

AD-A092 387

WISCONSIN UNIV-MILWAUKEE DEPT OF PHYSICS F/G 20/3
CHARACTERIZATION OF SUPERCONDUCTORS BY SURFACE WAVE TECHNIQUES.(U)
OCT 80 M LEVY AFOSR-76-2893

UNCLASSIFIED

AFOSR-TR-80-1173

NL

1 1 1
AD-A092 387



END
DATE
FILMED
1 81
DTIC

AD A092387

DDC FILE COPY

1. REPORT NUMBER AFOSR-TR-80-1178		2. GOVT ACCESSION NO. AD-A092387		3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) CHARACTERIZATION OF SUPERCONDUCTORS BY SURFACE WAVE TECHNIQUES.				5. TYPE OF REPORT & PERIOD COVERED Final 10/1/75 - 9/30/80	
7. AUTHOR(s) Moises/Levy				8. CONTRACT OR GRANT NUMBER(s) AFOSR-76-2893	
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Wisconsin-Milwaukee Department of Physics Milwaukee, Wisconsin 53201				10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2306/CL 61102F	
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Office of Scientific Research/NE Bolling AFB Building 410 Washington, D. C. 20332				12. REPORT DATE Oct 1980	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) LEVEL				13. NUMBER OF PAGES 30	
				15. SECURITY CLASS. (of this report) UNCLASSIFIED	
				15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited					
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) Final rept. 1 Oct 75-3p Rep. 1p.					
18. SUPPLEMENTARY NOTES					
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)					
surface wave		Superconducting function		upper critical field	
superconductors		electron mean free path		NbN	
Beta-tungsten		Nb ₃ Sn		superconducting excitations	
Rocksalt structure		Superconducting energy gap		superconducting currents	
Nb ₃ Ge				nickel films	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)					
The objective of this research project was to initiate a program to characterize superconductors by means of ultrasonic surface waves. Initially thin films Beta-tungsten and rocksalt superconductors were investigated. Measurements on Nb₃Ge determined the superconducting fraction of the film as a function of temperature and the electron mean free path. Measurements on Nb₃Sn determined the temperature dependent of superconducting energy gap and the upper critical field of the film. Measurements on several NbN films appear					

DTIC
ELECTIC
DEC 3 1980

407839

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

19. Key Words - continued

ternary superconductor
reentrant superconductor
 ErRh_4B_4
magnetic field
type II/I superconductor
transverse staggered susceptibility
screened
bulk superconductors
mixed state
polycrystalline alloys
thin superconducting films
non-homogeneous
magnetic contribution
superconducting properties
vanadium
titanium
molybdenum
aluminum
magnetization curves
upper critical field
vortex anti-vortex structure
fluctuations
NbMo alloys
Ginzburg-Landau parameter
structural phase transition
dislocation damping
first order phase transition
mean field model
susceptibility
ferromagnetic transition
diamagnetic thermodynamic critical
field
microphotolithographic laboratory
cryogenics laboratories

dilatometer
thermal expansion coefficient
solution hardened titanium alloys
localized spins
ZnO films
terbium
Dysprosium
Type II superconductors
electron-phonon interaction
Erbium
induced magnetic order
sputtered films
aluminum nitride
 $\text{Nb}_{0.3}\text{Al}_{0.25}\text{Ge}_{0.75}$
ternary alloys
 LuRh_4B_4
 HoRh_4B_4
 YtRh_4B_4
amorphous superconductors
lithium niobate
quartz
amorphous molybdenum films
two dimensional superconductors
 NbSe_2
 MoSe_2
Chevrel Phase Superconductors
 PbMo_6S_8
tin based ternary single crystals
 $\text{Er}_x\text{Ho}_{1-x}\text{Rh}_4\text{B}_4$

20. Abstract - continued

to indicate that there is a new interaction mechanism between the surface wave and the superconducting excitations in this rocksalt structure compound.

The initial phase of the study on the effect of nickel films on the propagation of ultrasonic surface waves has been completed.

Ultrasonic measurements have been performed on a polycrystalline sample of the ternary reentrant superconductor ErRh_4B_4 as a function of temperature where it is superconducting. Evidence is obtained for characterizing this superconductor as type II/I and for the fact that the transverse staggered susceptibility is screened by superconducting currents in the mixed state.

Ultrasonic measurements have been performed in the superconducting and mixed states of bulk superconductors.

4

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

7500 21 500

Final

RESEARCH OBJECTIVES

The objective of this research project was to initiate a program to characterize superconductors by means of ultrasonic surface waves. This is a unique technique for ultrasonically investigating superconducting properties of polycrystalline alloys and thin superconducting films which may be extremely non-homogeneous. Initially thin films of Beta-tungsten and rocksalt structure superconductors were to be characterized.

