The work accomplished during the last six-month period (1 Apr 84 - 30 Sep 84) is reported below.

Work accomplished during the first six months is given in the Interim Technical Report (1 Oct 83 - 31 Mar 84), copy attached.

(Continued)
The Nb-Al system has been used as a model system to study the phase transformation in metastable alloys by using the superconductivity of the A15 phase to determine the composition with the highest Tc, and the lattice constant to determine the average composition. By depositing Nb-Al in a phase spread orientation onto substrates at 0°C, the bcc structure has been extended to about 40 at % (well above the equilibrium 9%). Subsequent annealing experiments transformed the bcc phase to A15. It was found that stoichiometric Nb₄Al could be formed in the A15 phase well above the concentration of the Al at equilibrium which is 22%, when the slopes of the free energy curves of the respective phases are equal. Thus the particular shape of the (free) energy curves is important and can determine the composition of the precipitated phase.

Nb-Sn-Ga alloys were prepared and studied as model systems to investigate the influence of third element additions on the normal and superconducting properties of alloyed Nb₃Sn phases. In spite of a decrease in the density of states at the Fermi level with increasing Ga content and upper critical field, Bc² was found to increase. Bc² maximized at 1 to 1.5 at % Ga for reaction temperatures at 700°C. High critical fields up to 31.5 T (at T=4.2K) have been achieved.

Additions of Nb, Ta, Sn, and Pt to V₃Ga were studied by co-deposition of the elements along with V and Ga. The accepted model of spin-orbit scattering predicts that substantial increases in critical field should have been observed. However, no increase was seen with any of the above additions. Further work is need to rule out unusual microstructural features before looking for a basic breakdown of the models of spin-orbit scattering.

New ion sources have been developed with high performance at low energy (1-100 ev) and high flux (.2 - 1.0 ma/cm²). The low energy prevents damage to ordered compounds and the high flux is desirable to match the arrival rate of evaporated metal atoms. The ion beam has been used in test runs to prepare NbN, C₃N₄, and in the hydrogen doping of amorphous Si. Future potential applications which have been identified include: (a) other compound syntheses (nitrides, carbides, oxides and borides of most elements); (b) surface mobility enhancement, including grain size control, internal strain modification, removal of impurities, gases, and low-temperature growth of ordered compounds; (c) interface modification of compounds (ion assisted wetting); (d) metastable high-pressure high-temperature phase formation.
ANNUAL TECHNICAL REPORT
FOR
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Contract No. F49620-82-0014
1 October 1983 - 30 September 1984

SUPERCONDUCTING THIN FILMS, COMPOSITES AND JUNCTIONS

By
Professor T. H. Geballe
Principal Investigator

Department of Applied Physics
Stanford University
Stanford, California 94305

G. L. Report 3783

October 1984
20. (Continued)

The Nb-Al system has been used as a model system to study the phase transformation in metastable alloys by using the superconductivity of the Al5 phase to determine the composition with the highest $T_c$, and the lattice constant to determine the average composition. By depositing Nb-Al in a phase spread orientation onto substrates at 0°C, the bcc structure has been extended to about 40 at% (well above the equilibrium 9%). Subsequent annealing experiments transformed the bcc phase to Al5. It was found that stoichiometric Nb-Al could be formed in the Al5 phase well above the concentration of the Al at equilibrium which is 22%, when the slopes of the free energy curves of the respective phases are equal. Thus the particular shape of the (free) energy curves is important and can determine the composition of the precipitated phase.

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(a) other compound syntheses (n. des, carbides, oxides and borides of most elements); (b) surface mobility enhancement, including grain size control, internal strain modification, removal of impurities, gases, and low-temperature growth of ordered compounds; (c) interface modification of compounds (ion assisted wetting); (d) metastable high-pressure high-temperature phase formation.


**Persons working on contract during the period**

1 April 1984 - 30 September 1984

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Ph.D. Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hammond, Robert H.</td>
<td>Senior Research Associate</td>
<td></td>
</tr>
<tr>
<td>Wellman, Frances</td>
<td>Ph.D. expected Winter 1985</td>
<td></td>
</tr>
<tr>
<td>Mael, David</td>
<td>Ph.D. expected Summer 1985</td>
<td></td>
</tr>
<tr>
<td>Broussard, Phillip</td>
<td>Ph.D. expected Summer 1985</td>
<td></td>
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<tr>
<td>Park, Sung</td>
<td>Ph.D. expected Summer 1986</td>
<td></td>
</tr>
<tr>
<td>Kent, Andrew</td>
<td>Ph.D. expected Summer 1986</td>
<td></td>
</tr>
</tbody>
</table>
Period: 1 Apr 84 - 30 Sep 84 (PI: T. H. Geballe)

Visitors and Seminars

1. George Mozurkewich, Physics Department, UCLA
   "Charged density waves"
   April 5, 1984

2. Gerd Bergmann, IFF der KFA Julich, West Germany
   "Weak localization in thin films -- a time-flight experiment with conduction electrons"
   April 17, 1984

