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# Quarterly Technical Summary

# Advanced Electronic Technology

15 May 1977

Prepared for the Department of the Air Force
under Electronic Systems Division Contract F19628-76-C-0002 by

**Lincoln Laboratory**

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LEXINGTON, MASSACHUSETTS

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Raymond L. Loiselle

Raymond L. Loiselle, Lt. Col., USAF
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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

# ADVANCED ELECTRONIC TECHNOLOGY

QUARTERLY TECHNICAL SUMMARY REPORT
TO THE
AIR FORCE SYSTEMS COMMAND

1 FEBRUARY – 30 APRIL 1977

ISSUED 17 JUNE 1977

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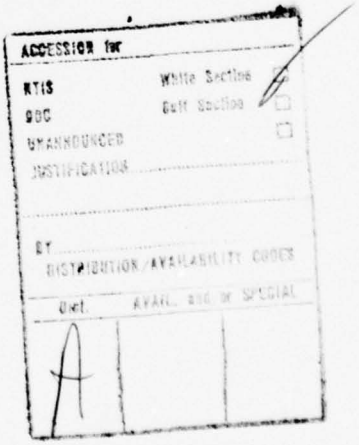
# INTRODUCTION

This Quarterly Technical Summary covers the period 1 February through 30 April 1977. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.



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CONTENTS





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# DATA SYSTEMS
# DIVISION 2

## INTRODUCTION

This section of the report reviews progress during the period 1 February through 30 April 1977 on Data Systems. Separate reports describing other work of Division 2 are issued for the following programs:

| | |
|---|---|
| Seismic Discrimination | ARPA/NMRO |
| Distributed Surveillance Networks | ARPA/IPTO |
| Education Technology | Bureau of Mines, ARPA/HRRO |
| Network Speech Processing | OSD-DCA |
| Digital Voice Processing | AF/ESD |
| Packet Speech | ARPA/IPTO |
| Communications Adaptive Internetting | ARPA/IPTO |
| Radar Signal Processing Technology | ARMY/BMDATC |
| Nuclear Safety Designs | NRC |

M. A. Herlin
Head, Division 2

A. J. McLaughlin
Associate Head

# I. INTRODUCTION

The first practical circuit fabricated with the poly-ox isolation process, an eight-bit serial/parallel converter designed with the goal of accepting a 1-GHz bit stream, was tested this quarter up to 540 MHz. Storage and readout was accomplished in a simulated million-bit MNOS capacitor array memory chip.

# II. APPLICATIONS

## A. Serial-Parallel Converter

Several runs of poly-ox isolated eight-bit Serial/Parallel converter wafers have been processed through wafer test. Devices from two wafers were packaged and performance tested using both an alternate one-zero and an eight ones-eight zeros test pattern. A simple evaluation circuit consisting of a single D-master/slave flip flop operated correctly at clock frequencies to 980 MHz. A converter circuit operated correctly to 540 MHz.

The high-speed test pattern generator has been completed except for delivery of a commercial gigahertz pulse generator. This system can apply arbitrary 16-bit test patterns to the converter at clock frequencies as high as 800 MHz.

## B. MNOS Capacitor Memory Array

Successful storage and readout has been accomplished in simulated million-bit arrays, using an offchip diode-resistor partial decoding circuit fabricated from discrete components. The array has 256 capacitors formed by 0.2- × 0.2-mil intersections and 768 larger capacitors which simulate the loading of a million-bit array. Considerable capacitor leakage as well as poor junction isolation between the silicon digit lines and the substrate were observed. Extensive electrical test are now being developed to determine the magnitude of the problem and, in conjunction with examination under the scanning electron microscope, will be used to identify processing steps which are responsible.

Experiments were performed on selection schemes which use two series MOS transistors and pullup resistors. Both of the transistors must be on to select the line connected through the two transistors to a selection bus. The number of leads, then, which must be controlled is approximately the fourth root of the number of capacitors. FET gate-drive levels necessary for switching ± 30 V into the word lines were established. On the basis of these tests, an array tester was designed for dynamically accessing MNOS capacitors. This tester will serve the same function as the present manually switched diode-resistor access circuitry.

