HARD SUPERCONDUCTING MATERIALS

Final Report

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ABSTRACT

During the period covered by this program (1962-1971), extensive studies of the material parameters and mechanisms controlling critical currents, flux creep and irreversibility in hard superconducting materials were carried out. Quantitative theories of the pinning and creep processes were developed and tested extensively using equipment and methods developed locally. The role of the superconducting surface sheath was explored in detail and somewhat similar phenomena were found to operate there. The superconducting quantum interferrometry developed for the creep studies proved to be an extremely valuable tool in the study of quantum fluctuations in one-dimensional superconductors. Initial attempts to study the flux structure by low temperature electron microscopy proved non-productive but later studies using the Bitter pattern technique of Trauble and Essmann were of value in the study of the flux structure transitions in thin films. Development of instrumentation based on superconducting technology such as a femtovoltmeter and practicable point contact flux detectors also arose under the program.

During the period (1962-1971) covered by the grant AT(11-1)-3156, "Hard Superconducting Materials", we prepared and distributed the 62 reports including approximately 50 publications described in the attached listing. These publications and reports describe in detail our research in this program and can be read for more information about it. Subsequent to the termination of funding in 1971, research still in progress continued under a variety of alternative sponsorships, until very recently. The last students who started their graduate research with research assistantships under this grant have just completed their Ph.D. degrees this year.

Some of the principal scientific contributions of our program are listed below:

1. Contributions to the basic understanding of the materials parameters and mechanisms controlling critical currents, flux creep and irreversibility in hard superconducting materials;
2. Development of an understanding of effects of materials parameters and crystal lattice defects on irreversibility in the superconducting sheath at high fields;
3. Determination of the alternating current properties of superconductors in the sheath region and demonstration that a.c. properties of superconductors were unfortunately not likely to be useful at magnetic fields between the upper critical field H_{c2} and the sheath field H_{c3} ;
4. Development of quantitative theories of pinning and creep in hard superconductors containing crystal dislocation;
5. Quantitative measurements of flux creep in hard superconductors;
6. Observation of quantum fluctuations in one-dimensional superconductors and demonstration of thermally activated phase-slip and tests of the applicability of theories based on time dependent Ginsburg-Landau theory;

7. Development of a superconducting femtovoltmeter and practicable point contact flux detectors as routine laboratory instruments;

8. Determination of the microcrystalline structure of thin films with high T_c 's and direct observations of the magnetic structure of thin films leading to observations of the transition from type I to type II behavior.

The list of titles of the publications and reports prepared under this program give a better indication of its scope and style. The reader is referred there for further information and finally to the publications for details.

We believe that this program contributed substantially to the development of understanding of hard superconductors and thus provided an appreciable part of the foundation for the technology now being applied to superconducting electrical power equipment such as transmission lines, motors and generators. Our work on fluctuations in superconductors, which was initiated as part of this program, similarly has contributed to the development of the technology of sensitive superconducting instruments.

Publications

- NYO-3029-1 M. R. Beasley, W. A. Fietz, R. W. Rollins, J. Silcox and W. W. Webb
"Annihilation Instability in Hard Superconductors"
- NYO-3029-2 R. H. Geiss, W. G. Lehman, M. Mistrich, R. W. Rollins and J. Silcox
"Some Comments on Acid-Saw Techniques"
Co#: NYO-3087-2
- NYO-3029-3 W. A. Fietz
"An Electronic Integration Scheme for Obtaining Magnetization Data on Hard Superconductors"
Later submitted as: "Electronic Integration Technique for Measuring Magnetization of Hysteretic Superconducting Materials"; NYO-3029-26
- NYO-3029-4 Annual Progress Report 1964-65
- NYO-3029-5 V. Matricardi
"Electron Microscopy Study of Magnetic Domain Configuration in Chromium Tribromide and Associated Contrast Theory"
- NYO-3029-6 W. A. Fietz
"A Stable Current Regulator for Superconducting Solenoids"
- NYO-3029-7 Norihisi Kitamura
"The Temperature Dependence of Diffuse Streaks in Single Crystal Silicon Electron Diffraction Patterns"
- NYO-3029-8 Wolfgang Gey
"Influence of Lattice Structure on Superconductivity in Thallium"
Later submitted as NYO-3029-25
- NYO-3029-9* Annual Progress Report 1965-1966
- NYO-3029-9* R. W. Rollins and J. Silcox
"Low Frequency Transitions and Critical Currents in the Superconducting Surface Sheath"
Duplicate submission NYO-3029-28
- NYO-3029-10 R. W. Rollins and J. Silcox
"Low Frequency Transitions and Critical Currents in the Superconducting Surface Sheath"
Duplicate listing.
- NYO-3029-11 Wolfgang Gey
"Increase of the Anisotropy of the Energy Gap in Superconducting Thallium under Pressure"

*Number assigned twice in error.