A program was initiated to investigate the superconducting ternary alloys with ultrasonic bulk waves in order to separate the magnetic contribution to the superconducting properties of these alloys.

A study of the effect of nickel films on the propagation of surface waves was initiated.

An investigation of the ultrasonic attenuation coefficient in the superconducting and mixed state of bulk Beta-tungsten alloys, alloys made of titanium, molybdenum aluminum and niobium, and very pure vanadium was initiated in order to characterize the superconducting properties of these materials.

The magnetization of some of these superconductors was measured in order to correlate this quantity with the data obtained ultrasonically.

Accession For	
NTIS GRA&I	☒
ERIC TAB	☐
Unannounced	☐
Classification	
By	
Distribution/	
Availability Codes	
and/or	
Special	
A	

AFOSR-76-2893

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (AFSC)
NOTICE OF TRANSMITTAL TO DDC
This technical report has been reviewed and is
approved for release under E.O. 12958 (7b).
Distribution is unlimited.
A. D. Steele
Technical Information Officer

RESEARCH ACCOMPLISHMENTS

The ultrasonic attenuation coefficient of surface waves propagating through superconducting Nb_3Ge films has been measured. This data has been used to determine the temperature at which different fractions of the film become superconducting and also to determine the mean free path in the film. Measurements have also been performed on Nb_3Sn films. These data yield the temperature dependence of the superconducting energy gap in Nb_3Sn and the upper critical field of this film. Both have a Beta-tungsten or A15 crystallographic structure. Measurements have been performed on several NbN films. The data appears to indicate that there is a new interaction mechanism between the surface waves and the superconducting excitations in this rocksalt structure superconductor. Attempts are being made to determine if this additional interaction may be attributed to the presence of a vortex anti-vortex structure in these films.

The investigation of the effect of Ni films on the propagation of ultrasonic surface waves has discovered that a large effect is produced for $200 \text{ \AA}$ films when low magnetic fields are applied in the plane of the Ni film. A theoretical model has been developed that appears to explain the qualitative features and the magnitude of the effect.

A theoretical model has been developed to extract the attenuation of a film from measurements of the attenuation of a surface acoustic wave that traverses both the film and the substrate supporting the film.

The contribution of fluctuations to the ultrasonic attenuation properties of type II superconductors near their upper critical field

was determined.

Measurements on a bulk beta-tungsten alloy were initiated and measurements in the mixed state of NbMo alloys were performed.

Magnetization measurements were performed on single crystals of vanadium in order to obtain values for their Ginzburg-Landau parameters.

A dilatometer that can be used to measure the thermal expansion coefficient of large and small samples at cryogenic temperatures has been constructed and calibrated.

Ultrasonic measurements have been performed on a polycrystalline sample of ErRh_4B_4 as a function of both temperature and magnetic field in the temperature range where it is superconducting. In the absence of a magnetic field, a broad attenuation maximum appears in this temperature range. The maximum may be due to a structural phase transition or to dislocation damping. The magnetic field data appears to yield unequivocal evidence for categorizing the transition at the lower critical field as a first order phase transition; and, therefore a type II/I transition. The behavior of the attenuation at the upper critical field indicates that the transverse staggered susceptibility is screened by superconducting currents immediately below the upper critical field. These two observations confirm recent theoretical predictions. Maxima in the attenuation coefficient as a function of temperature in constant magnetic fields appear to correlate with distinctive features of the magnetization curves evaluated using a mean field model.

The magnetization and susceptibility curves of ErRh_4B_4 have been measured experimentally from below the ferromagnetic transition temperature to above the superconducting transition temperature.

Tentative evidence for a small coexistence region is obtained. The diamagnetic contribution to the thermodynamic critical field is evaluated as a function of temperature.

The microphotolithographic laboratory was moved from the Engineering Building to a laboratory adjoining one of the cryogenics laboratories in the Physics Building. The laboratory is now operational.

TECHNICAL PERSONNEL

In addition to the principal investigator the following technical personnel have worked on this grant. The University has supported some of these personnel as part of their matching commitment.

Dr. Ralph A. Treder (Postdoctoral Fellow) 2 years.

Constructed and calibrated dilatometer for measuring thermal expansion coefficient of solution hardened titanium alloys.

Professor Masashi Tachiki (Visiting Professor) 2½ months.

Developed theory for the magnetic susceptibility of nickel films and the attenuation of surface acoustic waves by nickel films. Developed theoretical model for the interaction of ultrasonic waves with localized spins in a reentrant ternary alloy.

Mr. I-an Feng (Graduate Research Assistant) 3½ years

Received Ph.D. May, 1979. Effects of thin nickel films on surface wave propagation.

Mr. Hans Fredricksen (Graduate Research Assistant) 5 years.