# III. INTEGRATED CIRCUIT PROCESSING

## A. Poly-Ox Isolation Processing

Inversion of the starting substrate below the spoiler layer has been eliminated by ion implantation of a thin p-skin prior to forming the initial oxide or nitride spoiler. Two further process improvements are: (1) use of a single diffusion for both poly resistors and base handles, and (2) elimination of masking of the active-base implant.



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Problems have been encountered due to a high defect density in the epitaxial silicon islands. A contribution to the problem is silicon surface damage from the buried-collector spin-on-glass procedure. An alternative implanted arsenic process is being investigated. Moreover, it is possible that the presence of polycrystalline silicon increases the defect density near the epi-poly boundaries. A mask set has been designed to test this hypothesis.

### B. Self-Aligned Transistors

Double-implanted self-aligned bipolar transistors have been fabricated with base widths of 3500 Å, betas of ~100 (7% standard deviation), and peak $f_T$'s of 2.0 GHz. A modified implant-anneal schedule is now under development to produce narrow-basewidth transistors with a 5-GHz $f_T$ design goal.

Interesting data have been recorded regarding long (10- to 100-hr) 500°C anneals after emitter and base implant. The results suggest increased breakdown voltages, lower junction leakages, and tighter distribution of electrical parameters, all presumably due to lower defect density of the implanted silicon due to this anneal as indicated by recent literature.

### C. Photolithography and Plasma Etching

Excessive mask damage has been experienced after epi in the poly-ox processing. Originally thought to result from inadequate spike removal, the glass mask fractures are too numerous to be caused solely by epi spikes. Conceivably, the surface roughness of poly and some "beak" type phenomena also contribute to this effect.

Aluminum and Al-Si-Cu plasma etching experiments have begun. Early results are encouraging, with rapid, even aluminum removal. The Al-Si-Cu etches less evenly and the Si-Cu residue remains as a dark smut, which is readily removed chemically. Considerable work is needed to fully characterize the system and processing parameters. The oxide, nitride, silicon plasma reactor is fully functional providing faster and more uniform etching.

### D. Gate Array Processing

The limited amount of gate array processing which took place during this period was directed towards the development of an implanted arsenic emitter transistor. When compared to the standard diffused phosphorous emitter process, improved control of $f_T$ and current gain among gate array devices is expected since ion implantation provides precise control of dopant levels while the reduced diffusion coefficient of arsenic will permit more reproducible diffusion profiles. Experiments conducted jointly with the development of the poly-ox transistor indicated that a 30-keV implant of $5 \times 10^{15}$ arsenic ions/cm$^2$ followed by a 1000°C anneal in nitrogen would produce devices with characteristics similar to those of the standard gate array transistors. Some additional optimization is required before the implantation process can be fully adopted for fabrication since low breakdown emitter-base junctions are occasionally observed.

## IV. DESIGN, ANALYSIS, AND TESTING

### A. Integrated Injection Logic

One run of $I^2L$ gate chains has been made using essentially our ECL process. One set of devices used 0.1-mil minimum-space design rules. Typical measured characteristics were: minimum delay per stage, 10 nsec at 50 μA per gate bias current; speed-power product, 0.3 pJ;

minimum bias current to switch, 4μA. The fan out of these circuits was limited by high extrinsic base sheet resistance, which will be corrected in the next run.

B. Transistor Testing

The facilities for transistor testing have been upgraded by the design of a new computer-controlled bias generator using a type AD605 Precision Instrument Amplifier which provides very good common mode rejection. The test jig used in our $f_T$ (gain-bandwidth) test set has been replaced by a modified GR type 1607-P-42 grounded-emitter transistor mount. An older TO-51 transistor mount is being modified to allow measurements of transistors in this type of package. We will be able to make measurements at our standard 400 MHz, or if necessary, at 1.2 GHz. A digital capacitance meter has also been incorporated into the test facility. Some preliminary measurements of collector capacitance as a function of collector current have been made.

