

MIT-ONR Workshop Covers Functionally Graded Structural Materials

This article is a modified version of a report sent to the Office of Naval Research, to the MIT-ONR workshop attendees, and to FGM News in Japan.

An international workshop on Functionally Graded Structural Materials was held at the Massachusetts Institute of Technology March 28–29, 1994 under the sponsorship of the Materials Processing Center at MIT and the Office of Naval Research. The workshop was organized with two goals in mind: (1) to provide a forum for technical discussion within the rapidly growing community of researchers interested in the functionally graded materials (FGM) concept as applied to structural materials and (2) to provide other members of the United States structural-materials community with a source of information on the concept, from which they could gain a first-hand introduction to its underlying philosophy and its potential for structural applications. In composing the program, we, as workshop co-chairs, sought to provide an international overview of current research on functionally graded structural materials, covering both the processing and mechanics of these materials.

The structure of the workshop comprised (1) an introductory presentation by the co-chairs to define its theme and agenda, (2) technical presentations combining general overviews of work abroad, with more detailed presentations of domestic research, and (3) panel discussions to identify future research needs and possible thrusts of future research in the U.S.

The goals we had set in organizing the workshop were all met. Discussions were not only lively, but showed enthusiasm for, and agreement on, the opportunities available and the research necessary in the field of functionally graded structural materials. Attendance was strong, with significant representation from industry, academia, and government, both in the U.S. and abroad.

All invited foreign speakers attended, providing the workshop with five of the most significant organizers of research on functionally graded materials outside the U.S. Key speakers from Austria and Sweden also attended. Among U.S. attendants and speakers, industry was represented by 19 registrants from 14 companies ranging from large corporations

(such as Westinghouse Corporation, United Technologies Research Center, and Alcoa) to much smaller ones (such as Ultraclad Corporation). Academia was represented by 15 U.S. universities. Government attendees numbered 14 representatives from national laboratories and governmental agencies, including the Office of Naval Research (ONR), the Air Force Office of Scientific Research (AFOSR), the National Institute of Standards and Technology (NIST), and the Department of Energy (DOE).

Presentations from the Japanese delegation showed a high level of organization on the part of their national FGM project. The program combines breadth in its overall spectrum of activities and goals, but is focused on target applications (e.g., in the first program, actively cooled structural materials for extreme high-temperature service environments and, in the second program, energy conversion materials; see the article by Koizumi and Niino in this issue) and processes (restricted to four main classes in the first phase). Another important feature of the Japanese project is that it has addressed the difficult issue of testing, leading to the design of a somewhat standardized heat-flux resistance test and somewhat standardized specimen dimensions and geometries (30- and 300-mm-diameter disks, hemispherical domes, etc.).

Presentations from Europe showed an impressive level of activity, some in collaboration with Japan, exploring a variety of applications. Compared to Japan, the European effort is less structured and somewhat broader. The applications explored in Europe tend to involve short-term projects, such as the manufacture of auto and truck engine parts.

The level of U.S. activity was perhaps best summarized by a European delegate, Bernhard Ilschner (organizer of a major international conference on FGMs, held in Lausanne, Switzerland in October 1994), who remarked that what he had heard at the workshop showed a far greater American presence and level of activity in functionally graded materials than he had previously seen at conferences. U.S. presentations were varied in their focus and included research on the mechanics of graded structures, exploring a variety of issues (e.g., thermal stresses, fracture, and microstructural optimiza-

tion for improved mechanical performance), as well as research on a range of processing methods. The topic of processing for graded materials included newer methods, such as infiltration and centrifugal casting, as well as processes previously explored in Japan, such as self-propagating high-temperature synthesis and plasma spraying. Attendees left the conference with the sense that the level of enthusiasm and potential for research on functionally graded materials in the U.S. far exceeds what one would have anticipated, based on conferences and publications to date. Finally, it was also apparent that there is, at present, relatively little international integration with research on functionally graded materials in the U.S.

The workshop also revealed a high level of U.S. interest in learning about and potentially implementing the FGM concept in industry. The panel discussions on the second day also highlighted the willingness of the industrial participants to collaborate with academia and to contribute to a coordinated research effort in this area.

