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## Quarterly Technical Summary

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## Advanced Electronic Technology

15 November 1970

Prepared under Electronic Systems Division Contract F19628-70-C-0230 by

## Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts



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Issued 23 December 1970

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## INTRODUCTION

This Quarterly Technical Summary covers the period from 1 August through 31 October 1970. It consolidates the reports of Division 2 (Data Systems), Division 7 (Engineering), and Division 8 (Solid State) on the Advanced Electronic Technology Program, formerly the General Research Program, at Lincoln Laboratory.

Accepted for the Air Force  
Joseph R. Waterman, Lt. Col., USAF  
Chief, Lincoln Laboratory Project Office

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## DATA SYSTEMS DIVISION 2

### INTRODUCTION

This section of the report reviews progress during the period 1 August through 31 October 1970 for the Advanced Electronic Technology Program of Division 2. Separate progress reports on Graphics, Propagation Studies, Seismic Discrimination and the Educational Technology Program describe other work in the Division.

M. A. Herlin  
Acting Head, Division 2

## DIGITAL COMPUTERS GROUP 23

### I. CIRCUIT AND NEW MACHINE DEVELOPMENT

#### A. Functional Testing

A single-gate-fault-detection test set for the ADDER 80-gate LSI array was generated using the LOGSIM program. This test set consisted of approximately 50 input-output test patterns (an exhaustive test of the 14-input ADDER array consists of 16,384 test patterns). The tests in the set are chosen so that every possible single stuck-at-one or stuck-at-zero failure which may occur in the net will cause an incorrect output for at least one of the test patterns. The array to be tested is described to the program in terms of the logic function performed by each circuit and the interconnection of circuit inputs and outputs.

The computer-controlled wafer prober was used to apply the ADDER test set to a discrete integrated circuit equivalent of the ADDER 80-gate LSI array. It also applied an empirically generated test set, based on the system function, consisting of approximately 600 test patterns. Faults were manually introduced in the array at all interconnection points. The 50-test single-gate-fault-detection test set indicated an error in all cases, while two additional test patterns were required before the 600-test empirically derived test set would find all errors.

#### B. Noncontact Integrated-Circuit Current Probe

It would be desirable to have the ability to sense the currents flowing in interior portions of large-scale integrated circuitry, i.e., those portions not directly connected to the pads. One possible means of accomplishing this is to position a film of a magnetoresistive material directly above the current path being tested and measure the effect of the magnetic field from that current upon the resistance of the film.

A project to build such a current probe has begun. Preliminary measurements of magnetoresistive effect in permalloy films and calculations based on the published thermal conductivity of type IIa diamond heat sinks indicated that a current of 1 mA in an integrated-circuit current path could produce a signal voltage of a few hundred microvolts across a permalloy film square 20 microns across.

It is not expected that the probe will respond at the operating speed of the circuits. Its use will be in DC testing and diagnosis.

#### C. SEL810A Test Computer

The SEL810A computer and its tester interface unit were moved to new, larger quarters. The tester interface was modified and now has a 128-bit functional-test input buffer, a 128-bit functional-test output buffer, a digital voltmeter and its control unit, four 12-bit digital-to-analog converters, a storage scope and its control unit, and an interface for the TX-2 TIC terminal.

A general-purpose functional-test interface unit, now being built, will provide driver and sensing circuits for testing ECL or DTL logic cards and LSI circuits.

## Division 2

The SEL test computer has had several new applications. One application is monitoring and data logging for a keyboard lifetest; another is testing, debugging, and evaluating the new TSP display character generator. In this latter application, the SEL computer acted both as the character-defining read-only-memory for the character generator and as a source of commands for the display system. Each of the characters to be displayed was examined critically, in an actual line of text, and changes in the character shape were made prior to ordering the read-only-memory.

New library routines were written for handling the modified tester interface, storage scope, digital voltmeter, and D/A converters.

### D. Interconnection of Integrated Circuits

A number of 4-chip test arrays (no active devices) have been assembled to date including four with 2-layer wiring. Three arrays have been on continuous life test and 12 are available for tests. Test arrays with interconnected conductors (no active devices) withstood static testing over a 2000-hour period at 150°C, as well as cycling between 28° and 150°C at a rate of 1.5 hours per cycle for over 2000 cycles without failure or significant changes in interconnection resistance.

Arrays of four series-connected chips containing gate chains are being assembled to evaluate the interconnection process using chips containing active devices.

