AD-A241 944

IENTATION PAGE

Form Approved
OMB No. 0704-0188

(2)

1. AGENCY USE ONLY	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	9/17/91	Final, April 1-September 17, 1991

4. TITLE AND SUBTITLE
1991 Gordon Research Conference on Physical Metallurgy

5. FUNDING NUMBERS
G-AFOSR-91-0173

6. AUTHOR(S)
Alexander M. Cruickshank and John H. Perepezko

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Gordon Research Conferences, Incorporated
University of Rhode Island
Kingston, RI 02881-0811

8. PERFORMING ORGANIZATION REPORT NUMBER
0876

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NE
Building 410
Bolling AFB, DC 20332-6448

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Prepared in collaboration with Dr. W. J. Boettinger

12a. DISTRIBUTION/AVAILABILITY STATEMENT
unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

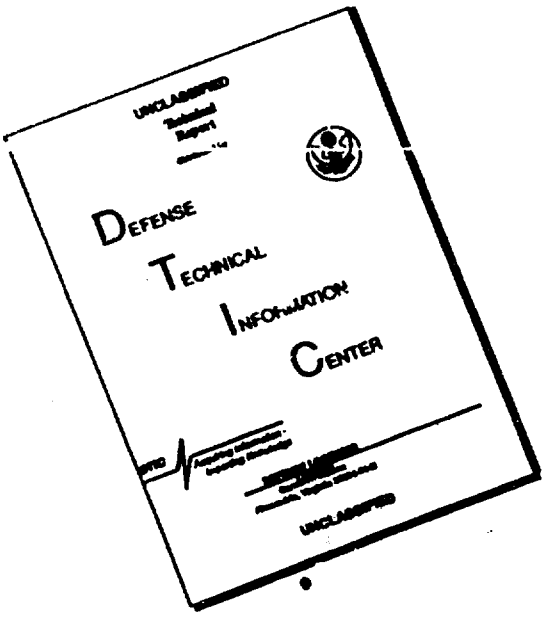
The 1991 Gordon Research Conference on Physical Metallurgy was held July 29-August 2, 1991 at the Plymouth College South location in Plymouth, New Hampshire. The Conference topic was Foundations of Microstructure Development. The study of microstructural development in metals and alloys is a cornerstone of physical metallurgy. From an understanding of the compositional, thermodynamic and kinetic constraints, new levels of control and the development of new microstructures may be possible. The discussion was organized to present state-of-the-art developments in such keynote issues as alloy phase stability, crystal growth and solidification, diffusion in ordered alloys and multicomponent systems, interfacial structure and phase decomposition kinetics. There was a balanced coverage between theoretical and modeling analysis and critical experimental work involving verification tests and applications. In addition, an industrial perspective in the areas of aluminum alloys, aerospace materials and electronic materials was included in the program.

In light of the vigorous discussion during the conference the foundations of microstructural development clearly generated a keen interest. Several emerging new issues in alloy phase stability, in crystal growth and solidification, diffusional reactions, interfacial structure and phase decomposition were highlighted during the meeting. Equally important is the industrial perspective that allowed for the often pointed out gap between theoretical and experimental developments and industrial applications to be bridged to some extent. New perspectives and new interactions were developed at the meeting which will yield future dividends.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Gordon Research Conference, Physical Metallurgy, Phase Transformations, Solidification, Interfaces, Diffusion, Elastic Strain, Ordered Alloys, Phase Equilibria	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

FINAL REPORT

AFOSR Grant (AFOSR-91-0173) for the Support of the 1991 Gordon Conference on Physical Metallurgy

"Foundations of Microstructure Development"

Submitted to

Air Force Office of Scientific Research
Division of Research Grants, Building 410
Bolling AFB, Washington, DC 20332-6448

Attention: Dr. Alan H. Rosenstein

Submitted by

Dr. John H. Perepezko (Co-Chairman and P.I.)
Professor, Department of Materials Science and Engineering
University of Wisconsin-Madison
1509 University Avenue
Madison, WI 53706

Dr. William J. Boettinger
National Institute of Standards and Technology
Metallurgy Division
Building 223 Room A153

and

Dr. Alexander M. Cruickshank (Director)
Gordon Research Conferences
University of Rhode Island
Kingston, RI 02881

Introduction

The 1991 Gordon Research Conference on Physical Metallurgy was held July 29-August 2, 1991 at the Plymouth College South location in Plymouth, New Hampshire. The Conference topic was Foundations of Microstructure Development. US Government grants were made to the Gordon Research Conference to offset partially the travel and registration cost of many the speakers and discussion leaders, a few attendees, and the co-chairman. Grants totaled $18,000.00. Of this total, $6,000.00 each was provided by AFOSR (AFOSR-91-0173), ONR and NSF (DMR-9102779). In this final report a brief description of the conference is given and includes some of the highlights of the meeting and discussions.