Received Master's Degree May, 1977. Preparation of surface wave devices for surface wave investigation of Nb_3Ge , Nb_3Sn , and Ni films. Development of sputtering techniques for producing surface acoustic waves with ZnO films. Surface wave investigation of Nb_3Sn films.

Mr. Guo-Tai Lee (Graduate Research Assistant) 3 years.

Received Master's Degree August, 1979. Thermal expansion coefficient of solution hardened titanium alloys. Preparation of surface wave devices for surface wave investigation of Ni films and NbN films.

Ms. Ruby Chen Lee (Graduate Research Assistant) 2 years.

Received Master's Degree August, 1979. Ultrasonic investigation of superconducting alloys and pure vanadium single crystals.

Mr. Harry L. Salvo, Jr. (Graduate Research Assistant) 3½ years.

Received Ph.D. May, 1979. Surface Wave Investigation of Nb₃Ge Films.

Ms. Susan C. Schneider (Graduate Research Assistant) 5 years.

Elastic constants of solution hardened titanium alloys, the effect of fluctuations at H_{c2} in pure niobium and vanadium single crystals, and the ultrasonic investigation of superconducting ternary alloys.

PUBLICATIONS

1. Ultrasonic Study of Terbium in a Magnetic Field, S. Maekawa, R. A. Treder, M. Tachiki, and M. Levy, Phys. Rev. B. 13, 1284 (February 1, 1976).
2. Magnetic Field-Dependent Attenuation of Surface Waves by Nickel Thin Films, C. Krischer, I. Feng, J. B. Block and M. Levy, Applied Physics Letters, Vol. 29, 76 (15 July 1976).
3. Temperature Dependence of the Interaction Between Surface Waves and Thin Nickel Films, I. Feng, C. Krischer, M. Lee, and M. Levy, Physics Letters 59A, (No. 4) 329 (1976).
4. New Ultrasonic Maxima for Single Crystal Dysprosium in a Magnetic Field, R. A. Treder, S. Maekawa and M. Levy, Physics Letters 59A, (No. 3), 245 (1976).
5. Surface Acoustic Wave Investigation of Superconducting Films, Moises Levy, Harry Salvo, Jr., David A. Robinson, Kazumi Maki and Masashi Tachiki, Proceedings 1976 IEEE Ultrasonic Symposium, p. 633 (76 CH 1120-5 SU, Editor J. de Klerk, IEEE, New York, 1976).
6. Magnetic Field Dependent Attenuation of Surface Waves by Nickel Thin Films, Charles Krischer, I-an Feng, Jeffrey B. Block and Moises Levy, Proceedings 1976 IEEE Ultrasonic Symposium, p. 642 (76 CH 1120-5 SU, Editor J. de Klerk, IEEE, New York, 1976).
7. Ultrasonic Attenuation Investigation of the Mixed State in Three Vanadium Samples of Varying Purity, J. Waynert, H. Salvo, Jr., S. Schneider, and M. Levy, Phys. Rev. B15, 2559 (1977).
8. Fluctuation Contribution to Sound Attenuation in a Clean Type II Superconductor, S. Schneider, J. Waynert, M. Levy, and K. Maki, Phys. Rev. B15, 2600 (1977).
9. Ultrasonic Study of Dysprosium in a Magnetic Field, R. A. Treder and M. Levy, Journal of Magnetism and Magnetic Materials 5, 9 (1977).
10. Ginzburg-Landau Parameters for a Vanadium Single Crystal of $T_c = 7$, F. Behroozi, H. Salvo, and M. Levy, Journal of Low Temperature Physics, 29, #1-2, 89 (1977).
11. Correlation Between the Magnetic Susceptibility of Nickel Films and their Effect on Surface Acoustic Waves, I-an Feng, Hans Fredrickson, Charles Krischer, M. Tachiki, and Moises Levy, Proceedings 1977 IEEE Ultrasonic Symposium, p. 328 (77 CH1264-1SU Editors J. deKlerk and B.R. McAvoy, IEEE, New York, (1977)).