### E. Mask Making

The mask-making facility on the TX-2 computer has been used on the following tasks during the last quarter:

- (1) Rerouting of metallization of the 80-gate ADDER and LOADCHIP LSI arrays to eliminate a broken wire problem.
- (2) Feasibility studies for a CDI process read-only-memory LSI circuit.
- (3) Metallization patterns for use in the chemically deposited circuit interconnection work.
- (4) Redesign of the masks for the high-speed multiplier chip.
- (5) A mask set for devices to be made by the Lincoln Laboratory semiconductor group.
- (6) Word line pad patterns for magnetic film memory.
- (7) Patterns for a magnetic film current probe.

### F. LX-1 Microprocessor

The LX-1 Microprocessor has been integrated into the design of the TSP system. Initial designs for the three interfaces between LX-1 and other portions of the TSP system have been completed and details are being worked out. Hardware for the I/O backpanel portion of LX-1 has been assembled. A design for the Control Panel has been proposed.

## II. MAGNETIC FILM ENGINEERING

### A. 10-Megabit Memory Feasibility Study

The final phase of the feasibility study of the 10-Megabit Memory Module will be completed during the next quarter along with a final report. Preliminary results on the test stack indicate

that all major objectives have been achieved. However, due to recent reductions in manpower and resources, no attempt will be made to build a complete operating memory.

#### B. Word Decoding Matrix

The silver-filled conductive epoxy for electrical and mechanical connection of diode chips to the substrate and interconnection bus has exhibited silver migration under high humidity conditions that causes short circuits. Use of gold-filled epoxy apparently eliminates this problem. Attaching the plastic bus pattern to the substrate with nonconductive epoxy eliminates the opens caused by spontaneous lifting of the bus pattern off of the diodes.

#### C. Digit Substrates

Three glass digit substrates, 52 inches long, with 1-mil-thick laminated copper having an electroplated magnetic keeper layer have been scribed and installed in the memory stack. Anodized aluminum substrates are now being fabricated by the lamination process to evaluate the electrical effects of a conductive ground plane close (4 mil) to the digit lines. The anodic layer affords both insulation and a hard surface for the scribing tool to work against. This oxide does react with the epoxy and cause bubbles in the glue layer. Application and cure of a very thin epoxy "seal coat" prior to lamination eliminates this difficulty.

Ferrite or carbonyl iron-filled epoxy has been used to fill the slots between the lines to serve as a keeper. This material is "doctor bladed" on thin layers to eliminate air bubbles which would cause discontinuities in the keeper.

#### D. Word Lines

Undercut and lifting of word lines has been minimized. It was discovered that the selective etchant for the magnetic layer removed the Co-Ni-Zn alloy approximately 10 times faster than permalloy. Appropriate reduction of this etching time corrected the undercut problem.

#### E. Magnetic Film Plating

Sensitization of word films by contact at the lands with plated Ni is quite successful; an intermediate electroless Ni-B film is used to ensure uniform surfaces on entry into the magnetic plating solution. This technique eliminates the need for the ammonium bifluoride etch, which was a significant cause of peeling. This has not, however, eliminated the nonuniform coercivity over the area of the substrate.

Nonmagnetic Ni films with complete coverage and good adhesion have been plated directly on glass as a starting step toward completely nonevaporated word films.

#### F. LCM II Digit Lines

A digit line with a 5-mil-wide Cu line on a 6-mil-wide permalloy keeper with carbonyl iron between lines gives a signal 2.3 times as great as with an unkeepered line. The same configuration works equally well when laminated onto an aluminum substrate.

#### G. Experimental Stack

After initial experiments with evaporated-copper digit lines, the experimental stack was reassembled with 52-inch laminated digit pieces with electroplated keeper. Measurements of

## Division 2

digit-line common-mode voltage from group selection showed that word-to-digit spacing varied widely, from less than the nominal 0.5-mil insulation thickness to more than 1 mil, the latter spacing being enough to degrade magnetic performance. The more severe spacing variations are apparently a consequence of warping of the 0.040-inch glass word pieces. Fortunately, the spacing variations are gradual enough that they do not produce significant word or group-select noise: observations on regions in the stack interior have shown no word noise significant with respect to a 0.25-mV signal. There is a good deal of localized group-select noise, but none that would extend group-select time beyond about 0.3 $\mu$ sec, after an extended ringing caused by common-mode digit-line ringing was removed by lossy termination of unselected word groups.