Conference Description

The study of microstructural development in metals and alloys is a cornerstone of physical metallurgy. An effective approach to this theme can be developed by examining the limiting bounds for a given microstructural type. From an understanding of the compositional, thermodynamic and kinetic constraints, new levels of control and the development of new microstructures may be possible. As a result, the conference program was focused on the critical processes governing microstructural development. The discussion was organized to present state-of-the art developments in such keynote issues as alloy phase stability, crystal growth and solidification, diffusion in ordered alloys and multicomponent systems, interfacial structure and phase

decomposition kinetics. There was a balanced coverage between theoretical and modeling analysis and critical experimental work involving verification tests and applications.

The conference program was organized on the basis of the realization that major advances in physical metallurgy leading to novel insight or new discoveries have often occurred as a result of a steady, concerted study effort on an experimental and theoretical front to examine fundamental physical processes. Often the discoveries appear as anomalies, but with further examination the anomaly becomes recognized as a new aspect of a basic mechanism. In addition, there is an important realization that much of the work in the physical metallurgy of advanced materials is intended for eventual applications. As a result, the initial session of the first day provided that perspective in the areas of aluminum alloys, aerospace materials, and electronic materials. This was followed by a session on interface reactions where the theoretical and experimental developments including the latest studies were described. Since most metals undergo a melting and solidification process sometime during their fabrication, the importance of crystal growth and solidification is apparent and occupied most of the discussion of the second day. Similarly, the basis of materials processing is rooted in diffusional transformations which was the basic theme of the third day where the discussion ranged from the very early stages of precipitation to multicomponent systems and basic mechanisms of diffusion in more complex systems. This discussion carried over to the fourth day with some of the detailed studies of

interface structure including the effects of elastic stresses. Finally, the program ended with discussion of ordering reactions and displacive transformation that are becoming recognized as crucial in many of the latest developments in transformation kinetics.

While every effort was made to identify frontier issues with each of the foundation topics, it was recognized that such a listing can not be completely comprehensive and still allow time for the extensive discussion that is the hallmark of a successful Gordon Conference. Certainly, further issues and perspectives were brought out in the discussion. However, each of the foundation topics could be a theme of a separate conference. Indeed one of the advantageous of the Gordon Conference forum is the ability to bring together various groups and perspectives to have a high level exchange of experimental and theoretical developments.

Following the tradition of previous Gordon Conferences, a relatively small number of speakers were invited to make presentations to the conference. The main purpose of these talks was to describe recent progress and set the stage for further thought and discussion. A copy of the program and speakers and discussion leaders is appended to this report. In addition, a poster session was also held during the conference in order to allow some of the participants to present their research results. This was a well attended session with over 20 contributed

posters, provided a basis for broad exposure of very new results and stimulated a great deal of excitement that are often continued late into the evening.

The conference attracted participants from a wide variety of institutions and backgrounds. A list of attendees appended to this report shows that a total of 124 scientists and engineers participated in the conference. Of these only 31 were on the program as speakers and discussion leaders. The attendees included 106 from the United States and 18 from foreign countries. Of these 68 were from universities, 37 from government laboratories or offices and 19 from industry. Finally it is worth noting that the number of applicants for this conference exceeded the number of places available.

Program Highlights

The major attraction at Gordon Conferences is the opportunity to interact on an informal level with a large number of scientists interested and knowledgeable in a given subject. Facilities at the Plymouth College catered to this aspect in a number of ways; the main lounge, the game room, and the grounds were excellent sites for informal discussion. These facilities were in use throughout the day and night for numerous small group discussions which led to the development of research ideas and interactions. This informal aspect of the Gordon Conference, was therefore a success.