12. Surface Wave Attenuation Due to the Electron-Phonon Interaction in a Thin Metal Film, H. L. Salvo, Jr. and M. Levy, Proceedings 1978 IEEE Ultrasonics Symposium, p. 400 (78 CH1344-1 SU, Editors, J. de Klerk and B. R. McAvoy, IEEE, New York, (1978)).
13. Ultrasonic Attenuation in Erbium Under an Applied Magnetic Field for T near 83.8K and 53.9K, R. A. Treder and M. Levy, Proceedings 1978 IEEE Ultrasonics Symposium, p. 405 (78 CH1344-1 SU, Editors, J. de Klerk and B. R. McAvoy, IEEE, New York, (1978)).
14. Ultrasonic Attenuation Study of Erbium in a Magnetic Field, R. A. Treder, M. Tachiki and M. Levy, Journal of Magnetism and Magnetic Materials 12, pp. 167-175 (1979).
15. Ultrasonic Attenuation of Surface Acoustic Waves in a Superconducting Thin Film of Nb₃Sn in an Applied Magnetic Field, H. P. Fredricksen, H. L. Salvo, Jr., M. Levy, R. H. Hammond, and T. H. Geballe, Proceedings 1979 IEEE Ultrasonics Symposium, pp. 435-438 (79 CH1482-9, Editors, J. de Klerk and B. R. McAvoy, IEEE, New York (1979)).
16. Ultrasonic Attenuation by a Thin Film of High Transition Temperature Nb₃Ge, H. L. Salvo, Jr., H. P. Fredricksen, M. Levy and J. R. Gavaler, Solid State Communication, Vol. 33, pp. 781-784, (1980).
17. Ultrasonic Attenuation of Surface Acoustic Waves in a Thin Film of Superconducting Nb₃Sn, H. P. Fredricksen, H. L. Salvo, Jr., M. Levy, R. H. Hammond and T. H. Geballe, Physics Letters, Vol. 75A, No. 5, pp. 389-391, (1980).
18. Temperature Dependence of the Ultrasonic Attenuation Coefficient for ErRh₄B₄ between 1.5 K and 20 K, Susan C. Schneider, Moises Levy, Bernd T. Matthias and David C. Johnston (to be published in Physics Letters).
19. Ultrasonic Surface Acoustic Wave Investigation of Thin Films of Superconducting NbN, Hans P. Fredricksen, Moises Levy, John Gavaler and Martin Ashkin (To be published in Proceedings of the 1980 Applied Superconductivity Conference).
20. Precision Magnetization and Susceptibility Measurements on ErRh₄B₄ in the Ferromagnetic and Superconducting Phases, F. Behroozi, G. W. Crabtree, S. A. Campbell, M. Levy, D. Snider, D. C. Johnston and B. T. Matthias (to be published in the 1980 Proceedings of the International Conference on Ternary Superconductors).

21. Ultrasonic Study of Induced Magnetic Order in ErRh_4B_4 ,
S. Schneider, R. Chen, M. Levy, D. C. Johnston and B. T. Matthias,
(to be published in the 1980 Proceedings of the International
Conference on Ternary Superconductors).
22. Diamagnetic Thermodynamic Critical Field of Superconducting
 ErRh_4B_4 as a function of Temperature, F. Behroozi, M. Levy,
D. C. Johnston and B. T. Matthias (submitted to Solid State
Communications).
23. Mechanism for the Interaction of Surface Waves with 200 Å Nickel
Films, I-an Feng, M. Tachiki, C. Krischer and M. Levy (to be
submitted to Journal of Applied Physics).
24. Ultrasonic Surface Wave Investigation of Nb_3Ge Films, H. Salvo,
H. Fredricksen, M. Levy and J. Gavalier (to be submitted to
Journal of Low Temperature Physics).
25. Surface Acoustic Wave Attenuation by a Thin Film, D. Snider,
H. Fredricksen and S. Schneider (submitted to Journal of
Applied Physics).
26. Ultrasonic Attenuation Determination of H_{c1} and H_{c2} for
 ErRh_4B_4 at 1.5 K, S. Schneider, R. Chen, M. Tachiki, M. Levy,
D. C. Johnston and B. T. Matthias (submitted to Solid State
Communications).
27. Experimental Determination of the Magnetic Landau Parameters of
 ErRh_4B_4 , F. Behroozi, G. W. Crabtree, Steve Campbell, M. Levy,
D. Snider, D. H. Johnston and B. T. Matthias (to be submitted to
Phys. Rev. Letters).
28. Continuous Magnetization Curves of a Single Crystal of Vanadium
With a Resistivity Ratio of 25, F. Behroozi and M. Levy (submitted
to Journal of Low Temperature Physics).

Coupling

1. Nb₃Ge Sputtered Films

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration (continuing).
- c. The ultrasonic attenuation coefficient of surface waves propagating through Nb₃Ge films deposited by John Gavaler, Westinghouse Laboratory, has been measured from 0.8°K up to room temperature. A clean path on the aluminum nitride covered substrate has also been measured so that the attenuation due to the Nb₃Ge film alone could be determined. From this data the density of superconducting material in the film as a function of temperature could be determined as well as the electron mean free path on the Nb₃Ge film.

2. Nb₃Ge and Nb₃Sn Films

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration.
- c. Robert Hammond, Stanford University, has deposited Nb₃Sn films on a quartz and a lithium niobate substrate. Measurements of the ultrasonic attenuation coefficient of surface waves propagating through these films have been made. The data has been analyzed to determine the temperature dependence of the superconducting energy gap of Nb₃Sn. Robert Hammond will attempt to deposit Nb₃Ge films on aluminum nitride substrates and also on quartz and lithium niobate substrates.