On digit lines near the edge of a digit piece, or near the edge of the stack, word and group-select noises are generated by asymmetry in line charging currents. Noise from this source was surprisingly low, rendering unusable only the first two to six digit-line pairs.

Initial experiments have shown signal-to-random-noise ratios of about 25:1 from 0.25-mV film signals; with amplifier coupling time constants shortened for good digit recovery, this drops to about 20:1. Digit recovery times have been on the order of 1 $\mu$ sec or better.

### III. COMPUTER SYSTEMS

#### A. ARPA Network (IMP)

Experience in "echoing" messages back and forth between TX-2 and the ARPA IMP computer led to a more detailed investigation of the electrical and logical characteristics of the IMP Distant Host Interface. Subsequent discussions with IMP design personnel resulted in several modifications to handle conditions which were inadequately described in the IMP documentation. The IMP will continue to run in the test mode until the telephone facility is installed.

#### B. Printer-Plotter (LDX)

The design of the In/Out Control box which makes logical and electrical connection between TX-2 and the PDP-8/L controller for the LDX Printer has been completed, together with flow charts. Layout and wiring of the remaining control portion of the hardware is in progress. The buffer portion of the IOC box previously wired was modified to simplify the design.

## PSYCHOLOGY GROUP 25

### I. RECKONER/MEDIATOR APPLICATION STUDIES

The Reckoner/Mediator is being used extensively in a forthcoming publication entitled "Free Energy of Formation of Binary Compounds," by Dr. T. B. Reed. The free-energy-vs-temperature data for almost 500 compounds has been put into Reckoner arrays, including indexing information that identifies each compound. Slopes and intercepts at the phase changes of the compounds are computed, and tables are produced and automatically edited by Reckoner processes. The output from the computer terminal will be reproduced directly, thus bypassing the problems of proofing type-set tables of numerical data. This is a totally unexpected and fruitful application of the system.

A study is being made regarding the feasibility of extending the capability of the Reckoner to work on larger-scale computational problems, mainly those involving numerical solutions to differential equations. Our hypothesis is that much of the difficulty in working on these problems can be eliminated by bringing to bear interactive techniques, because the nature of the difficulty lies in discovering the right tactical steps to uncover paths that may lead to a solution. The Reckoner is an excellent base on which to build. Effort should be placed on developing a simple method of getting the routines of the Scientific Subroutine Package into the Mediator environment. Strategies for displaying the results of tactical steps toward the solution are also needed.

The Reckoner/Mediator was exhibited at the annual meeting of the Association for Computing Machinery in New York City from 1 to 3 September 1970.

### II. OTHER WORK

Group 25's work on the design and use of a new learning machine is reported separately in the Quarterly Technical Summary of the Educational Technology Program.

Other work on computer graphics is reported in the Quarterly Letter Reports to the Advanced Research Projects Agency.

## COMPUTER SYSTEMS GROUP 28

On 1 August 1970, the IBM 360/67 computer was reconfigured from a duplex to a half-duplex machine. This meant that one of the central processing units and its associated input/output channels were removed. However, the full million bytes of memory and most of the secondary storage were retained. The net result is a single machine which is considerably larger than either of the two halves of the duplex.

The CP/CMS time-sharing system was easily adapted to the new configuration. Together with the new "bakery number" system, which has been previously described, the larger memory now handles up to 39 users with a high degree of satisfaction. Improvements in the dispatcher have reduced overhead and increased "useful time" to an average of 40 percent or more. Considerable attention has been given to a measurements program to assist in evaluating and improving performance still more. In addition, these measurements will permit a more sophisticated accounting system based on specific items of equipment used.

The new version of the Laboratory's batch-processing system (IBM OS/360-MVT-HASP) was installed on the new configuration with very little inconvenience to the users. Because of the concurrent change in the method of accounting for time, users received the additional bonus of considerably smaller CPU charges for the equivalent amount of computing work. As with CP/CMS, this new system will permit more extensive recording of specific items used.

From the point of view of operations, OS/360 has increased efficiency by some 25 percent or more. This means that more jobs are being processed in a given time period than was possible with the older "one-at-a-time" system. Without this improvement, scheduling of CP/CMS and OS would be considerably more difficult.

ENGINEERING  
DIVISION 7

# DIVISION 7 REPORTS ON ADVANCED ELECTRONIC TECHNOLOGY

15 August through 15 November 1970

## UNPUBLISHED REPORTS

### Journal Article

JA No.

3753	Mean-Square Response of a Second-Order System to Nonstationary, Random Excitation	L. Bucciarelli* C. Kuo*	Accepted by J. Appl. Mech.
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### Meeting Speech

MS No.