In the formal program the initial session provided an industrial perspective on advanced materials. For example, Staley from Alcoa discussed aluminum alloy development and as

requested raised a number of issues for future work including how the grain size is limited by a various particles in aluminum alloys, some new areas in presolidification processing to initiate particulate formation, and the need for additives in aluminum alloys to remove undesirable impurities. In a similar vein Blackburn from Pratt & Whitney discussed the importance of modeling in scaling-up processing from laboratory operations to production operations. He also pointed out that the best property in any given category cannot usually be obtained in the best combination of properties and as a result process models are essential to allow for an optimum balance of properties. Rosenberg from IBM provided information on many exciting developments in the miniaturization of electronic circuits down to 0.1 microns in scale. Devices have been made in the laboratory, but again the point was made on how to scale-up the processing. He pointed out that more than 98% of system failures are related to metallization treatments and that this issue provides a wealth of important problems to deal with. Next, John Cahn provided an informative discussion of heterogeneous nucleation along the lines of Gibbs including very interesting new developments in wetting behavior and crystal morphologies. This discussion was complemented very nicely by Dahmen who provided some outstanding TEM micrographs to illustrate the development of crystal morphology at the atomic scale. The next day was devoted to solidification. Trivedi gave an overview of some of the unsolved problems in solidification microstructure development. He also provided useful insight into the

understanding of study state processes and the development of microstructure over a range of velocity. Brown followed this with a more focused discussion on wavelength selection during cellular solidification where the complete domain of velocity-wavelength behavior is being mapped out including the important onset ranges of breakdown of planar interface and the various time scales appropriate for the different breakdown behavior. Dantzig gave summary of the modeling approaches to process development ranging from nucleation kinetics models, which are sorely lacking to approaches for accounting for growth kinetics and heat evolution during solidification. The evening session belonged to the theoreticans. Sekerka provided very effective introduction to the main theoretical developments in diffuse interface theories of crystal growth and phase field calculations of solidification. These are two approaches to deal the difficulties of matching solutions in the liquid and solid state at the interface. In the diffuse interface model Oxtoby described perturbation approaches where the liquid is treated as a perturbed solid and the solid treated as a perturbed liquid as a means of modeling their behavior. Wheeler approached the problem from phase field model method which deals with the existence of various potentials which are expressed in terms of an order parameter. While each approach has advantages, it is not clear at present which is superior. They both appear to give effective descriptions of observed behavior. Clearly more development of analysis is needed. On the third day Cohen provided an excellent overview of the early stages of

participation including the formation of GP zones, initially ordered configurations and clustering effects where strain energy factors become important. This is followed Purdy's discussion of precipitation in ternary systems where the concept of local equilibrium sometimes needs to be modified to include paraequilibrium i.e. equilibrium with respect to one component. The morning ended with a discussion by Greer of recent developments in solid state amorphization during interdiffusion reactions. The various thermodynamic and kinetic behaviors were analyzed including how to treat diffusion in the very steep concentration gradients that develop in multilayer structures at the onset of interdiffusion which is a new realization.

These discussions were followed in the evening by a presentation on diffusion in ordered alloys by Bakker who pointed out that there is a much stronger correlation factor in ordered crystals than in disordered crystals and that one must consider defect structures on the sublattices in ordered crystals. For example, when this is done in Ni_3Al, it is found that nickel can diffuse on its own sublattice at much the same rate as for self diffusion in pure nickel. Van Loo presented an elegant discussion of the Kirkendall effect during multiphase diffusion. He described methods to analyze diffusion path sequences in multicomponent systems which is crucial in the development of composite structures. The importance of interfaces and domain structures that develop in elastically strained systems was the highlight in the next session. Howe presented video images of lattice resolution TEM studies conducted at high temperature to