C. Charge Storage and Conduction in Nitride Films

A physical model for charge storage and conduction in thin nitride films has been developed. Two types of charged (when empty) traps are assumed to exist in the nitride: (1) a deep donor trap (charged positively when empty), and (2) a shallow acceptor trap (charged negatively when empty). Essentially, the donor trap acts as a recombination center for holes and electrons and the acceptor trap acts as a Poole-Frenkel trap for holes. Conduction in the bulk of the nitride is of the Poole-Frenkel type and due to holes. Carrier injection at the contacts, however, can be either holes or electrons. If the injected carriers are electrons, they recombine with holes through the donor-like recombination centers within a short distance (≈ 30 Å) of the injecting contact so that dominant carriers in the bulk of the nitride are holes. Charge storage in the nitride takes place in the vicinity of the injecting contact. The sign of the charge stored depends on the carrier being injected. Electrons are stored in the donor traps and holes in the acceptor traps. Dischcarge of stored electrons takes place by donor hole capture, i.e., hole-electron recombination. Stored holes can be discharged by electron capture. However, the acceptor trap is sufficiently shallow that field detrapping of the holes is most likely to be the dominant mechanism for hole discharge.

D. Circuit Simulation

SPICE2,* a general-purpose circuit simulation program developed at the University of California at Berkeley, has been installed on our IBM 370/168 computer.

*L. W. Nagel, "SPICE2: A Computer Program to Simulate Semiconductor Circuits," ERL Memo No. ERL-M520, Electronics Research Laboratory, University of California, Berkeley (May 1975).

# COMPUTER SYSTEMS
## GROUP 28

A one-year study, in conjunction with the IBM Watson Research Laboratory, of the effectiveness of a low-speed online data collection device (Device Coupler) has been successfully completed. The Device Coupler provides a standard interface between the IBM 370/168 and familiar digital or analogue laboratory apparatus. Designed to operate inline with a user's terminal and exploit standard terminal software support, the Device Coupler provides the researcher with a simple tool for collecting and processing low-speed (134-baud) experimental data and for controlling low-speed experiments in real time. In addition to this mode of operation, the Device Coupler has been run in an out-of-line configuration at speeds up to 2400 baud. Considerable effort has gone into providing both software and interfacing support for this configuration, and investigation into the possibility of supporting even higher data rates (4800 to 9600 baud) is under way. Currently, there are five Device Couplers installed in various laboratories, with several more on order.

The past several months have seen a sharply increased number of requests from the user community to connect a variety of devices to the central computer. These requests, which have included high-speed terminals, minicomputers and microcomputers, and the above-mentioned Device Couplers, have severely taxed both the addressing capacility of the present hardware and the throughput capacity of the Communications Controller through which such connections are established. A second Communications Controller has been ordered and will be installed early in the summer. This will relieve the overload on the present Controller and allow outstanding requests for connections to be satisfied. The addressing limitation is a potentially more serious long-term restriction, and an investigation is under way to determine the most cost-effective hardware/software solution. Considerable software development is likely to be necessary if costly hardware upgrades are to be avoided.

In response to an upcoming security check and a revised list of Department of Defense guidelines for classified data processing, the computer facility has completed a thorough review of its procedures for handling classified work. Although a few potential loopholes were identified and closed, in the main, the facility's practices were in conformance with recommended procedures. The computer center routinely operates as a controlled area, with access permitted only to those cleared Laboratory and vendor support personnel, or other individuals under escort, whose presence in the center is necessary to the operation. All classified work is processed in dedicated mode, using a special version of the batch operating system. A part of the procedure for bringing up this dedicated system involves the physical disabling of all teleprocessing equipment or other devices with communications capabilities outside of the controlled area. The initialization procedure has been modified to verify that all such devices are indeed disabled, and to inform the operator if they are not. Procedures for handling unclassified output of classified runs have also been reviewed, and more stringent restrictions placed on the release of such output to users, especially in the case of magnetic tapes to be used in unclassified operations. Finally, both internal and user documentation have been updated to reflect current practices and requirements.

# SOLID STATE
# DIVISION 8

## INTRODUCTION

This section of the report summarizes progress during the period 1 February through 30 April 1977. The Solid State Research Report for the same period describes the work of Division 8 in more detail. Funding is primarily provided by the Air Force, with additional support provided by the Army, ARPA, NSF, and ERDA.