3. Hidetoshi Fukuyama, Institute for Solid State Physics, University of Tokyo
   April 17, 1984

4. Masaki Suenaga, Brookhaven National Laboratory, Upton, NY
   May 16, 1984

5. V. Ambegaokar, Cornell University and Institute for Theoretical Physics, UC Santa Barbara
   "Microscopic theory of shot noise in the Josephson effect"
   May 17, 1984

6. G. Sawadsky, University of Groningen, The Netherlands
   "Electron spectroscopy studies of the electronic structure of dilute transition metal alloys"
   May 24, 1984

7. H. Poppa, NASA, Ames Research Center
   "Physics and chemistry of UHV deposited metal particles and clusters"
   June 7, 1984

8. J. E. Kunzler, AT&T Bell Laboratories
   June 25, 1984

9. Jean-Paul Maneval, ENS Physique des Solides, Paris, France
   August 1984

10. Atsushi Kome, Institute of Materials Science, University of Tsukuba, Ibaraki, Japan
    August 1984

11. William McLean, Rutgers University
    September - November 1984

12. H. Weinstock, AFOSR
    September 6, 1984

13. R. Flukiger, Institute fur Technische Physik, Karlsruhe, FRG
    September 13, 1984
Visitors and Seminars (Continued)

   September 14, 1984

15. Rudi Bormann, Universitat Gottingen, FRG  
   September 15-30, 1984

16. Tord Claesson, Chalmers University of Technology, Gothenburg, Sweden  
   September 17-21, 1984

17. Alex Braginski, Westinghouse Research Laboratories, Pittsburgh, PA  
   September 17, 1984

18. Oystein Fischer, E.T.H., Switzerland  
   September 18-19, 1984
Committees

The National Research Council

Solid State Science Committee

Ad Hoc Committee for NSF-MRL Directors

Member, Editorial Board of Chinese Physics, AIP

Member, Editor for Materials Letters, North-Holland Publishing Company, The Netherlands

Member, Committee for the American Physical Society International Prize for New Materials

Member, Advisory Board of the Miller Institute for Basic Research in Science

Member, Program Committee for meeting on "Materials and Mechanisms of Superconductivity" in Ames, Iowa, May 29-31, 1985

Scientific projects are being carried out in close collaboration with industry

R. M. White, Xerox Corporation, Palo Alto, California
J. Boyce, Xerox Corporation, Palo Alto, California

I. H. Wernick, Bell Laboratories, Murray Hill, New Jersey
J. M. Rowell, Bell Laboratories, Murray Hill, New Jersey
C. W. Hull, Bell Laboratories, Murray Hill, New Jersey
M. Hong, Bell Laboratories, Murray Hill, New Jersey
W. P. Lowe, Bell Laboratories, Murray Hill, New Jersey

R. Greene, IBM, San Jose, California

J. Harper, IBM, Yorktown Heights, New York

A. Braginski, Westinghouse Research Laboratories, Pittsburgh, Pennsylvania

A. Green, Naval Research Lab, China Lake, California
V. Rehn, Naval Research Lab, China Lake, California

New discoveries, inventions or patent disclosures

None
INTERIM TECHNICAL REPORT
FOR
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Contract No. F44620-82-C-0014
1 October 1983 - 31 March 1984

SUPERCONDUCTING THIN FILMS, COMPOSITES AND JUNCTIONS

By
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Principal Investigator

Department of Applied Physics
Stanford University
Stanford, California 94305

G. L. Report 3722

April 1984
**Title:** Superconducting Thin Films, Composites and Junctions

**Report Date:** April 1974

**Controlled Office Name and Address:**
Air Force Office of Scientific Research
Building AFB Building H, Washington, D.C.

**Distribution Statement:** Approved for public release; distribution unlimited.

**Abstract:**
The first specific heat measurements on artificially layered superconducting composite structures have been made. Small sample calorimeter has been used to measure the specific heat of Nb2Zr multilayers with a bi-layer period varying from 10 A to 420 A (to a sample thickness of 1.5 um) over the temperature range from 1.5 to 10K. The normal state parameters agree with the presence of an interface of an Nb Zr alloy in agreement with earlier X-ray results. The behavior of the thermally measured transition into the superconducting state and the magnitude of the associated specific heat increase also agree with the...
tri-layer model.

The presence of oxygen during the growth of NbGe films is known to be essential for forming A-15 structures with the highest known superconducting transition temperatures. Experiments have been initiated to discover the role that oxygen plays. They show surprisingly that no oxygen is present in the film upon removal from the evaporator. The non-presence of oxygen has been found to eliminate a number of possible models. Evidence has been obtained for a model in which the oxygen is present in the film during growth at high ~300°C, but that it diffuses out as the film cools down. Techniques have been introduced using a thin layer of the yttrium as a getter for the oxygen, combined with Auger profiling, in order to obtain the evidence.