reveal the dynamics of interface motion. This is truly a remarkable experimental achievement. Voorhees discussed an interesting analysis of the competition between strain energy and interfacial energy in determining the equilibrium shape of a precipitate in the later stages of reaction. Roytburd followed with a detailed analysis of the formation and development of polydomain structures that often occur in twinning and martensite reactions and involve multiple subdivision with the development of increasing levels of elastic strain. The last two sessions dealt with various aspects of the thermodynamics and kinetics of ordering reactions. Inden gave an informative overview of phase diagram modeling starting from the regular solution all the way up to cluster variation methods that are used to treat more complex interactions. This is followed by Allen's analysis of the behavior of diffuse interfaces with respect to order parameter as well as concentration gradients. He applied this analysis to explain some of the domain coarsening kinetics observed in ordered alloy. In a detailed study of the kinetics of ordering reactions, Banerjee highlighted some of the crystallographic aspects. Often BCC phases develop transformations by various shears of (110) planes. In the last presentation Johnson tried to integrate the diffusive and displacive characteristics of transformations. It is becoming clear that both aspects can occur in given transformation types and that the traditional distinction between displacive and diffusional transformations is not as sharp as it has been viewed previously. As a sign of the interest and animated discussion

during the conference, it is useful to point out that more than 85 people were on hand to hear the last presentation on Friday morning.

In light of the vigorous discussion, the foundations of microstructural development clearly generated a keen interest. Several emerging new issues in alloy phase stability, in crystal growth and solidification, diffusional reactions, interfacial structure and phase decomposition were highlighted during the meeting. Equally important is the industrial perspective that allowed for the often pointed out gap between theoretical and experimental developments and industrial applications to be bridged to some extent. New perspectives and new interactions were developed at the meeting which will yield future dividends.

Physical Metallurgy
Gordon Conference
Plymouth State College (South), Plymouth, NH
July 29 - August 2, 1991

William J. Boettinger and John H. Perepezko, Cochairmen
Anthony W. Thompson and Robert O. Ritchie, Vice-Cochairmen

1991 Conference Topic
Foundations of Microstructure Development

Morning sessions start at 8:30 AM
Evening sessions start at 7:30 PM

Monday AM: Industrial Perspective on Advanced Materials (Alan Rosenstein, AFOSR)

James Staley, Alcoa	Al Alloy Development
Martin Blackburn, Pratt & Whitney	Advanced Aerospace Alloys
Robert Rosenberg, IBM	Electronic Materials

Monday PM: Interface Reactions (Frans Spaepen, Harvard)

John Cahn, NIST	Hetrogeneous Nucleation
Ulrich Dahmen, Lawrence Berkerley Lab.	TEM Study of the Development of Grain Boundaries & Precipitates

Tuesday AM: Solidification Microstructures (John Hunt, U. of Oxford)

Rohit Trivedi, Iowa State U.	Solidification Microstructures
Robert Brown, MIT	Nonlinear Dynamics & Wavelength Selection in Cellular Solidification
Jonathan Dantzig, U. of Illinois-Urbanna	Macro/Micromodelling of Eutectic Castings

Tuesday PM: Crystal Growth Kinetics (Bob Sekerka, Carnegie-Mellon)

David Oxtoby, U. of Chicago	Diffuse Interface Theories of Crystal Growth
Adam Wheeler, U. of Bristol	Phase Field Calculations of Binary Alloy Solidification

Wednesday AM: Diffusional Transformations (Bill Morris, UC-Berkeley)

Jerry Cohen, Northwestern U.	Early Stages of Precipitation
Gary Purdy, McMaster U.	Precipitation in Ternary Systems
Lindsay Greer, U. of Cambridge	Solid-State Amorphization

Wednesday PM: Diffusion Mechanisms (John Morral, U. Conn.)

Hans Bakker, U. Amsterdam	Diffusion Mechanisms in Ordered Intermetallics
Frans van Loo, Eindhoven U.	Kirkendall Effect in Multiphase Diffusion

Thursday AM: Interfaces & Domains (Caroi Handwerker, NIST)

Jim Howe, U. of Virginia	HRTEM of Interfaces
Peter Voorhees, Northwestern U.	Dynamics of Interfaces in Elastically Stressed Solids
Alexander Roytburd, U. of Maryland	Formation of Polydomain Structures

Thursday PM: Ordering Transformations (Ben Burton, NIST)

Gerhard Inden, Max Planck Inst. Eisenforschung	Phase diagram Modeling
Sam Allen, MIT	Diffuse Interfaces in Ordering Systems

Friday AM: Displacive Transformations (Lee Tanner, Lawrence Livermore)