A. L. McWhorter
Head, Division 8

I. Melngailis
Associate Head

# DIVISION 8 REPORTS
# ON ADVANCED ELECTRONIC TECHNOLOGY

15 February through 15 May 1977

## PUBLISHED REPORTS

### Journal Articles

| JA No. | | | |
|---|---|---|---|
| 4621 | Minority Carriers in Graphite and the H-Point Magnetoreflection Spectra | W. W. Toy*<br>M. S. Dresselhaus*<br>G. Dresselhaus | Phys. Rev. B 15, 4077 (1977) |
| 4622 | Infrared Third-Harmonic Generation in Phase Matched CO Gas | H. Kildal | IEEE J. Quantum Electron. QE-13, 109 (1977) |
| 4629 | Graphite Intercalation Compounds: Electronic Properties in the Dilute Limit | M. S. Dresselhaus*<br>G. Dresselhaus<br>J. E. Fischer* | Phys. Rev. B 15, 3180 (1977) |
| 4647 | Multiple-Energy Proton Bombardment in $n^+$-GaAs | J. P. Donnelly<br>F. J. Leonberger | Solid-State Electron. 20, 183 (1977) |
| 4666 | Temperature-Gradient LPE Growth of $Pb_{1-x}Sn_xTe$ | S. H. Groves | J. Electron. Mater. 6, 195 (1977) |
| 4667 | Frequency Dependence of the Dissociation of Polyatomic Molecules by Radiation | D. M. Larsen | Opt. Commun. 19, 404 (1976) |
| 4684 | Microscopic Theory of the Lattice Dynamics of hcp Rare-Earth Metals | J. C. Upadhyaya*<br>A. O. E. Animalu | Phys. Rev. B 15, 1867 (1977) |
| 4693 | Resonant Infrared Third-Harmonic Generation in Cryogenic Liquids | H. Kildal<br>S. R. J. Brueck | Phys. Rev. Lett. 38, 347 (1977) |
| 4700 | Low-Dose n-Type Ion Implantation into Cr-Doped GaAs Substrates | J. P. Donnelly<br>C. O. Bozler<br>W. T. Lindley | Solid-State Electron. 20, 273 (1977) |
| 4703 | 1500-h Continuous cw Operation of Double-Heterostructure GaInAsP/InP Lasers | C. C. Shen<br>J. J. Hsieh<br>T. A. Lind | Appl. Phys. Lett. 30, 353 (1977) |
| 4705 | Room-Temperature cw Operation of Buried-Stripe Double-Heterostructure GaInAsP/InP Diode Lasers | J. J. Hsieh<br>C. C. Shen | Appl. Phys. Lett. 30, 429 (1977) |

* Author not at Lincoln Laboratory.



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## Meeting Speeches

| MS No. | | | |
|---|---|---|---|
| 4177E | Wavelength-Selective Surfaces for Solar Energy Utilization | J. C. C. Fan | Proc. SPIE Vol. 85: Optics in Solar Energy Utilization II (Society of Photo-Optical Instrumentation Engineers, Bellingham, Washington, 1976) pp. 39-46. |
| 4238 | Preparation of Polycrystalline Si Thin Films by Laser Crystallization | J. C. C. Fan<br>H. J. Zeiger<br>P. M. Zavracky | Proc. National Workshop on Low Cost Polycrystalline Solar Cells, Dallas, Texas, 18-19 May 1976, pp. 89-104. |
| 4262 | The Physical Properties of Cadmium Telluride | A. J. Strauss | Rev. Phys. Appl. 12, 167 (1977) |
| 4280 | CdTe Optical Waveguide Modulators | D. L. Spears<br>A. J. Strauss | Rev. Phys. Appl. 12, 401 (1977) |

