ROLE OF INTERFACES IN DEFORMATION AND STRENGTHENING (C)
The primary purpose of the conference was to bring together scientists and engineers concerned with the mechanical properties of finely structured materials with scientists interested in the structure and properties of interfaces. Many of the participants indicated that they had developed new ideas which they intended to pursue in the coming months. This is regarded by most as the primary benefit of the Gordon Research Conference.
FINAL REPORT

AFOSR GRANT (85-0219) FOR THE SUPPORT OF THE 1985 GORDON RESEARCH CONFERENCE ON PHYSICAL METALLURGY

"ROLE OF INTERFACES IN DEFORMATION AND STRENGTHENING"

Submitted to

Air Force Office of Scientific Research
Division of Research Grants, Building 410
Bolling AFB, Washington, D.C. 20332

Attention: Dr. Alan H. Rosenstein

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September, 1985
INTRODUCTION

The 1985 Gordon Research Conference on Physical Metallurgy was held 5-9 August 1985 at Holderness School in Plymouth, New Hampshire. The conference topic was "Role of Interfaces in Deformation and Strengthening". An AFOSR grant was made to the Gordon Research Conference to partially cover the travel and registration costs of some of the speakers and chairmen. A grant of $15,000 was made for this purpose. Of this total, $5,000 each was provided by AFOSR, ARO (150-85) and ONR (N0001485 RCM 2409). In this report we give a brief description of the conference and describe some of the highlights of the meeting.

CONFERENCE DESCRIPTION

The primary purpose of the conference was to bring together scientists and engineers concerned with the mechanical properties of finely structured materials with scientists interested in the structure and properties of interfaces. The joining of these two groups was expected to lead to the development of new ideas and to the cross-fertilization of these ideas. Following the tradition of previous Gordon Conferences, a relatively small number of speakers were invited to make presentations to the conference. The primary purpose of these talks was to stimulate discussion and thought on the topic of interfaces in deformation and strengthening. A copy of the program of speakers and chairmen is appended to this report.

A poster session was also held during the conference so that some of the participants could present their research results. A list of the poster presentations is also appended to this report.

The conference attracted participants from a wide variety of institutions
and countries. The list of participants appended to this report shows that a total of 96 scientists and engineers were a part of the conference. Of these, 75 were from the United States and 21 were from foreign countries. In terms of institutional affiliation, 60 were from universities, 23 from government laboratories or offices and 13 from industry. These figures are typical of most previous Gordon Conferences on Physical Metallurgy.

**PROGRAM HIGHLIGHTS**

The highlights of any Gordon Conference are the stimulating environment and the informal scientific discussions which lead to new ideas. Many of the participants indicated that they had developed new ideas which they intended to pursue in the coming months. This is regarded by most as the primary benefit of the Gordon Conference.

The lecture by Vitek set the tone for the first few days of the conference. He discussed the nature of grain boundary structure in terms of grain boundary dislocations. Through subsequent discussions, this served as an introduction to the concept that crystal dislocations can react with grain boundaries to form grain boundary dislocations. Thus the link between crystal plasticity and the structure of grain boundaries was established. This idea took explicit form in Grabski's lecture. He showed that when crystal dislocations run into grain boundaries they gradually "dissolve" and become part of the boundary structure. In this way one can think of crystal dislocations transforming to become grain boundary dislocations. When the dislocations have only recently entered the boundary they are called extrinsic dislocations but when they have completely "dissolved", new dislocations formed are called intrinsic dislocations.
because they are part of the structure of the boundary.

Arzt showed that the grain boundary dislocation structure can be extremely important in connection with high temperature creep of particle strengthened alloys. In particular, emission or absorption of vacancies at climbing grain boundary dislocations can be inhibited by the presence of grain boundary particles and this can lead to threshold stresses for diffusional creep.