Srikumar Banerjee, Bhabha Atomic Research Centre, Bombay, India	Replacive/Displacive Ordering
Bill Johnson, Carnegie-Mellon	Transformations Displaying Diffusive and Displacive Characteristics

GORDON RESEARCH CONFERENCE
Physical Metallurgy

Registration List
July 29 - August 2, 1991
Plymouth State College, Plymouth, NH

Dr. Ralph Adler 626
Army Materials Tech. Lab.
SLCMT-EMM Arsenal St.
Watertown, MA 02172

Dr. Robert Aikin Jr. 719
Martin Marietta Labs.
1450 South Rolling Rd.
Baltimore, MD 21227

Dr. Donald Robert Allen 511
University of Wisconsin
Dept. of Materials Sci. & Engineering
1509 University Ave.
Madison, WI 53706

Dr. Samuel Allen 513
Massachusetts Institute of Technology
RM. 13-5056 77 Massachusetts Ave.
Cambridge, MA 02139

Agren 623
Division of Physical Metallurgy
Royal Inst. Technology
S-100 44 Stockholm, Sweden

Dr. Iver Anderson 713
Ames Lab. & Iowa State University
122 Metals Development BLDG.
Ames, IA 50011

Alan Ardell O.C.
University of California
Dept. of Materials Science & Engineering
5732-J BH Los Angeles, CA 90024-1595

Dr. Harry Atwater 622
Caltech, MS 128-95
Pasadena, CA 91125

Dr. Michael Aziz 526
Harvard University
Division of Applied Sciences, 29 Oxford St.
Cambridge, MA 02138

Dr. Hans Bakker 623
University of Amsterdam
Valckenierstr. 65
Amsterdam, The Netherlands NL1018XE

Dr. Srikumar Banerjee 326
Bahadha Atomic Research Center
Metallurgy Div. Bombay, India 400 085

Dr. Michael Baskes 404
US Dept. of Energy
Division of Material Sciences ER-131/GTN
Washington, DC 20585

Paxal Bellon 606
SRMP, Centre D/Etudes de Saday
Elsur Yrette, France 91191

Dr. Leonid Bendersky 30-
NIST, Metallurgy Div. BLDG 223,A-155
Gaithersburg, MD 20899

Dr. Martin J. Blackburn 325
Pratt & Whitney
Materials Engin. Mail Stop 114-43
400 Main Street
E. Hartford, CT 06108

Dr. William Boettinger 509
NIST, A153-Bldg. 223
Gaithersburg, MD 20899

Richard Braun 504
Dept. of Engineering Sciences
Technological Inst. Northwestern Univ.
Evanston, IL 60208

Yves Brechet 302
CR. Pechiney, 38000 Vorteppe
France

Manfred Breiter 622
Inst. Techn. Elektrochem
9 Getreidemarkt
Wien, Austria 1060

Dr. John Brooks 621
Sandia National Labs. 312
Livermore, CA 94550

William Brower Jr. 621
Marquette University
Dept. of Mech. & Indust. Engineer.
1515 W. Wisconsin Ave.
Milwaukee, WI 53233

Dr. Robert Brown 324
Massachusetts Institute of Technology
Chemical Engineering Dept. 66-342
Cambridge, MA 02139

Dr. Lucien Brush 323
University of Washington
Dept. of Materials Sci. & Engin.
325 Robers Hall FB-10
Seattle, WA 98195

Dr. Benjamin Burton 519
NIST, A153/223
Gaithersburg, MD 20899

Dr. Daniel Butrymowicz 710
National Institutes of Standards & Techn.
Materials Bldg., RM B309
Materials Science & Engineering Lab.
Gaithersburg, MD 20899

Dr. John Cahn 222
NIST, 223/A153
Gaithersburg, MD 20899

Dr. Ray Carpenter 405
Center for Solid State Science
Arizona State University
Tempe, Arizona 85287-1704

Dr. William Cassada III 717
Reynolds Metals Company
Corporate Research & Development
4th & Canal St.
Richmond, VA 23229

Dr. Long-Qing Chen 620
Rutgers University
Dept.of Matl. Sci., PO Box 909
Piscataway, NJ 08855-0909

Dr. Jerome Cohen 619
Northwestern University
McCormick School of Engineering
Evanston, IL 60208

