the temperature-composition dependent magnetic properties. Other major questions relate to their stability and properties in a fusion environment. The swelling resistance of MA957 irradiated in fast reactors is encouraging. Preliminary evidence suggests that the nano-clusters and high dislocation densities may also effectively trap and disperse helium. Helium management is a critical ingredient in avoiding high-temperature embrittlement associated with low creep ductility and rupture times. Preliminary evidence also suggests that in contrast to RAMS, NCFs may not soften under strain cycling. Therefore coupled with their high strength, they may manifest a superior range of fatigue properties.

Other challenges relate to processing, fabrication, joining, and costs. The number of alloy composition and MA processing variables is very large and is far from optimized. Fabrication of tubing by extrusion and more complex components and joints by HIPing appears to be technically feasible, but has not been demonstrated in terms of the quality and property-performance limits of the products. Likewise, joining by friction or stir welding appears promising, but remains under development. Finally, costs are always a potential issue. Current estimates suggest that NCF products may be 4 to 5 times more expensive than those made of conventionally processed and fabricated RAMS. However, actual cost advantages versus disadvantages depend on innumerable details, including system level considerations, and may beneficially yield to concerted research and development efforts and the economies of scale

Implications to Design and a Final Perspective

Figure 5. shows an assessment of the 'allowable' primary stress for 12WYT and MA957 prepared by Mattas (ANL). This assessment is based on the lower of the ultimate tensile strength and the stress corresponding to a 2-year creep rupture life. The results shown in Figure 5 should be considered only illustrative, but indicates that primary stresses on the order of 100 MPa may be tolerated at temperatures of about 800°C in NCF alloys. For comparison, the allowable stress for F82H RAMS drops below 100 MPa at about 550°C. Therefore, NCFs offer the potential for increasing the maximum operating temperature by more than 200°C compared to current RAMS.

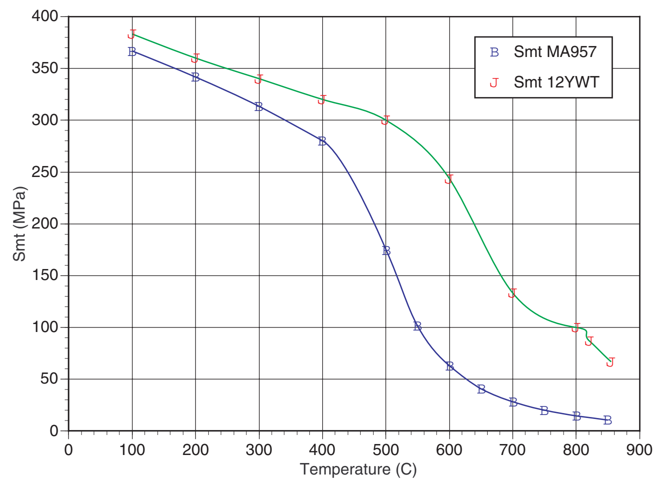


Figure 5 Preliminary maximum allowable stress estimates for 12WYT and MA957 based on tensile strength or creep rupture criteria.

Compelled by the sometimes cruel realities of the laws of physics, the fusion materials community has often been the bearer of 'bad news' about what 'won't work' in transforming the dream of fusion power into an energy sustaining reality for mankind. Developments of NCF alloys and other advanced materials systems may be the beginning of a good news story. We are only at the start of a long journey, but a journey that promises to be well worth taking.

Acknowledgements

The authors wish to acknowledge the many people around the world who have contributed to the progress summarized in this article. Unfortunately they are too numerous to mention adequately let alone to properly cite. We also acknowledge the support provided to ORNL and UCSB by the US DOE Office of Fusion Science and helpful discussions with our colleagues in the Advanced Fusion Materials Science Program.

INTERNATIONAL ACTIVITIES:

Highlights of the Sixth International Symposium on Fusion Nuclear Technology: Charles C. Baker, Conference General Chairperson, University of California, San Diego, CA

The Sixth International Symposium on Fusion Nuclear Technology (ISFNT-6) was held in San Diego on April 8-12, 2002. The Symposium is recognized as a major event for the international exchange of technical information on all aspects related to fusion nuclear technologies (FNT) and for the promotion of international collaboration. The total number of participants was about 250 (including 27 students) who came from approximately 16 countries.

The conference provided an excellent opportunity to report on recent technical progress, discuss key issues and identify means to resolve these issues. The conference covered both near-term fusion devices and long-term reactor technologies for both inertial and magnetic fusion energies. Papers related to technology, experiments, facilities, modeling, analysis, and design were presented on the following topics:

1. First Wall Technology and High Heat Flux Components
2. Blanket Technology
3. Fuel Cycle and Tritium Processing
4. Material Engineering
5. Vacuum Vessel
6. Nuclear System Design
7. Safety Issues and Waste Management
8. Models and Experiments
9. Repair and Maintenance
10. Burning Plasma Control and Operation
11. Inertial Confinement Fusion Studies and Technologies
12. FNT Contributions to Other Fields of Science & Technology.