One of the more exciting developments at the conference was presented by Briant who showed that first principle calculations of atomic configurations which resemble grain boundaries could be used to understand certain aspects of grain boundary cohesion. In particular, he showed that the presence of B tends to "increase cohesion" in Ni based materials while the presence of S tends to have the opposite effect. A limitation of the present technique is that the energy cannot be calculated reliably and that the cohesive strength cannot be determined directly.

Remarkable mechanical properties of multilayered crystals was reported by Tsakalakos. He described composite crystals consisting of alternating layers of Cu and Ni, each about 20-30 Å in thickness. In this dimensional regime the layers are fully coherent and the elastic stiffness of the composite is extremely large. Under some conditions the elastic modulus parallel to the layers is 5-10 times the expected modulus of the two materials. These unusual effects appear to be a consequence of the residual strain states found in these materials.

The classical subject of polycrystal hardening was reviewed at the conference. One new idea that emerged is that the ordinary Hall-Petch plot may indicate not only the effect of grain size on flow strength but
also the effect of grain boundary character. Annealing to produce a
given grain size may also determine the character of the grain
boundaries involved. This observation indicates the need for careful
studies of grain boundary hardening in which the nature and density of
grain boundaries are controlled separately.

Another exciting talk was given by Gleiter, who discussed an
entirely new class of materials called Nanocrystalline Solids. These
materials are made by forming and consolidating extremely fine powders
of ordinary metals. Grain sizes are typically a few nanometers
(20-30 Å) in diameter. Under these conditions about half of the atoms
in the solid reside in the regions between the crystals. These materials
are surprisingly stable and have extraordinary strength properties.

Interfaces play a key role in determining the mechanical properties
of microelectronic thin film materials. Some of the most recent research
in this area was discussed by Murakami of IBM and Flinn of Intel. These
reports represent the first efforts in this area, although this is a
rapidly growing area of research for the mechanical behavior community.
For many this was the first exposure to the importance of mechanical
properties in integrated circuit structures.

Although most of the program focused on grain boundaries, one very
exciting talk was given by Nutt on the structure of interfaces in metal
matrix composites. It is well known that the mechanical properties of
metal matrix composites are determined almost completely by the interfaces
between the fiber and matrix phases.
1985 GORDON CONFERENCE ON PHYSICAL METALLURGY

August 5-9, 1985, Holderness School, Plymouth NH

TOPIC: ROLE OF INTERFACES -- DEFORMATION AND STRENGTHENING

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Monday, August 5, 1985

SESSION I

GRAIN BOUNDARY STRUCTURE

Session Chairman:
Prof. T. Watanabe
Tohoku University
Sendai, Japan

8:30-9:10 AM GRAIN BOUNDARY DISLOCATIONS AND ATOMIC STRUCTURE OF GRAIN BOUNDARIES
Prof. V. Vitek
University of Pennsylvania
Philadelphia, Pennsylvania

9:10-9:25 AM DISCUSSION

9:25-10:00 AM ATOMISTIC CALCULATIONS AND GRAIN BOUNDARY STRUCTURE
Dr. P. Bristowe
Massachusetts Institute of Technology
Cambridge, Massachusetts

10:00-10:15 AM DISCUSSION

10:15-10:40 AM BREAK

10:40-11:00 AM ATOMIC LEVEL RESOLUTION OF GRAIN BOUNDARIES
Dr. W. Krakow
IBM Thomas J. Watson Research Center
Yorktown Heights, New York

11:00-11:15 AM DISCUSSION

11:15-11:50 AM SPREADING OF EXTRINSIC GRAIN BOUNDARY DISLOCATIONS
Prof. W.M Grabski
Warsaw Technical University
Warsaw, Poland

11:50-12:00 noon DISCUSSION
Monday, August 5, 1985

SESSION II

GRAIN BOUNDARY RELAXATION PROCESSES

Session Chairman:

Prof. A.K. Mukherjee
University of California, Davis
Davis, California

8:00-8:40 PM EXTRINSIC GRAIN BOUNDARY DISLOCATIONS AND DEFORMATION OF POLYCRYSTALS

Prof. K. Tangri
University of Manitoba
Winnepeg, Manitoba, Canada

Dr. R.A. Varin
University of Waterloo
Waterloo, Ontario, Canada

8:40-9:00 PM DISCUSSION

9:00-9:40 PM SLIP INTERFACE INTERACTIONS AT ELEVATED TEMPERATURES

Dr. M.H. Yoo
Oak Ridge National Laboratory
Oak Ridge, Tennessee

9:40-10:00 PM DISCUSSION
Tuesday, August 6, 1985

SESSION III

INTERFACE CONTROLLED PROCESSES

Session Chairman:

Prof. R. Gibala
University of Michigan
Ann Arbor, Michigan

8:30-9:10 AM INTERACTIONS BETWEEN CRYSTAL SLIP AND GRAIN BOUNDARIES IN NICKEL

Prof. R. Rai
Cornell University
Ithaca, New York

9:10-9:30 AM DISCUSSION

9:30-10:10 AM INTERFACE CONTROLLED DIFFUSIONAL CREEP

Dr. E. Arzt
Max Planck Institute
Stuttgart, West Germany

10:10-10:30 AM DISCUSSION

10:30-11:00 AM BREAK

11:00-11:40 AM GRAIN BOUNDARY MIGRATION

Prof. A.S. Argon
Massachusetts Institute of Technology
Cambridge, Massachusetts

11:40-12:00 noon DISCUSSION
Tuesday, August 6, 1985

SESSION IV

INTERFACIAL BONDING

Session Chairman:
Dr. B. Kear
Exxon Research and Engineering
Annandale, New Jersey

8:00-8:40 PM COHESIVE STRENGTH OF GRAIN BOUNDARIES
Dr. C.L. Briant
General Electric Company
Schnectady, New York

8:40-9:00 PM DISCUSSION

9:00-9:40 PM MECHANICAL PROPERTIES OF MODULATED STRUCTURES
Prof. T. Tsakalakos
Rutgers University
Piscataway, New Jersey

9:40-10:00 PM DISCUSSION
Wednesday, August 7, 1985

SESSION V

POLYCRYSTAL DEFORMATION

Session Chairman:

Prof. R.D. Doherty
Drexel University
Philadelphia, Pennsylvania

8:30-9:20 AM GRAIN SIZE STRENGTHENING:
YIELDING BEHAVIOR

Prof. H. Margolin
Polytechnic Institute of New York
New York, New York

POST YIELDING BEHAVIOR

Prof. A.W. Thompson
Carnegie Mellon University
Pittsburgh, Pennsylvania

9:20-9:40 AM DISCUSSION

9:40-10:20 AM TEXTURE AND MICROSTRUCTURAL EVOLUTION AT LARGE STRAINS

Prof. H. Mecking and Dr. J. Estrin
University of Hamburg
Hamburg, West Germany

10:20-10:40 AM DISCUSSION

10:40-11:00 AM BREAK

11:00-11:40 AM NANOCRYSTALLINE SOLIDS - AN APPROACH TO A NEW TYPE OF MATERIALS

Prof. H. Gleiter
University of Saarlandes
Saarbrucken, West Germany

11:40-12:00 noon DISCUSSION
Wednesday, August 7, 1985

SESSION VI

MECHANICAL PROPERTIES OF THIN FILMS

Session Chairman:
Dr. D. Gupta
IBM Watson Research Center
Yorktown Heights, New York

8:00-8:40 PM
MECHANICAL PROPERTIES OF THIN FILMS ON SUBSTRATES
Dr. M. Murakami
IBM Watson Research Center
Yorktown Heights, New York

8:40-9:00 PM
DISCUSSION

9:00-9:40 PM
MECHANICAL PROPERTIES OF INTERCONNECT AND PASSIVATION THIN FILMS
Dr. P.A. Flinn
Intel Corporation
Santa Clara, California