Dr. Ulrich Dahmen 221
National Ctr. for Electron Microscopy
Lawrence Berkeley Lab, BLDG. 72
1 Cyclotron Rd.
Berkeley, CA 94720

Dr. Jonathan Dantzig 619
University of Illinois
Dept.of Mechanical & Industrial Engrg.
1206 West Green St.
Urbana, IL 61801

Dr. Siddhartha Das 507
University of WIsconsin-Madison
Dept. of Materials, Science & Eng.
1509 University Ave.
Madison, WI 53706

Dr. James Dela'O 617
Michigan Technological University
Metallurgical Materials Eng. Dept.
Houghton, MI 49931

Larry DeVries O.C.
MEB 2220 University of Utah
Salt Lake City, Utah 84112

Dr. James Early 220
National Institutes Of Standards
Materials Bldg., Rm B309
Materials Science & Engineering Lab.
Gaithersburg, MD 20899

Dr. John Elmer 617
Lawrence Livermore National Lab.
PO Box 808, L355
Livermore, CA 94551

Dr. Paul Evans 219
Alcan International
Banbury Lab., Southam Rd.
Banbury, Oxon, England OX 16 7SP

Dr. Harold Frost 611
Dartmouth College
Thayer School of Engineering
Hanover, NH 03755

Pro. Hans Fecht 721
University of Augsburg
Inst. of Physics Memmingerstr. 6
8900 Augsburg Germany

Dr. Steven Fishman 217
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217

Peter Frankwicz 511
University of Wisconsin
Dept. of Materials Sci. & Engin.
1509 University Ave.
Madison, WI 53706

Dr. Frank Gayle 519
NIST, RM 223/A153
Gaithersburg, MD 20899

Dr. Uwe Glatzel 626
Stanford University
Dept. of Materials Science & Engin.
TU-Berlin, BH18,7000 Berlin 12 FRG
Stanford, CA 94305-2205

Dr. Rolf Gotthardt 406
Ecole Polytechnique Federale Lausanne
Lausanne, Switzerland CH-1015

Dr. Douglas Granger 407
Alcoa Lab., Alcoa Technicla Center
Alcoa Center, PA 15069

Dr. A Greer 211
University of Cambridge
Dept. of Materials Science & Metallurgy
Pembrooke St.
Cambridge, UK CB2 2QZ

Dr. Amitava Guha 209
Brush Wellman Inc.
17876 St. Clair Ave.
Cleveland, OH 44110

Dr. Carol Handwerker O.C.
NIST, 233/A153
Gaithersburg, MD 20899

Dr.Stewart Harris 611
SUNY, CEAS
Stony Brook, NY 11794

David Hoglund 608
Harvard University
Gordon Mskay LB 9 Oxford Street
Cambridge, MA 02138

Dr. William Hopfe 608
University of Connecticut
Box U-136, Dept. of Metallurgy
Storrs, CT 06269-3136

Dr. James Howe 208
University of Virginia
Dept. of Materials Science, Thornton Hall
Charlottesville, VA 22902-2442

Dr. J D Hunt O.C.
University of Oxford
Dept. of Materials, Parks Rd.
Oxford, United Kingdon OX1 3PH

Dr. Gerhard Inden 206
Max-Planck-Institut Eisenforschung
Max-Planck-Str. 1
Dusseldord Germany

Dr. Mel Jackson 205
General Electric CRD, K-1 MB 223 Box 8
Schenectady, NY 12301

Dr. William Johnson 505
Carnegie Mellon University
3325 Wean Hall
Pittsburgh, PA 15213-3890

Dr. Bimal Kad 607
Ohio State University
116 W. 19th Ave.
Columbus OH 43210

Mike Kaufman 502
University of Florida
201 Rhines Hall
Dept. of Materials Science & Engr.
Gainesville, FL 32611

Pro. Ryoichi Kikuchi 408
University of California, Los Angeles
Materials Science & Engineering
Los Angeles, CA 90024-1595

Dr. Carl Koch 321
North Carolina State University
Materials Science & Eng. Depc.
PO Box 7907
Raleigh, NC 27695