* * * * *

## UNPUBLISHED REPORTS

### Journal Articles

| JA No. | | | |
|---|---|---|---|
| 4694 | X-Ray Photoemission Spectroscopy Studies of Sn-Doped Indium-Oxide Films | J. C. C. Fan<br>J. B. Goodenough | Accepted by J. Appl. Phys. |
| 4709 | Selective Black Absorbers Using RF-Sputtered $Cr_2O_3$/Cr Cermet Films | J. C. C. Fan<br>S. A. Spura | Accepted by Appl. Phys. Lett. |
| 4718 | $Ag_2Se$-$Ga_2Se_3$ Pseudobinary Phase Diagram | J. C. Mikkelsen, Jr. | Accepted by Mat. Res. Bull. |
| 4721 | CW Operation of Distributed Feedback $Pb_{1-x}Sn_xTe$ Lasers | J. N. Walpole<br>A. R. Calawa<br>S. R. Chinn<br>S. H. Groves<br>T. C. Harman | Accepted by Appl. Phys. Lett. |
| 4724 | Second Vibrational Overtone Absorption Spectrum of the $\nu_3$ Mode of $SF_6$ | H. Kildal | Accepted by J. Chem. Phys. |
| 4726 | Thin-Film $VO_2$ Submillimeter-Wave Modulators and Polarizers | J. C. C. Fan<br>H. R. Fetterman<br>F. J. Bachner<br>P. M. Zavracky<br>C. D. Parker | Accepted by Appl. Phys. Lett. |

| JA No. | | | |
|---|---|---|---|
| 4728 | Flash-Lamp Excited $NdP_5O_{14}$ Laser | S. R. Chinn<br>W. K. Zwicker* | Accepted by Appl. Phys. Lett. |
| 4734 | Optoacoustic Measurements of Energy Absorption in $CO_2$ TEA Laser Excited $SF_6$ at 293 and 145 K | T. F. Deutsch | Accepted by Opt. Lett. |
| MS-4271 | X-Ray Lithography | H. I. Smith<br>D. C. Flanders | Accepted by Jap. J. Appl. Phys. |

## Meeting Speeches†

| MS No. | | | |
|---|---|---|---|
| 4230E | GaInAsP/InP Double-Heterostructure Diode Lasers | J. J. Hsieh | Electrical Engineering and Computer Science Seminar, M.I.T., 16 February 1977 |
| 4361A, B | GaInAsP/InP Double-Heterostructure Diode Lasers for Fiber Optical Communications | J. J. Hsieh | Seminar, IBM Thomas Watson Research Center, Yorktown Heights, New York, 21 March 1977; Philips Research Laboratory, Briarcliff Manor, New York, 22 March 1977 |
| 4362A | Surface State Studies on $SrTiO_3$ Electrodes | J. G. Mavroides | Electrochemistry and Physics of Semiconductor-Liquid Solution Interfaces Under Illumination Meeting, Airlie, Virginia, 3 May 1977 |
| 4378 | 1000-Hour Continuous cw Operation of Double-Heterostructure GaInAsP/InP Lasers | C. C. Shen<br>J. J. Hsieh<br>T. A. Lind | Optical Fiber Transmission Meeting, Williamsburg, Virginia, 22-24 February 1977 |
| 4379 | Room-Temperature cw Operation of Buried Stripe, Double-Heterostructure GaInAsP/InP Diode Lasers | J. J. Hsieh<br>C. C. Shen | |
| 4381A | Interaction of $O_2$ and $H_2O$ with Surface Defects on $TiO_2$ and $SrTiO_3$ | H. J. Zeiger<br>V. E. Henrich<br>G. Dresselhaus | American Physical Society Meeting, San Diego, 21-24 March 1977 |
| 4398 | Theory of Spin-Disorder-Raman Scattering in Magnetic Semiconductors | S. A. Safran*<br>G. Dresselhaus<br>B. Lax* | |

* Author not at Lincoln Laboratory.