- NYO-3029-12 R. W. Rollins and J. Silcox
"The Nature of AC Transition in the Superconducting Surface Sheath in Pb 2% In"
- NYO-3029-13 R. W. Rollins
"The Nature of AC Transitions and Critical Currents in the Superconducting Surface Sheath"
Thesis
- NYO-3029-14 W. W. Webb and W. A. Fietz
"Mechanisms Determining Critical Magnetization Current Densities in Cold Worked Type II Superconductors"
- NYO-3029-15 Robert F. Engle
"Analysis of a Superconducting Solenoid and of Flux Flow Velocity Using an NMR Field Probe"
Thesis
- NYO-3029-16 N. Kitamura, O. N. Srivastava and J. Silcox
"A Tilt and Magnetic Stage for Operation at Liquid Helium Temperatures"
Co#: NYO-3087-8
- NYO-3029-17 V. Matricardi, W. G. Lehman, N. Kitamura and J. Silcox
"Magnetic Domains in Chromium Tribromide"
Co#: NYO-3087-9
- NYO-3029-18 R. W. Rollins and J. Silcox
"Surface Instabilities in Type II Superconductors"
- NYO-3029-19 W. A. Fietz and W. W. Webb
"Magnetic Properties of Some Type II Alloy Superconductors Near the Upper Critical Field"
- NYO-3029-20 W. A. Fietz
"Reversible and Irreversible Magnetic Properties of Some Type II Alloy Superconductors"
Thesis
- NYO-3029-21 S. Burns
"Dynamical Cleavage of LiF: Fracture Surface Energies of a Dislocation Process and Transfer Fracture Markings"
Thesis
- NYO-3029-22 R. Labusch
"Elasticity Effects in Type II Superconductors"
Duplicate submission NYO-3029-28
- NYO-3029-23* M. R. Beasley and W. W. Webb
"Operation of Superconducting Interference Devices in Appreciable Magnetic Fields"

*Numbers assigned twice in error.

- NYO-3029-23* V. Matricardi, W. G. Lehman, N. Kitamura and J. Silcox
"Electron Microscope Observations of Ferromagnetic Domains
in Chromium Tribromide"
Co#: NYO-3087-11
- NYO-3029-24 Progress Report for the period June 1, 1966 to November 30, 1967.
- NYO-3029-25 Wolfgang Gey
"Influence of Lattice Structure on Superconductivity in Thallium "
Previously submitted as NYO-3029-8.
- NYO-3029-26 W. A. Fietz
"Electronic Integration Technique for Measuring Magnetization
of Hysteretic Superconducting Materials"
Previously submitted as "An Electronic Integration Scheme for
Obtaining Magnetization Data on Hard Superconductors";
NYO-3029-3.
- NYO-3029-27 W. W. Webb and R. J. Warburton
"Intrinsic Quantum Fluctuations in Uniform Filamentary
Superconductors"
- NYO-3029-28* R. W. Rollins and J. Silcox
"Low Frequency Transitions and Critical Currents in the
Superconducting Surface Sheath"
Duplicate submission NYO-3029-9
- NYO-3029-28* R. Labusch
"Elasticity Effects in Type II Superconductors"
Duplicate submission NYO-3029-22.
- NYO-3029-29 M. R. Beasley
"Flux Creep in Hard Superconductors"
Thesis
- NYO-3029-30 W. A. Fietz and W. W. Webb
"Hysteresis in Superconducting Alloys--Temperature and Field
Dependence of Dislocation Pinning in Niobium Alloys"
- NYO-3029-31 R. Brand and W. W. Webb
"Effects of Stress and Structure on Critical Current Densities
in Superconducting V_3Si "
- NYO-3029-32 R. Labusch
"Elastic Constants of the Fluxoid Lattice Near the Upper
Critical Field"
- NYO-3029-33 W. W. Webb
"Voltage Steps in the Resistive Transitions of Superconducting
Microcrystals"

*Numbers assigned twice in error.