3. Aluminum Nitride Films and Visit Laboratory, Hanscom AFB

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration (continuing).
- c. Substrates of aluminum covered sapphire have been obtained from Paul Carr, RADC Hanscom AFB. Some of these films had been grown by Kenneth Lakin, USC. Visited Hanscom AFB Labs to obtain substrates and discuss nickel film experiments.

4. Aluminum Nitride Films from Air Force Materials Laboratory, Wright-Patterson Air Force Base

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration.
- c. Obtained aluminum nitride films grown on sapphire substrates from Robert L. Hickmott, Air Force Materials Laboratory, Wright-Patterson Air Force Base. These films were grown by Kenneth M. Lakin, USC. After receiving them from Robert L. Hickmott substrates were sent to Kenneth Lakin for polishing and then to John Cavalier for depositing the Nb_3Ge films.

5. Solution Hardened Titanium Alloys

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration (continuing).
- c. The collaboration with E. W. Collings, Battelle Labs, on the measurement of solution hardened titanium alloy has been continued.

6. Effect of Nickel Films on Surface Wave Devices

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion.
- c. Held separate discussions with Ernest Stern, Lincoln Labs, Robert Adler, Zenith Labs, and Manfred Schultz, Raytheon Labs, concerning possible sources for the large observed effect and possible applications of the effect.

7. Nickel Film Switching of Surface Wave Delay Lines

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration (continuing).
- c. Discussed with Robert Moore, Westinghouse Laboratory, Baltimore, and Bruce McAvoy, Westinghouse Laboratory, Pittsburgh, the possibility of initiating a program to use the large observed effect of nickel films on the attenuation of surface acoustic waves in order to produce variable attenuation on surface acoustic wave delay lines.

8. Superconducting Fluctuations in Al Films

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Collaboration.
- c. Continued to use surface wave delay lines provided by E. Stern and R. Williamson, Lincoln Labs, to investigate superconducting fluctuations in thin Al films.

9. High Frequency Surface Wave Devices and Visit Lincoln Labs

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration.
- c. Obtained masks whose overtones would be used to excite 2 GHz surface acoustic waves from E. Stern and R. W. Williamson, Lincoln Labs. Visited Labs to receive masks and discuss appearance of two signals when 1100 MHz surface waves propagate through a half micron film deposited on an aluminum nitride covered sapphire substrate.

10. $\text{Nb}_3\text{Al}_{0.25}\text{Ge}_{0.75}$ Alloy

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaborating (continuing).
- c. Obtained a superconducting polycrystalline alloy of $\text{Nb}_3\text{Al}_{0.25}\text{Ge}_{0.75}$ from Klaus Andres, Bell Telephone Labs. Attempts to make ultrasonic measurements of this alloy have been initiated.

11. Ternary Alloys

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration (continuing).
- c. Measurements of the ultrasonic attenuation coefficient in a polycrystalline sample of ErRh_4B_4 have been made as a function of both temperature and magnetic field. The sample was obtained from Bernd T. Matthias and David Johnston, U.C.-San Diego. Obtained a sample of LuRh_4B_4 and a sample of HoRh_4B_4 from Bernd T. Matthias.

12. Chemically Vapor Deposited Nb₃Ge Films

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion.
- c. Discussed with George Webb, U.C.-San Diego, the possibility of making surface acoustic wave measurements on chemically vapor deposited Nb₃Ge films. When appropriate substrates become available, he will chemically vapor deposit Nb₃Ge films.

13. Sputtered Aluminum Nitride Films

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion.
- c. The possibility of obtaining aluminum nitride films which have been sputtered on sapphire substrates has been discussed with Dr. Thomas Reeder, United Technologies Research Center.

14. Westinghouse Research Laboratory Visit

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion.
- c. Visited Westinghouse Laboratory on September 29, 1978. Discussed with John Gavalier possibility of measuring properties of niobium nitride films using surface acoustic wave techniques. Discussed with Cliff Jones possibility of measuring ultrasonic attenuation near H_{c3} in superconducting films using surface acoustic wave techniques. Discussed with Martin Ashkin possible model for explaining regular flux jumps in polished niobium single crystal.

15. Niobium Nitride Films

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Collaboration and discussion.
- c. John Gavaler, Westinghouse Research Laboratory, has deposited NbN films of different thickness on LiNbO_3 substrates. Half of each substrate is covered with NbN and the other half is blank so that the background attenuation may be measured on a part of the substrate that has undergone the same treatment as that under the NbN films.