2732	A Weather Stressed Bond	E. B. Murphy	1970 National SAMPE Technical Conference, Dallas, 6-8 October 1970
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\* Department of Aeronautics and Astronautics, M.I.T.

## ENGINEERING GROUP 71

### SOLID STATE RESEARCH

The need to pass a light through a chamber in which high hydrostatic pressure can be generated is well established. A variety of experiments can be obtained with such a device: the effect of isotropic stress on the absorption, reflection, emission and polarization of radiation, and more complex phenomena such as Faraday rotation, Voigt effect, Stark effect, photoelectric effect, magnetoabsorption, magnetoreflexion and magnetoemission.

For this purpose, a pressure vessel has been designed which will withstand pressures up to 15 kbars, with windows opposite one another and enclosing the cavity at each end. The pressure windows used are cylinders, polished on both ends, and with one end pressed against an optically polished face on a BeCu plug which has an aperture in its center. Window material is dependent on the light source to be used; germanium and silicon are quite transparent to long wavelengths, while MgO can be utilized from the visible to  $6.5\mu\text{m}$ . BeCu is used for the vessel material.

## SOLID STATE DIVISION 8

### INTRODUCTION

This section summarizes the work of Division 8 from 1 August through 31 October 1970. A more detailed presentation is covered by the Solid State Research Report for the same period.

A. L. McWhorter  
Head, Division 8

P. E. Tannenwald  
Associate Head

# DIVISION 8 REPORTS ON ADVANCED ELECTRONIC TECHNOLOGY

15 August through 15 November 1970

## PUBLISHED REPORTS

### Journal Articles\*

JA No.			
3320	Single Crystal Lead-Tin Chalcogenides	I. Melngailis T. C. Harman	Chapter 4 in <u>Semiconductors and Semimetals</u> (Academic Press, New York, 1970), p. 111
3539	Positron Annihilation in Copper – Comparisons of Different Results	J. Melngailis	Phys. Rev. B <u>2</u> , 563 (1970)
3546	Transport Equation for a Fermi System in Random Scattering Centers. II. Independent Electrons in an Arbitrarily Varying Electric Field and Strong Single-Center Potentials	J. L. Sigel P. N. Argyres <sup>†</sup>	Phys. Rev. B <u>1</u> , 1845 (1970), DDC AD-709758
3587	Split-Off Valence Band Parameters for GaAs from Stress-Modulated Magnetorefectivity	M. Reine <sup>†</sup> R. L. Aggarwal <sup>†</sup> B. Lax <sup>†</sup> C. M. Wolfe	Phys. Rev. B <u>2</u> , 458 (1970)
3608	Vapor-Crystal Equilibrium and Electrical Properties of HgTe	A. J. Strauss R. F. Brebrick	J. Phys. Chem. Solids <u>31</u> , 2293 (1970)
3618	Phase Diagram of the Zn-Cd-Te Ternary System	J. Steininger A. J. Strauss R. F. Brebrick	J. Electrochem. Soc. <u>117</u> , 1305 (1970)
3620	Interband Magnetoreflexion of $\alpha$ -Sn	S. H. Groves C. R. Pidgeon <sup>†</sup> A. W. Ewald <sup>†</sup> R. J. Wagner <sup>†</sup>	J. Phys. Chem. Solids <u>31</u> , 2031 (1970)
3663	Crystal Structure of Hexagonal RbNiF <sub>3</sub> (6H)	R. J. Arnott <sup>†</sup> J. M. Longo	J. Solid State Chem. <u>2</u> , 416 (1970)
3678A	Rigid and Nonrigid Beam Lead Substrates	F. J. Bachner R. A. Cohen R. E. McMahon	Solid State Tech. <u>13</u> , 62 (1970)
3686	Polarized Maser Emission from Interstellar OH and H <sub>2</sub> O	M. M. Litvak	Phys. Rev. A <u>2</u> , 937 (1970)

\* Reprints available.

<sup>†</sup> Author not at Lincoln Laboratory.

Division 8

JA No.