Previous, current and planned meetings in this series are:

ISFNT-1	Tokyo	April 1988
ISFNT-2	Karlsruhe	June 1991
ISFNT-3	Los Angeles	June 1994
ISFNT-4	Tokyo	April 1997
ISFNT-5	Rome	Sept. 1999
ISFNT-6	San Diego	April 2002
ISFNT-7	Tokyo	May 2005

The conference had two noteworthy keynote speakers: Richard Rhodes, a Pulitzer Prize winner, and Stephen Baum, Chairman, President and CEO of Sempra Energy. Rhodes addressed why rational introduction of new primary energy sources has been complicated and compromised historically by sociocultural barriers as well as technological, infrastructure and competitive challenges. His talk entitled "Energy Transitions: A History Lesson" explored past experience with transitions such as wood to coal, gas light to electric light, and especially fossil fuel to nuclear power that offer lessons for transitioning to fusion. Baum detailed his view of the role of nuclear power in the nation's energy roadmap in a talk entitled "Beyond the Crisis: Solutions for Our Energy Future." Geo-political uncertainty combined with the fallout of the California energy crisis and the Enron debacle has created a new reality for the energy industry.

The conference had three plenary sessions covering topics of broad interest. The closing plenary session on the last day of the conference included four overview papers highlighting the status of fusion nuclear technology in Japan, Europe, Russian Federation and the United States. There were 12 oral sessions which included 48 invited papers. A total of 173 contributed papers were presented in five poster sessions. Peer reviewed papers will be published in a special issue of *Fusion Engineering and Design*.

The ISFNT issued two awards for the first time (the Miya-Abdou Award named after the founding leaders on the ISFNT series of conferences) which acknowledge outstanding contributions to fusion nuclear technology by people relatively early in their careers. The awards were presented to Dr. Lance Snead (ORNL) and Dr. Neal Morley (UCLA).

The conference represents the combined effort of many hardworking people. Dr. Rene Raffray served as the Executive Secretary and co-editor of the proceedings and Mrs. Claudia Hennessy served as the Symposium Secretary and Chair of the Local Organizing Committee.

Calendar of Upcoming Conferences on Fusion Technology

ANS Annual Meeting
June 9-13, 2002, Hollywood, Florida, USA
http://www.ans.org/

Second IAEA Technical Meeting on Physics and Technology of Inertial Fusion Energy Targets and Chambers
June 17-19, 2002, San Diego, California, USA
Dan.goodin@gat.com
http://web.gat.com/conferences/iaea-tm

14th International Conference on High-Power Particle Beams and
5th International Conference on Dense Z-Pinches
June 23-28, 2002, Albuquerque, New Mexico, USA
http://www.sandia.gov/BeamsDZP

2002 Fusion Summer Study
July 8-19, 2002, Snowmass Village, Colorado, USA
jdeloope@pppl.gov
http://web.gat.com/snowmass/

15th ANS Topical Meeting on Technology of Fusion Energy
November 17-21, 2002, Washington, D.C., USA
rkn@ornl.gov
http://www.ans.org/meetings/text.cgi?category=0

ANS Winter Meeting
November 17-21, 2002, Washington, D.C., USA
http://www.ans.org/

22nd Symposium on Fusion Technology - SOFT
September 9-13, 2002, Helsinki, Finland
http://www.vtt.fi/val/soft2002/

19th IAEA Fusion Energy Conference
October 14-19, 2002, Lyon, France
u.schneider@iaea.org
http://www.iaea.org/worldatom/Meetings/2002/infcn94.shtml

7th International Conference on "ENGINEERING PROBLEMS OF THERMONUCLEAR REACTORS
October 28-31, 2002, St. Petersburg, Russia
ljublbv@niiefa.spb.su, EPTR@niiefa.spb.su
http://eptr7.niiefa.spb.su/index_e.html

ANS Annual Meeting
June 1-5, 2003, San Diego, California, USA
http://www.ans.org/

3rd International Conference on Inertial Fusion Sciences and Applications – IFSA-2003
September 7-12, 2003, San Francisco Bay Area, USA
hogan5@llnl.gov

20th IEEE/NPSS Symposium on Fusion Energy - SOFE-2003
October 2003, Livermore Area, CA, USA
foley2@llnl.gov

ANS Winter Meeting
November 9-13, 2003, New Orleans, Louisiana, USA
http://www.ans.org/

11th International Conference on Fusion Reactor Materials - ICFRM-11
December 7-12, 2003, Kyoto, Japan
Icfrm@iae.kyoto-u.ac.jp
http://icfrm.iae.kyoto-u.ac.jp/

20th IAEA Fusion Energy Conference
October 2004, Braga, Portugal
u.schneider@iaea.org

The content of this newsletter represents the views of the authors and the ANS-FED Board and does not constitute an official position of any U.S. governmental department or international agency.