Dr. David Lee 411
USAF, Materials Directorate, WL/MLLM
WPAFB, OH 45433

David Y. Lee 618
Materials Sci. & Engin.
Postech
Pohang, Korea 790-600

Richard Lewis 502
LMSC Inc., 93-10/204
3251 Hanover St.
Pal Alto, CA 94304

Dr. Harry Lipsitt 420
Wright State University
Dept. of Mech. & Mats. Eng.
Dayton, OH 45435

Dr. A Loiseau 320
ONERA, 29 Ave. DE LA Division Leclerc
BP 72 Chatillon France 92322

Dr. Blair London 409
Howmet Corp. 1500 S. Warner St.
Whitehall, MI 49461-1895

Dr. David Luzzi 426
University of Pennsylvania
Dept. of Materials Science
3231 Walnut St.
Philadelphia, PA 19104-6272

Dr. Steven Marsh 607
Naval Research Lab. Code 6325
Washington, DC 20375-5000

Dr. Patrick Martin 319
Rockwell International Science Center
1049 Camino Dos Rios
Thousand Oaks, CA 91360

Dr. Carolyn MacDonald 418
SUNY Albany, Physics Dept.
Albany, NY 12222

Dr. Bruce MacDonald 225
National Science Foundation
Div. of Material Research 6800 G. St.
Washington, DC 20550

Dr. Arthur McEvily 318
University of Connecticut
Metallurgy Dept., U-136
Storrs, CT 06268

Dr. CJ McMahon Jr. 425
University of Pennsylvania
Dept. of MSE, 3231 Walnut St.
Philadelphia, PA 19104

Dr. Mark McCormack 625
Lawrence Berkeley Lab/UCB
#1 Cyclotron Rd. MS 66-200
Center For Advance Material/MS&ME
Berkeley, CA 94720

Dr. Jyothi Menon 410
Wright Patterson Air Force Base
WL/MLLM
Wright-Patterson A, OH 45433-6533

Dr. John Morral 606
University of Connecticut
97 N. Eagleville Rd., RM 111
Storrs, CT 06269-3136

Dr. James Morris 606
University of Kentucky
Light Materials Research Labs.
Anderson Hall
Lexington, KY 40506

Dr. John Morris Jr. 625
University of California, Berkeley
One Cyclotron Rd. MS 66-800
Manter for Advance Materials/MS&ME
Berkeley, CA 94720

Dr. Dongkyu Na 521
Northwestern University
Tech. Inst. of Materials Sci. & Engin.
2145 Sheridan
Evanston, IL 60201

Dr. Tai Nguyen 605
LBL/UC Berkeley
Lawrence Berkeley Lab.
MS 2-400, 1 Cyclotron Rd.
Berkeley, CA 94720

Dr. Ben Oliver 605
University of Tennessee
Dept. of Materials Science & Engin.
RM 425, Dougherty Engineering Bldg.
Knoxville, TN 37996-2200

Dr. David Oxtaby 317
University of Sydney
Dept. of Theoretical Chemistry
Sydney, Australia NSW 2006

Dr. John Perepezko 509
University of Wisconsin
Dept. of Mat. Sci. & Eng.
1509 Univ. Ave.
Madison, WI 53706

Kevin Peters 521
Dept. of Materials Science
Evanston, IL 60202

Dr. Jean Philibert 311
Universite Paris -SUD
Metallurgie - BAT 413
Orsay France F-91405

Dr. David Pope 603
University of Pennsylvania
MEAM Dept. Towne Bldg.
220 S. 33rd St.
Philadelphia, PA 19104-6315

Dr. Gary Purdy 424
McMaster University 1280 Main St. West
Materials Science & Engineering
Hamilton, Ontario, Canada L8S 4L7

Dr. James Rawers 310
US Bureau of Mines
Albany Research Center
1450 SW Queens Ave.
Albany, Oregon 97333

Steven H. Reichman 309
Wyman-Gordon, Worcester St.
North Grafton, MA 015

Dr. Rosenberg 308
IBM TJ Watson Research Center
PO Box 210
Yorktown Heights, NY 10598

Dr. Alan Rosenstein 306
A.F.O.S.R., AFOSR/NE Bldg. 410
Bolling AFB
Washington, DC 20332

Dr. Alexander Roytburd 304
University of Maryland
Materials & Nuclear Engineer. Dept.
College Park, MD 20742-2115