16. YtRh_4B_4

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration.
- c. Obtained a twinned crystal of YtRh_4B_4 from Phillip Tse, Argonne National Laboratory. Attempts will be made to measure the ultrasonic properties of this ternary alloy in order to correlate them with those of ErRh_4B_4 .

17. Amorphous Superconductors

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration.
- c. Discussed with Ted Geballe and Robert Hammond, Stanford University, the possibility of obtaining amorphous molybdenum films stabilized with a small amount of Nb. The films will be deposited on quartz and lithium niobate substrates.

18. Two Dimensional Superconductors

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration.
- c. Discussed with Mike Sienko, Cornell University, the possibility of obtaining platelet samples of the layered compounds NbSe_2 and MoSe_2 . Attempts will be made to characterize these samples using surface acoustic wave techniques.

19. Chevrel Phase Superconductors

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration.
- c. Powder samples of the Chevrel phase superconductors will be obtained from Clyde Kimball, Northern Illinois University, in order to determine if it is possible to propagate ultrasonic waves through them which will provide information about their superconducting energy gap and electron mean free path.

20. PbMo_6S_8

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration.
- c. Discussed with Mike Sienko, Cornell University, the possibility of obtaining films of PbMo_6S_8 deposited on lithium niobate in order to investigate its properties with surface acoustic waves.

21. Tin Based Ternary Single Crystals

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion and collaboration.
- c. Discussed with Klaus Andres and J. P. Remeika, Bell Labs, the possibility of obtaining single crystals of tin based ternary single crystals that are both magnetic and superconducting. These crystals would permit the transmission of higher frequencies than in the polycrystalline ternary alloys. The frequency dependence of the attenuation coefficient should make it possible to distinguish between different models that have been proposed to explain the observed effects.

22. Electron Phonon Interaction in Normal Metals and Superconductors

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Lecture (January 1976).
- c. A lecture was given on this topic to the Acoustics Club of Milwaukee.

23. APS March Meeting - 1976

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference.
- c. Presented paper.

"Ultrasonic Attenuation Study of Fluctuation Effects in Clean Superconducting Vanadium and Niobium", S. Schneider, J. Waynert, M. Levy and K. Maki.

Also had discussion with E. W. Collings, Battelle Labs.

24. Electron Phonon Interaction in Type II Superconductors

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Lecture (April 1976).
- c. A lecture on this topic was given to the Physics Department, Ohio State University, Columbus, Ohio. Discussed possible mechanism for strong surface wave interaction with nickel films with Phil Wigen, Physics Department, Ohio State University. Visited E. W. Collings at Battelle Labs and obtained superconducting alloy from him.

25. Electron Phonon Interaction in Superconductors

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Colloquium (June 9, 1976).
- c. A lecture was given on this topic in Spanish at the Instituto Venezolano de Investigaciones Cientificas (Federal Research Center of Venezuela in Caracas).

26. Ultrasonic Attenuation in Normal Metals

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Lecture (June 1976).
- c. A lecture was given on this topic in Spanish at the Physics Department, Universidad de los Andes, Merida, Venezuela.

27. Ultrasonic Attenuation in Normal Metals and Superconducting Metals

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Lecture (June 1976).
- c. A lecture was given on this topic in Spanish at the Physics Department, University of Panama, Panama, Republic of Panama.

28. 1976 Applied Superconductivity Conference

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (17-20, August 1976).
Discussions (12, 13, and 23, August 1976).
- c. Attended conference held at Stanford University, Stanford, California. During conference held discussions with J. M. Rowell, Bell Labs, concerning multiple gaps in Nb_3Ge . Also held discussions with D. Langenberg, University of Pennsylvania, concerning the evaluation of the product of the electron phonon interaction parameter times the density of states at low frequencies.
Before and after the conference had discussionw with Ken Lakin, USC, concerning aluminum nitride films, also did experiment to search for third harmonic of surface wave device.

29. 1976 IEEE Ultrasonic Symposium

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (September 29 to October 1, 1976).
- c. Presented invited paper and contributed paper.

Intited paper:

"Surface Acoustic Wave Investigation of Superconducting Film."

Contributed paper:

"Magnetic Field Dependent Attenuation of Surface Waves by Nickel Thin Films." Charles Krischer, I-an Feng, Jeffrey B. Block and Moises Levy.

Also continued discussions with Ken Lakin and Paul Carr concerning aluminum nitride films. Discussed with E. Stern, Lincoln Labs, and Richard W. Damon, Director Applied Physics Laboratory, Sperry Research Center, possible application of nickel covered surface wave device.

30. ASM Conference on Manufacture of Superconducting Materials

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (November 8-10, 1970).
- c. Presented invited paper:

"Device Fabrication for Surface Acoustic Wave Investigation of Superconducting Films."