NYO-3029-34* J.F. Emerson
"Dynamic Response of the Superconducting Surface Sheath"
Thesis
Duplicate submission NYO-3029-46

NYO-3029-34* W. W. Webb
"Determination of T_c from Resistance Measurements"

NYO-3029-35* W. W. Webb
"Critical Current Behavior of Hard Superconductors"

NYO-3029-35* C. H. Arrington, III
"Rate Dependent Effects in the A.C. Response of the Superconducting Surface Sheath"
Thesis
Duplicate submission NYO-3029-47

NYO-3029-36* J. Gosselin, J. U. Trefny and J. Silcox
"Flux Motion Through the Superconducting Surface Sheath"

NYO-3029-36* Progress Report for December 1, 1967 through November 30, 1968.

NYO-3029-37 M. R. Beasley, R. Labusch and W. W. Webb
"Flux Creep in Type II Superconductors"

NYO-3029-38 R. J. Warburton, B. R. Patton, J. W. Wilkins and W. W. Webb
"Fluctuation Effects in the Resistive Transition of Thin Filamentary Superconductors"
(Technical Report #9; ONR/N0014-A-0077-0010)

NYO-3029-39 Annual Progress Report 1968-69

NYO-3029-40 R. A. Brand, S. A. Letzring, H. S. Sack and W. W. Webb
"Dielectric Cryogenic Thermometer for Use in High Magnetic Fields"
Final version: "Dielectric Low...Fields"
Co#: NYO-2471-46

NYO-3029-41 W. W. Webb
"Mechanisms Determining the Critical Current in Hard Superconductors"

NYO-3029-42 J. E. Lukens, R. J. Warburton and W. W. Webb
"Versatile Superconducting Femtovolt Amplifier and Multimeter"

NYO-3029-43 R. Labusch
"Calculation of the Critical Field Gradient in Type II Superconductors"

NYO-3029-44 R. J. Warburton, J. E. Lukens and W. W. Webb
"Fluctuations Near the Onset of the Resistive Transition in Filamentary Superconductors"

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- NYO-3029-45 R. J. Warburton and W. W. Webb
"Fluctuations Near the Phase Transition in 'One-Dimensional'
Superconductors"
- NYO-3029-46 J. F. Emerson
"Dynamic Response of the Superconducting Surface Sheath"
Thesis
Duplicate submission NYO-3029-34
- NYO-3029-47 C. H. Arrington, III
"Rate Dependent Effects in the A.C. Response of the Super-
conducting Surface Sheath"
Thesis
Duplicate submission NYO-3029-35
- NYO-3029-48 Progress Report, December 1, 1969 - November 30, 1970
- NYO-3029-49 J. E. Lukens, R. J. Warburton and W. W. Webb
"Onset of Quantized Thermal Fluctuations in 'One-Dimensional'
Superconductors"
- NYO-3029-50 R. J. Warburton
"Fluctuations Near the Phase Transition in 'One-Dimensional'
Superconductors"
- NYO-3029-51 W. H. Henkels and W.W. Webb
"Intrinsic Fluctuations in the Driven Josephson Oscillator"
(Technical Report #2; ONR#N000-67-A-0077-0016)
- NYO-3156-52 R. A. Brand
"The Paramagnetic Critical State: Pinning in a Series of
Type II Superconducting Alloys"
- C00-3156-53 R. B. Pettit
"Structure and Enhanced Superconductivity of Evaporated
Aluminum Films"
- C00-3156-54 G. J. Dolan and J. Silcox
"Transition to the Mixed State in Lead Films at 4.2°K"
- C00-3156-55 R. B. Pettit, J. Silcox and R. Vincent
"Measurement of Surface Plasmon Dispersion in Oxidized
Aluminum Films"
- C00-3156-56 J. H. Claassen
"Fluctuation Diamagnetism of Aluminum and Aluminum Alloys
above the Superconducting Transition Temperature"
- C00-3156-57 W. H. Henkels
"Intrinsic Fluctuation Effects and Certain Other Aspects of
Superconducting Weak Links"
Thesis

- C00-3156-58 R. B. Pettit and J. Silcox
"Oxide Structure in 'Dirty' Aluminum Films"
- C00-3156-59 R. B. Pettit and J. Silcox
"Film Structure and Enhanced Superconductivity in Evaporated
Aluminum Films"
- C00-3156-60 Final Report