3687	Phase Diagram of the CdTe-CdSe Pseudobinary System	A. J. Strauss J. Steininger	J. Electrochem. Soc. <u>117</u> , 1420 (1970)
3691	Phase Transitions in Perovskite-like Compounds of the Rare Earths	S. Geller* P. M. Raccah	Phys. Rev. B <u>2</u> , 1167 (1970)
3712	Translational Symmetry and Orbital Anisotropic Exchange in Cr <sub>2</sub> O <sub>3</sub>	J. W. Allen	Phys. Rev. Letters <u>25</u> , 934 (1970)
3716	Phase Diagram of the PbTe-PbSe Pseudobinary System	J. Steininger	Metallurgical Trans. <u>1</u> , 2939 (1970)
3721	Seebeck Coefficients in Vanadium Spinel	J. B. Goodenough	Mat. Res. Bull. <u>5</u> , 621 (1970)
3749	Acoustic Surface Wave Amplification Using an Accumulation Layer on Silicon	B. E. Burke A. Bers* H. I. Smith R. A. Cohen R. W. Mountain	Proc. IEEE <u>58</u> , 1775 (1970)
MS-2681	Optical Reflectance Study of Magnetic Ordering Effects in EuO, EuS, EuSe and EuTe	C. R. Pidgeon* J. Feinleib W. J. Scouler J. O. Dimmock T. B. Reed	IBM J. Res. Dev. <u>14</u> , 309 (1970)

UNPUBLISHED REPORTS

Journal Articles

JA No.

3627	Polarons Bound in a Coulomb Potential. II. 2P State Zeeman Effect	D. M. Larsen	Accepted by Phys. Rev.
3661	Collective Oscillations in a Simple Metal. I. Spin Waves	A. R. Wilson D. R. Fredkin*	Accepted by Phys. Rev. B
3725	Harmonic Generation in Cold Nonuniform Plasma in a Magnetic Field	F. A. Blum	Accepted by Phys. Fluids
3735	High Pressure Synthesis	J. B. Goodenough J. A. Kafalas J. M. Longo	Accepted as chapter in <u>Preparative Methods in Solid State Chemistry</u> (Academic Press, New York)
3740	Resonant Coupling of Landau Levels via LO Phonons in Polar Semiconductors and Its Effect on the Landau Level Raman Scattering from Semiconductor Plasmas	K. L. Ngai	Accepted by Phys. Rev.

\* Author not at Lincoln Laboratory.

JA No.			
3748	Shubnikov-deHaas Measurements in $\text{Pb}_{1-x}\text{Sn}_x\text{Te}$	J. Melngailis T. C. Harman J. G. Mavroides J. O. Dimmock	Accepted by Phys. Rev.
3751	Composition Stability Limits for the Rocksalt-Structure Phase ( $\text{Pb}_{1-y}\text{Sn}_y$ ) $_{1-x}\text{Te}_x$ from Lattice Parameter Measurements	R. F. Brebrick	Accepted by J. Phys. Chem. Solids
3761	Conceptual Phase Diagram and Its Application to the Spontaneous Magnetism of Several Pyrites	J. B. Goodenough	Accepted by J. Solid State Chem.
3765	Raman Scattering in $\text{CsMnF}_3$	S. R. Chinn	Accepted by Phys. Rev.
3767	The Structure of the High and Low Pressure Forms of $\text{SrIrO}_3$	J. M. Longo J. A. Kafalas R. J. Arnett*	Accepted by J. Solid State Chem.
3772	Polaron Zeeman Effect of Shallow Donors in CdTe	D. R. Cohn* D. M. Larsen B. Lax*	Accepted by Solid State Commun.
3773	Even Parity Levels of Donors in Si	W. H. Kleiner W. E. Krag	Accepted by Phys. Rev. Letters
3777	Perturbation Theory for the Bound Polaron	D. M. Larsen	Accepted by J. Phys. Chem. Solids
3789	Identification of Exciton- Neutral Donor Complexes in the Photoluminescence of High Purity GaAs	J. A. Rossi C. M. Wolfe G. E. Stillman J. O. Dimmock	Accepted by Solid State Commun.
3795	The Fermi Surface and Optical Properties of Potassium	G. Dresselhaus A. Wilson C-Y. Young	Accepted by Solid State Commun.
3796	Acceptor Luminescence in High Purity n-Type GaAs	J. A. Rossi C. M. Wolfe J. O. Dimmock	Accepted by Phys. Rev. Letters
3799	Continuous Stimulated Spin-Flip Raman Scattering in InSb	A. Mooradian S. R. J. Brueck F. A. Blum	Accepted by Appl. Phys. Letters
3812	Two-Magnon Raman Scattering and Exchange Interactions in Antiferromagnetic $\text{KNiF}_3$ and $\text{K}_2\text{NiF}_4$ and Ferrimagnetic $\text{RbNiF}_3$	S. R. Chinn H. J. Zeiger J. R. O'Connor	Accepted by Phys. Rev. B

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\* Author not at Lincoln Laboratory.