Dr. Vladimir Segal 525
Mechanical Engineering
University of Delaware
Newark, DE 19716

Dr. Adam Schwartz 303
Lawrence Livermore NL L-355 PO Box 808
Livermore, CA 94550

Dr. Yoontto Son 602
University of Connecticut
Dept.of Metallurgy, U-136
Storrs, CT 06268

Dr. David Skinner 602
Allied Signal Research & Technology
PO Box 1021, Columbia Rd.
Morristown, NJ 07962

Dr. Frans Spaepen 722
Harvard University
Division of Applied Sciences
29 Oxford Street
Cambridge, MA 02138

Dr. Brian Spencer 504
Northwestern University
Dept. ES/AM Technological Inst.
Evanston, IL 60208

Dr. James Staley 422
ALCOA, ALCOA Labs
ALCOA Tech. Center, PA 15069

Dr. James Steele Jr. 522
Los Alamos National Lab
Mail Stop E506
Los Alamos, NM 87545

Dr. P R Subramanian 610
Universal Energy Systems Inc.
Materials Research Division
4401 Dayton-Xenia Road
Dayton, OH 45432

Dr. Bruce Taggart 624
National Science Foundation
Division of Materials Research
1800 G.St. NW Washington, DC 20550

Dr. Seiji Takeda 624
Osaka University
College of General Education
Toyonaka, Osaka Japan 560

Dr. Lee Tanner 402
Lawrence Livermore Nat. Lab.
Chemistry & Materials Science
7000 East Ave.
Livermore CA 94550

Dr. Nagappan Thangaraj 226
National Center for Electron Microscopy
Bldg. 72 Lawrence Berkeley Lab
1 Cyclotron Rd.
Berkeley, CA 94720

Dr. Dan Thoma 507
University of Wisconsin-Madison
Dept. of Materials Science & Engin.
1509 University Ave.
Madison, WI 53706

Dr. Anthony Thompson 604
Carnegie Mellon University
Dept. of Metallurgy & Engin.
Pittsburgh, PA 15213

Dr. Ariel Traiber 604
M.I.T. Rm 13-5126
Cambridge, MA 02139

Dr. Rohit Trivedi 524
Iowa State University
100 Wilhelm Hall
Ames, IA 50011

Dr. David Van Aken 508
University of Michigan
2300 Hayward St.
Dept.Mater Sci. & Engineering
Ann Arbor, MI 48109-2136

Dr. Roy Vandermeer 419
Naval Research Lab, Code 6320.1
4555 Overllok Ave.
Washington, DC 20375-5000

Dr. Frans Van Loo 603
Eindhoven University of Technology
Lab. TVM-CTK, PO Box 513,
5600 MB Eindhoven The Netherlands

Dr. Clinton Van Siclen 223
EG&G Idaho, Inc.
Inel Research Center, Phys. & Mat. Group
PO Box 1625
Idaho Falls, ID 83415-2211

Dr. Vijay Vasudevan 524
University of Cincinnati
Dept. of Materials Science & Engineering
ML 12 Cincinnati, OH 45221

Dr. Peter W. Voorhees 505
Northwestern University
Dept. Materials Science & Engineering
Evanston, IL 60208

Dr. David Vul 523
University of California, Berkeley
Dept. of Materials Science & Mineral Eng
Berkeley, CA 94720

Dr. John Wei 202
RES-12 Timken Co.
1835 Dueber Ave. S.W.
Canton, OH 44706

Dr. GErhard Welsch 523
Case Western Reserve University
10900 Euclid Ave.
Cleveland, OH 44106

Zhang Wenzheng 403
McMaster University
Dept. of Materials Sci & Engineering
1280 Main St. W.
Hamilton, Ontario, Canada 285 4L7

Dr. A A Wheeler 510
NIST, C/O Robin Bickel
AISI Technology NIST
Caithersburg, MD 20899

Dr.George Yoder 204
Office of Naval Research
Materials Division, Code 1131
800N. Quincy St.
Arlington, VA 22217-5000

Dr. Frederick Yost 203
Sandia National Lab.
Dept. 1830A
Albuquerque, NM 87108

Dr. Jacob Zindel 508
Ford Motor Company
Rm S-2046 SRL
PO Box 2053
Dearborn, MI 48121-2053