Held discussion with Ken Rose, Rensselaer Polytechnic Institute, concerning the structure factor and the effective electronic mean free path in superconducting and normal thin films. Discussed with Robert Hammon, Stanford University, surface wave investigation of both Nb_3Ge films and Nb_3Sn films.

31. APS March Meeting 1977

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference
- c. Attended conference held in San Diego. During conference held discussions with Kazumi Maki, USC, concerning the effect of fluctuations on the ultrasonic attenuation coefficient near the upper critical field of very pure niobium. Also had discussions with E. W. Collings, Battelle Labs, concerning the solution hardened titanium alloys. Initiated collaboration with Bernd T. Matthias, U.C.-San Diego, concerning ternary alloys. Continued the discussion with Klaus Andres, Bell Labs, concerning measurements on $Nb_3Al_{0.25}Ge_{0.75}$ alloys.

32. Ultrasonic Attenuation in Normal and Superconducting Metals

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Lecture (May 24, 1977).
- c. A lecture on this topic was given to the Physics Department of Harvey Mudd College, Claremont, California.

33. Electron Phonon Interaction in Type II Superconductors

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Lecture (May 25, 1977).
- c. A lecture on this topic was given to the Physics Department, California State University-Los Angeles, Los Angeles, California.

34. 1977 Ultrasonic Symposium

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (October 26-28, 1977).
- c. Presented paper:
"Correlation Between the Magnetic Susceptibility of Nickel Films and Their Effect on Surface Acoustic Waves," Tsan Feng, Hans Fredricksen, Charles Krischer, M. Tachiki and Moises Levy.

Held discussions with Fred Hickernell, Motorola Inc., Phoenix, Tom Reeder, United Technologies Center, Shi Kay Yao, Rockwell International Science Center, and R. L. Gunshor, Purdue University, on the methods for sputtering piezoelectrically active ZnO films which could be used for producing surface acoustic waves in the GHz frequency range.

35. APS March Meeting 1978

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference.
- c. Attended conference held in Washington, D.C. Held discussions with David Johnston, concerning possibility of obtaining

ternary alloys prepared from pure elements. These alloys may be more homogeneous. Discussed with George Webb dimensions of lithium niobate substrates for chemically vapor deposited Nb_3Ge films. Discussed with John Gavalier measurements on Nb_3Ge films. Discussed with Kazumi Maki fluctuation contribution to the ultrasonic attenuation of niobium near the upper critical field. Discussed with Klaus Andres the possibility of obtaining the superconducting alloy $\text{Nb}_3\text{Al}_{0.25}\text{Ge}_{0.75}$.

36. Ultrasonic Attenuation in Normal and Superconducting Metals

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Lecture (July 25, 1978) and discussion.
- c. A lecture on this topic was given to the Physics Department, University of Alberta, Edmonton, Alberta. Discussions on this topic were held with Hiroomi Umezawa and Masashi Tachiki. Discussions on transport phenomena were held with A. Bhatia.

37. 1978 IEEE Ultrasonics Symposium

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (September 24-25, Cherry Hill, New Jersey).
- c. Presented two papers:
"Surface Wave Attenuation Due to the Electron Phonon Interaction in a Thin Metal Film," H. L. Salvo, Jr. and M. Levy and
"Ultrasonic Attenuation in Erbium Under an Applied Magnetic Field for T near 83.8 K and 53.9 K," R. A. Treder and M. Levy.

38. 1978 Applied Superconductivity Conference

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (September 27-28, Pittsburgh, Pennsylvania).
- c. Attended conference. Discussed Nb_3Sn films with Ted Geballe. Discussed Nb_3Ge films with George Webb.

39. Ultrasonic Investigation of Superconductors

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Lecture (January 2, 1979).
- c. A lecture in Spanish was given on this topic to the Physics Department, University of Sao Paulo, Sao Paulo, Brazil.

40. Ultrasonic Investigation of the Rare Earth Metals

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Lecture (January 5, 1979).
- c. A lecture in Spanish was given on this topic to the Physics Department, University of Sao Paulo, Sao Paulo, Brazil.

41. 1979 APS March Meeting

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference.
- c. Two papers were presented:
"Ultrasonic Attenuation in ErRh_4B_4 ," S. Schneider, M. Levy,
M. Tachiki, B. T. Matthias, and D. C. Johnston
and
"Ultrasonic Surface Wave Attenuation in a Nb_3Ge Film,"
H. Salvo, H. Fredricksen, M. Levy and J. Cavalier.

Held discussions with John Gavaler and Martin Ashkin concerning niobium nitride and niobium carbonitride films. Held discussions with R. Hammond concerning Nb_3Ge and Nb_3Sn films. Held discussions with T. Geballe concerning possible investigation of layered superconductors with ultrasonic surface wave techniques. Discussed with B. T. Matthias the measurements on ErRh_4B_4 and the possibility of obtaining samples of LuRh_4B_4 and HoRh_4B_4 .