Division 8

JA No.

3814 Absence of Hartree-Fock Behavior in Simple Decoupling Solution of Correlated Narrow-Energy-Band Model R. A. Bari  
T. A. Kaplan Accepted by Phys. Letters

Meeting Speeches\*

MS No.

2528D	Light Scattering in Semiconductors	A. Mooradian	Seminar, Japan Broadcasting Corporation, Tokyo, 4 September 1970
2702A	Rigid and Nonrigid Beam Lead Substrates	R. E. McMahon R. A. Cohen F. J. Bachner	EPECON, Toronto, Canada, 28 September - 1 October 1970
2723G	Laser Raman Spectroscopy	A. Mooradian	Seminar, Worcester Polytechnic Institute, 22 October 1970
2799A	Optical Study of the Semiconductor to Metal Transition in $Ti_2O_3$	P. M. Raccah	Solid State Seminar, Purdue University, 10-11 November 1970
2850A	Comparison of Experimental Charge Densities with Solid-State Calculations	P. M. Raccah	
2863	Effects of Hydrostatic Pressure and of Jahn-Teller Distortions on the Magnetic Properties of $RbFeF_3$	J. B. Goodenough N. Menyuk K. Dwight J. A. Kafalas	Conférence Internationale de Magnétisme, Grenoble, France, 14-19 September 1970
2873	Detection, Generation and Mixing of Far Infrared Radiation in GaAs	P. E. Tannenwald H. Fetterman G. E. Stillman C. M. Wolfe J. O. Dimmock I. Melngailis	Sixth International Quantum Electronics Conference, Kyoto, Japan, 7-10 September 1970
2911	Light Scattering in Solids	A. Mooradian	
2877	Magneto-Optics of Polarons in Semiconductors	D. M. Larsen	Tenth International Conference on the Physics of Semiconductors, Cambridge, Massachusetts, 17-21 August 1970
2880	Excited 1s-Like Levels of Bi Donors in Si	W. E. Krag W. H. Kleiner H. J. Zeiger	
2882	Electron and Phonon Dispersion Relations in Tellurium	G. Dresselhaus M. S. Dresselhaus	
2883	Light Scattering from Plasmons in InSb	F. A. Blum A. Mooradian	

\* Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

MS No.			
2884	Polaron Zeeman Effects in the Silver Halides	R. C. Brandt D. M. Larsen D. R. Cohn*	Tenth International Conference on the Physics of Semiconductors, Cambridge, Massachusetts, 17-21 August 1970
2886	Interaction of Bound Electrons with Local and Resonant Modes in Semiconductors	R. W. Davies H. J. Zeiger	
2888	Role of the Crystal C/A Ratio in $Ti_2O_3$ and $V_2O_3$	J. B. Goodenough	
2892	Variational Approach to the Metal-Semiconductor Transition	T. A. Kaplan R. A. Bari	
2893	A Raman Study of the Semiconductor-Metal Transition in $Ti_2O_3$	A. Mooradian P. M. Raccach	
2907	Light Scattering from Hot Electrons in Semiconductors	A. Mooradian A. L. McWhorter	
2917	High-Purity GaAs	C. M. Wolfe G. E. Stillman J. A. Rossi E. B. Owens W. T. Lindley J. O. Dimmock	Third International Symposium on GaAs and Related Compounds, Aachen, Germany, 5-7 October 1970
2919	GaAs Far Infrared Detectors and Emitters	G. E. Stillman C. M. Wolfe J. O. Dimmock	
2926	Aluminum Beam Leaded Chips, Substrates and Crossovers: A Single Metal System	R. A. Cohen F. J. Bachner R. E. McMahon	Conference on Preparation and Properties of Electronic and Magnetic Materials for Computers, New York, 30 August - 2 September 1970
2937	Effect of Pressure on the Structure and Properties of $ABX_3$ Compounds	J. M. Longo	American Chemical Society Regional Meeting, Providence, R.I., 19 October 1970
2950	Excitation of Interstellar Molecules	M. M. Litvak	Fourteenth General Assembly of the International Astronomical Union, Brighton, Sussex, England, 18-27 August 1970
2951	Localized versus Itinerant Electrons in Magnetic Solids	J. B. Goodenough	Summer School on Theory of Magnetism of Metals, Zakopane, Poland, 31 August - 11 September 1970
2962	A Low Power Density GaAs/ $LiNbO_3$ Surface Wave Amplifier	D. L. Spears B. E. Burke	Symposium on Sonics and Ultrasonics, San Francisco, 21-23 October 1970

\* Author not at Lincoln Laboratory.