Workshop discussions were conducted as a series of three parallel panel sessions (on processing, mechanics, and design). They focused on specific questions concerning three main issues: (1) practical applications of functionally graded materials, (2) optimal modes of conducting FGM research in order to address a variety of generic fundamental issues relevant to a broad range of practical applications, and (3) the challenge of vertical integration in engineering activities—inherent to the FGM concept. Many applications, such as aerospace and automotive engines, were cited as areas of opportunity for the concept. (Two hundred candidate applications were identified from the two phases of the Japanese program described in this article.) On research, there was a surprisingly high consensus in all three panels on the utility of chosen target applications and fundamental goals in driving research and education.

In summary, the workshop, whose proceedings can be found in Reference 1, has shown that: (1) there is considerable interest in the FGM concept across the board in the U.S., (2) the greatest challenge presented by the FGM concept is the development of strong vertical integration among hitherto isolated engineering activities, (3) development of the FGM concept is best conducted using defined and tangible target applications (as is done in Japan), and (4) there are many

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possible target applications, as well as a correspondingly large, interested U.S. and international industrial base for functionally graded structural materials.

Acknowledgments

The authors thank Dr. G.B. Kenney, Prof. L. Kimerling, and other staff members of the Materials Processing Center at

MIT; and Drs. S.G. Fishman and A.K. Vasudevan of the Office of Naval Research for their support and help in organizing this workshop.

References

1. *Functionally Graded Structural Materials*, edited by S. Suresh, A. Mortensen, and H. McManus, workshop brief from The

Materials Processing Center, MIT, Cambridge, MA, March 1994.

S. SURESH, A. MORTENSON,
AND H. MCMANUS

For information on S. Suresh, A. Mortenson, and H. McManus, please see the author biographies on pages 15-18.

UPCOMING CONFERENCE

SAM'95 Meeting in Argentina Features Magnetic Materials

The Materials Argentine Association (SAM) is sponsoring the SAM'95 Meeting and the First Argentine Workshop on Magnetic Materials and Their Applications in "Centro di Materiales y Metrologia" in Cordoba, Argentina, May 17-20, 1995.

The SAM'95 Meeting promotes links between scientists, professionals, technicians and industrialists who develop their activities in the materials field, facilitating the divulging and spreading of their work results through the various specialized sessions. This year's meeting emphasizes the magnetic materials field.

The sessions will consist of 10-minute oral presentations followed by 5-minute discussions. Plenary sessions, with the participation of specialists from all over the world, and Techno-Commercial sessions are also planned. The meeting will

cover the following areas:

1. Extractive and Manufacturing Metallurgy
2. Melting, Solidification, and Welding
3. Physical Metallurgy
4. Plastic Deformation and Welding
5. Thermal Treatments and Phase Transformations
6. Fracture and Fatigue
7. Corrosion and Protection Methods
8. Defects Analysis
9. Special Tests and Techniques
10. New Materials
11. Biomaterials
12. Ceramics and Refractories
13. Pulvimetallurgy
14. Polymers. Composites
15. Tribology
16. Technology Management and Human Resources
17. Historic Metallurgy

The Workshop on Magnetic Materials will feature:

1. Magnetic Materials Processing. Raw Materials
2. Magnetic Properties
3. Models and Mechanisms
4. Measurement Systems. Standardization
5. Magnetic Circuit Design. Applications
6. Electromagnetic Interferences. Bioapplications. RMN

At the end of the meeting several awards will be given to researchers belonging to Latinoamerican University Laboratories: Jorge Sabato Award—Best Work of Technological Development; Jorge Kittl Award—Best Work of Research; Best Work on Steels Award; Best Work on Aluminum Award; and Best Work on Research or Technological Development Initiation Award.

For more information contact Ing. Raul Barbosa; "Jornadas SAM'95" Executive Secretary; CIMM; Av. Velez Sarsfield 1561; P.O. Box 884; 5000 Cordoba, Argentina; (Fax: 54-51-69-9459). □

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