The use of added thermally oxidized metallic coatings on single-crystal Nb surfaces has been found to modify the tunneling parameters systematically. High quality Nb/ZrO2/Pb and Nb/TlO2/Pb Josephson tunnel junctions based on single crystal niobium thin films coated with either Zr or Tl have been fabricated by thermal oxidation. The specific capacitance of these junctions has been determined from Fiske modes and Josephson interference patterns and found to be considerably less than found for oxide surfaces prepared upon polycrystalline pure Nb surfaces in a similar way. The ZrO and TlO barriers offer new possibilities for fabricating all refractory niobium-Josephson junction devices.


VISITORS AND SEMINARS

1. Dr. M. Gurvitch, Bell Laboratories
   "Boltzmann Transport and the Saturation of Electrical Resistivity"
   October 6, 1983

2. Dr. Gloria Lubkin, Editor, Physics Today
   "The Search for Stories: The Stories for Search"
   October 26, 1983

3. Dr. Jim McGroddy, IBM, Yorktown Heights
   October 27, 1983

4. Dr. Gerd Binnig, IBM Zurich Research Laboratory
   "Scanning Tunneling Microscopy, an Atomic Surface Probe"
   November 11, 1983

5. Professor Hans Dehmelt, University of Washington
   "Elementary Particle at Rest in Space: g-Factors and Structure of E^-/E^-
   November 11, 1983

6. Dr. Zachary Fisk, Los Alamos National Laboratory
   "Uranium Based Electronic Analogs of 3He-Helium(?)"
   November 22, 1983

7. Professor Sidney Drell, Deputy Director SLAC
   "Nuclear Weapons: Defense vs. Deterrents"
   November 30, 1983

8. Dr. James Boyce, Xerox, Palo Alto
   "Microstructure of Random Solid Solutions: EXAFS Studies"
   December 8, 1983

9. Dr. Richard Koyama, Tektronix Inc. Beaverton, Oregon
   January 5, 1984

10. Dr. Clyde Kinnall, Northeastern University
    January 5, 1984

11. Professor Rudolf Peierls, Oxford University, ENGLAND
    "Momentum and Pseudo-Momentum"
    January 17, 1984

12. Dr. Gordon C. Osbourn, Sandia Laboratories
    "Strained Layer Semiconductors"
    January 26, 1984

13. Professor M. Brian Maple, University of San Diego
    "Superconductivity, Magnetism and a Possible New Superconducting State"
    January 11, 1984
VISITORS AND SEMINARS (Cont.)

14. Dr. F. DiSalvo, Bell Laboratories
   "Non-Linear Charge Density Wave Properties of Potassium
   Molybdenum Bronze (K\textsubscript{0.3}MoO\textsubscript{3})"
   February 2, 1984

15. Dr. Bernardo Huberman, Xerox PARC
   "Dynamics of Computing Structures"
   February 15, 1984

16. Dr. John Rowell, Bell Laboratories
    February 12-23, 1984

17. Dr. Jene Golovchenko, AT&T Bell Laboratories
    "X-ray Wave Optics at 1 Å"
    February 23, 1984

18. Dr. R. Becker, AT&T Bell Laboratories
    "Alice in Wonderland: Atomic Surfaces Imaged with
    AT&T Bell Labs Tunneling Microscope"
    March 9, 1984

19. Dr. George S. Brown, Dept. of Applied Physics & SSRL
    "Recent Advances in Synchrotron Radiation Research"
    March 14, 1984

20. Dr. A. Kapitulnik, University of California, Santa Barbara
    "Percolation Processes in Thin Films"
    March 12, 1984

21. Dr. J. Orenstein, AT&T Bell Laboratories
    "Photogenerated Excitations in Conducting Polymers"
    March 15, 1984
COMMITTEES (T. H. Geballe)

The National Research Council
Assembly of Mathematic and Physical Sciences
Solid State Science Committee

Ad Hoc Committee for NSF-MRL Directors

Member, Editorial Board of Chinese Physics, AIP

Member, Editorial Advisor for Physics and Chemistry of Materials with Low-Dimensional Structures, D. Reidel Publishing Company, Dordrecht, Holland

Member, Editor for Materials Letters, North-Holland Publishing Company, The Netherlands

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C. W. Hull, Bell Laboratories, Murray Hill, New Jersey
M. Hong, Bell Laboratories, Murray Hill, New Jersey
W. P. Lowe, Bell Laboratories, Murry Hill, New Jersey
R. Greene, IBM, San Jose, CA
J. Harper, IBM Yorktown Heights, New York
A. Braginski, Westinghouse Res. Laboratories, Pittsburgh, PA
A. Green, Naval Research Lab., China Lake, CA
V. Rehn, Naval Research Lab., China Lake, CA

New Discoveries, Inventions or Patent Disclosures

NONE
Persons Working on Contract During the Period
1 October 1983 - 31 March 1984

Hammond, Robert H. Senior Research Associate
Hellman, Frances Ph.D. expected Fall 1984
Mael, David Ph.D. expected Summer 1985
Yoshizumi, Shozo Ph.D. expected Summer 1985
Broussard, Phillip Ph.D. expected Summer 1985
Park, Sung Ph.D. expected Summer 1986
Kent, Andrew Ph.D. expected Summer 1986