Division 8

MS No.

- |      |  |                  |   |
|------|--|------------------|---|
| 2964 | Magneto-Optical Properties of the Europium Chalcogenides | J. O. Dimmock    | Conference on the Physics of Opto-Electronic Materials, Warren, Michigan, 5-6 October 1970                                      |
| 2992 | Varied Roles of Outer d Electrons                        | J. B. Goodenough | The Robert A. Welch Foundation Conferences on Chemical Research. XIV. Solid State Chemistry, Houston, Texas, 9-11 November 1970 |

# SOLID STATE DIVISION 8

## I. SOLID STATE DEVICE RESEARCH

Hall coefficient and electrical resistivity measurements were carried out on  $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$  single crystal specimens obtained from a high-quality, highly homogeneous crystal grown by the new method described in the previous report.

The responsivity of GaAs extrinsic far infrared detectors has been studied under low background conditions using a calibrated GaAs far infrared spontaneous emitter as a source and a cold blackbody to provide the background. The observed variation in responsivity with blackbody temperature from 10° to 300°K correlates with the observed variation in sample impedance.

Lifetime measurements of the extrinsic photoconductivity response of GaAs to radiation at 337  $\mu$  (and in one case also at 195  $\mu$ ) have been obtained in the range between 25 and 250 nsec for samples with different donor and acceptor concentrations. In general, samples with higher acceptor concentrations have shorter lifetimes, as expected.

Photoluminescence lines involving exciton-neutral donor complexes in high-purity GaAs have been identified using a magnetic field. Two sets of five lines each are identified: a higher energy set including free exciton recombination, exciton recombination at a neutral donor, and exciton recombination at three complex centers all involving a neutral donor; and a replica of this set of five lines at lower energy consisting of the same transitions with the neutral donor left in a terminal excited ( $n = 2$ ) state.

The first CW operation of a Raman laser has been achieved using a liquid nitrogen cooled CO laser and the spin-flip scattering from conduction electrons in InSb in a magnetic field. CO laser pump threshold powers as low as 200 mW have been observed, and CW output powers between 0.5 and 1 W have been obtained with tuning between 5.65 and 5.88  $\mu$  for a maximum 50-kG field.

## II. MATERIALS RESEARCH

The total vapor pressure over molten  $\text{Bi}_2\text{Te}_3$  has been measured between 707° and 896°C by means of a new manometric technique. Comparison of the results with those obtained by measuring the optical density of the vapor shows that  $\text{Bi}_2\text{Te}_3(l)$  does not vaporize congruently, since the vapor contains at least 95 atomic percent Te over the entire temperature range investigated.

Three high-pressure polytypes of  $\text{RbFeCl}_3$  have been prepared at pressures between 15 and 35 kbars and then retained at atmospheric pressure. One polytype, which has the same structure as the atmospheric pressure form of  $\text{RbNiF}_3$ , is a ferrimagnet with Curie point of 109°K and is transparent between 0.3 and 24  $\mu\text{m}$ , except for some absorption bands between 0.3 and 0.7  $\mu\text{m}$ .

A review of high-pressure synthesis, as illustrated by studies on compounds with the chemical formula  $\text{ABX}_3$  or  $(\text{AX}_n)_m(\text{ABX}_3)_m$ , where A and B are cations and X is an anion, has been prepared for publication as a chapter in Preparative Methods in Solid State Chemistry.

The volume compression of cubic  $\text{TiO}_x$ , with  $x = 0.85, 1.0, 1.11,$  and  $1.25$ , has been determined by x-ray diffraction measurements of the lattice parameter as a function of pressure. For the first two compositions, the volume compression is independent of pressure up to 140 kbars. For the two oxygen-rich compositions, the relatively large initial compression decreases with increasing pressure until it becomes essentially constant above 20 kbars.

### III. PHYSICS OF SOLIDS

Shubnikov-deHaas measurements have been carried out in  $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$ , with  $x = 0.08, 0.17,$  and  $0.20$ . The results indicate pockets of holes and electrons at the L-point of the Brillouin zone and, if one assumes mirror bands, that a six-band model gives better agreement than a two-band model.