42. International Cryogenic Conference

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (August 21-24, Madison, Wisconsin).
- c. Attended Conference. Discussed NbN films with Alex Braginski. Discussed superconducting magnets for ultrasonic measurements with Robert Remsbottom, University of Wisconsin-Madison.

43. Metallurgical Society Meeting

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (Sept. 18-19, 1979, Milwaukee, Wisconsin).
- c. Attended meeting.

44. 1979 IEEE Ultrasonic Symposium

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (September 26-28, New Orleans, Louisiana).
- c. Presented a paper.
"Ultrasonic Attenuation of Surface Acoustic Waves in a Superconducting Thin Film of Nb_3Sn in an applied magnetic Field," H. P. Fredricksen, H. L. Salvo, Jr., M. Levy, R. H. Hammond and T. H. Geballe.

45. Inhomogeneous Superconductors

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (November 1-3, 1979, Berkeley Springs, W.V.)
and discussion.
- c. Attended conference. Obtained NbN films from John Gavaler.
Discussed preliminary data obtained on NbN with John Gavaler,
and Doug Finnemore.

46. Ultrasonic Attenuation in Magnetic Superconductors

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Lecture (December 5, 1979).
- c. A colloquium was given on this topic to the Physics
Department, University of Indiana, Bloomington, Indiana.

47. 1980 APS March Meeting

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (March 24-28, 1980, New York, NY) and
discussion.
- c. A paper was presented.
"Magnetic Field Dependence of Sound Attenuation in ErRh_4B_4 ,"
S. Schneider, R. Chen, M. Levy, B. T. Matthias and
D. C. Johnston.
Discussions were held with Martin Ashkin, Westinghouse
Research Labs, concerning the theoretical interpretation
of the ultrasonic attenuation data obtained on NbN films.

48. International Conference on Ternary Superconductors

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (September 24-26, 1980, Lake Geneva, Wisconsin) and discussion.
- c. Two papers were presented.

"Precision Magnetization and Susceptibility Measurements on ErRh_4B_4 in the Ferromagnetic and Superconducting Phase,"
F. Behroozi, G. W. Crabtree, S. A. Campbell, M. Levy,
D. Snider, D. C. Johnston and B. T. Matthias
and

"Ultrasonic Study of Induced Magnetic Order in ErRh_4B_4 ,"
S. Schneider, R. Chen, M. Levy, D. C. Johnston, and
B. T. Matthias.

Discussed with B. T. Matthias possibility of obtaining another sample of LuRh_4B_4 . Discussed with Brian Maple, U.C.-San Diego, the possibility of obtaining samples of $\text{Er}_x\text{Ho}_{1-x}\text{Rh}_4\text{B}_4$ samples. These samples would increase the magnetic phase transition to temperatures that are more easily attained in a He^4 cryostat. Discussed with J. R. Remeika, Bell Labs, the possibility of obtaining additional tin based ternary superconductors. Discussed with Paul Schmidt the possibility of depositing thin films of ternary superconductors on substrates which could be used for propagating surface waves. Held discussions with Fereidoon Behroozi, University of Wisconsin-Parkside, George W. Crabtree, Argonne National Labs, Charles Cooper,

Technion University and David C. Johnston, Exxon Research and Engineering Corporation concerning the magnetization curves of ErRh_4B_4 . Held discussions with Masashi Tachiki and Naoki Toyota concerning ultrasonic attenuation in the ternary superconductors.

49. 1980 Applied Superconductivity Conference

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Conference (September 29 - October 2, 1980, Santa Fe, New Mexico) and discussion.
- c. A paper was presented.
"Ultrasonic Surface Acoustic Wave Investigation of Thin Films of Superconducting NbN," Hans P. Fredricksen, Moises Levy, John Gavalier and Martin Ashkin.

Discussions were held with Martin Ashkin and John Gavalier concerning the theoretical interpretation of the data obtained on the NbN films. Discussed with Robert Hammond the possibility of obtaining Nb_3Sn films deposited on passivated LiNbO_3 substrates. Also discussed with him the possibility of obtaining amorphous molybdenum films stabilized with a small amount of Nb.

50. Group of Sonics and Ultrasonics

- a. Moises Levy, University of Wisconsin-Milwaukee.
- b. Discussion.
- c. Member of the program committee for the 1975, 1976, 1977, 1978, 1979, and 1980 IEEE Ultrasonic Symposium.

Member of the administrative committee of the Group of Sonics and Ultrasonics and chairman of the nominating committee. General chairman of the 1983 IEEE Ultrasonic Symposium.