9:40-10:00 PM
DISCUSSION
Thursday, August 8, 1985

SESSION VII

GRAIN BOUNDARY SLIDING AND SUPERPLASTICITY

Session Chairman:

Prof. T.G. Langdon
University of Southern California
Los Angeles, California

8:30-9:05 AM ROLE OF INTERFACES IN SUPERPLASTIC DEFORMATION

Prof. B. Baudelet
Institut National Polytechnique de Grenoble
Grenoble, France

9:05-9:20 AM DISCUSSION

9:20-9:55 AM GRAIN BOUNDARY DISLOCATION CREEP

Prof. G.L. Dunlop
Chalmers University of Technology
Goteborg, Sweden

9:55-10:10 AM DISCUSSION

10:10-10:25 AM BREAK

10:25-11:00 AM EVOLUTION OF GRAIN SIZE DISTRIBUTION DURING SUPERPLASTIC DEFORMATION

Dr. A.K. Ghosh
Rockwell International Science Center
Thousand Oaks, California

11:00-11:15 AM DISCUSSION

11:15-11:50 AM STRAIN ENHANCED MICROSTRUCTURAL CHANGES DURING SUPERPLASTIC FLOW

Prof. D.S. Wilkinson
McMaster University
Hamilton, Ontario, Canada

11:50-12:05 PM DISCUSSION
Thursday, August 8, 1985

SESSION VIII

AFTER DINNER LECTURE

Session Chairman:

Prof. B. Wilshire
University College of Swansea
Swansea, Wales

8:30-9:30 PM  SOAP, CELLS AND STATISTICS - RANDOM PATTERNS IN TWO DIMENSIONS

Prof. D. Weaire
Trinity College
Dublin, Ireland

9:30-10:00 PM  DISCUSSION
Friday, August 9, 1985

SESSION IX

INTERFACE EFFECTS IN DEFORMATION AND STRENGTHENING

Session Chairman:

Prof. H. Oikawa
Tohoku University
Sendai, Japan

8:30-9:10 AM BOUNDARIES AND INTERFACES IN ALUMINUM BASED COMPOSITES

Dr. S. Nutt
Arizona State University
Tempe, Arizona

9:10-9:30 AM DISCUSSION

9:30-10:10 AM STRENGTHENING MECHANISMS IN ORDERED ALLOYS

Prof. D.P. Pope
University of Pennsylvania
Philadelphia, Pennsylvania

10:10-10:30 AM DISCUSSION

10:30-11:00 AM BREAK

11:00-11:40 AM DIFFUSIONAL AND SLIDING RELAXATION PROCESSES AT INCLUSIONS

Dr. D. Srolovitz
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

11:40-12:00 noon DISCUSSION
Poster Presentations
1985 Gordon Conference on Physical Metallurgy
W.D. Nix, Chairman
August 6, 1985, 5:00-6:00 pm

1. K. Maruyama and H. Oikawa
   Tohoku University
   "Grain Boundary Strengthening at Elevated Temperatures"

2. V. Raman and T.G. Langdon
   Univ. of Southern California
   "Grain Boundary Effects in High-Temperature Low-Cycle Fatigue"

3. J.-L. Martin
   Ecole Polytechnique Federale de Lausanne
   "Interaction of Dislocations and Creep Subboundaries"

4. J.H. Schnabel
   Oak Ridge National Laboratory
   "Grain Boundary Sliding in Metals and Alloys with Bamboo Structure"

5. J. Don and S. Majumdar
   Argonne National Laboratory
   "Creep Cavitation and Grain Boundary Structure in Type 304 Stainless Steel"

6. J.E. Harris
   Central Electricity Generating Board
   "Diffusional Properties of Oxide/Metal Interfaces"

7. M.F. Doerner and W.D. Nix
   IBM and Stanford University
   "Mechanical Properties of Thin Films Using Sub-Micron Indentation Measurements"

8. J.T. Wetzel
   IBM Thomas J. Watson Research Center
   "Computed Grain Boundary Structures in Silicon"
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