Ultrasonic attenuation experiments in the frequency range 20 to 200 MHz have been initiated in order to explore the Fermi surface of holes in bismuth, which was recently reported to have a saddle point. No nonextremal Fermi surface cross sections are observed, even for the sound wave vector nearly perpendicular to the magnetic field.

High resolution, far infrared laser studies of hydrogenic donors in GaAs have been extended to higher magnetic fields, different transitions and additional samples. At the high fields, the central cell correction varies with magnetic field, since the wavefunction in the immediate vicinity of the impurity varies with field; using perturbation theory, quantitative agreement is obtained with a calculation based on effective mass wavefunctions.

A description of a smooth semiconductor-metal transition has been obtained, including both electron-electron Coulomb energy and lattice displacement energy. For  $\text{Ti}_2\text{O}_3$ , a calculation based on lattice displacement energy as dominant leads to reasonable qualitative agreement with experiment.

A procedure has been formulated for calculating the first few moments of the frequency dependent conductivity of a narrow band material in the Hubbard model. A method is proposed for using these moments to identify a Mott transition.

A relaxation time Ansatz has been established which treats both orbital and spin relaxation consistently in quantum transport theory. This approach conserves charge and spin density, and is important in treating such phenomena as spin-flip Raman scattering. This relaxation time Ansatz has also been incorporated into a calculation of the spectra of inelastic light scattering from acoustic plasma waves and single particle excitations in a semiconductor plasma in a magnetic field. The calculation indicates that the acoustic wave light scattering should be detectable with currently available experimental techniques.

Rushbrooke and Wood, and Domb and Sykes have contended on the basis of high-temperature power-series expansions that the standard procedure for determining experimentally the paramagnetic Curie temperatures, by extrapolating the (apparently) linear portion of the  $1/\chi$  versus  $T$  curve back to the temperature axis, is significantly in error. This has been examined in detail for  $\text{EuO}$  and  $\text{CdCr}_2\text{S}_4$ . The model-independent high-temperature power-series expansion is fit to experimental data, and from this fit true asymptotes are computed; these asymptotes are shown to be quite different from those obtained by the standard extrapolation procedure.

A finite temperature graphical theory for two-magnon scattering in a simple antiferromagnet has been constructed. The theory at  $T = 0^\circ\text{K}$  leads to the familiar result using two-time Green's functions and the Tyablikov decoupling scheme. Finite temperature calculations are under way.

A study of Raman scattering of argon ion laser radiation in the transparent antiferromagnet  $\text{FeF}_2$  has revealed, in addition to the Raman-active phonon and magnon excitations previously reported in the energy range below  $500\text{ cm}^{-1}$ , a new series of lines shifted approximately  $1100\text{ cm}^{-1}$  from the laser. The temperature dependence of this new series suggests some relation to magnetic ordering, although a detailed identification has not yet been made.

With the use of a simple theoretical model consisting of a one-dimensional slab of cold non-uniform plasma immersed in a uniform magnetic field, harmonic generation has been studied. This model, which has been previously proven capable of explaining qualitatively both CW linear response and nonlinear echo experiments, predicts (1) strong odd harmonic generation compared to even harmonic generation, and (2) for small collision frequencies, strongest odd harmonic generation occurring near cyclotron and upper hybrid resonances.

#### IV. MICROELECTRONICS

The semiconductor area is operational and several components have been delivered, including photodiode arrays, E-Bird devices, gallium arsenide Schottky barrier millimeter wave diodes, and surface wave amplifier silicon substrates.

The environmental test area useful in insuring that no fundamental faults exist in the hybrid or monolithic prototype integrated circuits is now operational. In addition to complete environmental tests of all fabricated units, sample lots are tested for long-term degradation.

Considerable effort is being made to institute inspection and process control procedures to insure the continued quality of existing processes and techniques and to improve the yield and quality of some presently unsatisfactory or low-yield process steps.

The laser scanning system for monolithic integrated circuit testing continues to show promise and is presently being implemented in our inspection and testing of integrated circuit chips. The design and construction of a faster scan for transient analysis, as well as for gain measurements, are in progress.

An empirically derived relationship predicting the total substrate area required for an integrated circuit layout based on component area and total number of internal and external connections is under study and currently has sufficient accuracy to be helpful in reducing or eliminating trial layouts. A computer program to make use of the predicted area, yield and cost relationship of different interconnecting line widths and process variables is in the planning stages. The empirical relationship derived is finding use in printed circuit layouts and monolithic structures, as well as in hybrid integrated circuits.

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