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

| MS No. | | | |
|---|---|---|---|
| 4402 | Surface States on $SrTiO_3$ | V. E. Henrich<br>G. Dresselhaus<br>H. J. Zeiger | American Physical Society Meeting, San Diego, 21-24 March 1977 |
| 4382 | Selective Black Absorbers Using rf-Sputtered $Cr_2O_3$/Cr Cermet Films | J. C. C. Fan<br>S. A. Spura | 151st Meeting of the Electrochemical Society, Philadelphia, 8-13 May 1977 |
| 4383 | Detect Surface States on $SrTiO_3$ Photoelectrolytic Electrodes | J. G. Mavroides<br>V. E. Henrich<br>H. J. Zeiger<br>G. Dresselhaus<br>J. A. Kafalas<br>D. F. Kolesar | |
| 4384 | New Lithium Solid Electrolytes | H. Y-P. Hong | |
| 4392 | Tunable Infrared Lasers | A. Mooradian | 3rd International Conference on Lasers and Their Applications, Dresden, Germany, 27 March – 2 April 1977 |
| 4405A | Efficient Infrared Third-Harmonic Generation in Cryogenic Liquids | H. Kildal | Seminar, M.I.T., 16 March 1977 |
| 4407, A | Heterodyne Sensitivity Evaluation of GHz Bandwidth 10.6 μm Photodiodes | D. L. Spears | IRIS Detector Specialty Group Meeting, U.S. Air Force Academy, Colorado, 22-24 March 1977; Symposium on 10.6 Micron Laser and Detector Technology for Compact Military Devices, Ft. Monmouth, New Jersey, 10 May 1977 |
| 4415 | Ternary Semiconductor Crystals for Nonlinear Optical Applications | G. W. Iseler<br>H. Kildal<br>N. Menyuk | Third International Conference on Ternary Compounds, Edinburgh, Scotland, 14-15 April 1977 |
| 4416 | Double Resonance Spectroscopy of $SF_6$ | P. F. Moulton<br>D. M. Larsen<br>J. N. Walpole<br>A. Mooradian | Laser Induced Chemistry Conference, Park City, Utah, 14-16 February 1977 |
| 4417 | Resonant Infrared Third-Harmonic Generation in Cryogenic Liquids | S. R. J. Brueck<br>H. Kildal | 7th Winter Colloquium on High Power Visible Lasers, Park City, Utah, 16-18 February 1977 |
| 4428, A | GHz Bandwidth HgCdTe Photodiodes for Heterodyne Radiometry | D. L. Spears | Seminar, NASA Langley Research Center, Langley, Virginia, 16 February 1977; Seminar, University of Maryland, College Park, 17 February 1977 |

| MS No. | | | |
|---|---|---|---|
| 4442 | Submicrometer Engineering | H. I. Smith | Electrical Engineering Colloquium, Rensselaer Polytechnic Institute, Troy, New York, 10 March 1977 |
| 4450 | Spanning the Gap Between Microelectronic and Surface Wave Signal Processors with Acoustoelectrics | R. W. Ralston | *IEEE Groups on Sonics and* Ultrasonics and on Electron Devices, Technical Meeting Of Boston Chapters, MITRE Corp., Bedford, Massachusetts, 13 April 1977 |
| 4463 | GaAs Thin-Film Solar Cells | J. C. C. Fan | ERDA Solar Photovoltaic R&D Review Meeting, Washington, D.C., 22-23 March 1977 |
| 4474 | New $Na^+$ and $Li^+$ Superionic Conductors | J. A. Kafalas | Fourth Biennial Air Force Electrochemistry Conference, Colorado Springs, 28-29 April 1977 |
| 4485 | Advance Schottky Diode Concepts | H. R. Fetterman | SPIE/SPSE Technical Symposium, Reston, Virginia, 18-21 April 1977 |

# SOLID STATE
# DIVISION 8

## I. SOLID STATE DEVICE RESEARCH

A GaAs 2 × 2 electrooptic waveguide switch in which the power isolation in both switch states can be electrically optimized has been demonstrated. The device exhibits up to 25 dB power isolation in both states with total power output constant to within ≤0.3 dB.

The p-n junction location in double-heterostructure (DH) GaInAsP/InP laser diodes was determined by using a scanning electron microscope. Even though undoped or Sn-doped quaternary layers are n-type if grown on insulating substrates, the quaternary layer in the grown DH is p-type, presumably due to Zn diffusion from the Zn-doped InP capping layer.

An investigation of the proton bombardment of InP indicates that the resistivity of n-type InP can be increased only to a level of about $10^3$ Ω-cm, while the resistivity of p-type InP can be increased to $>10^8$ Ω-cm for an optimum multiple-energy dose or an optimum combination of dose and post-bombardment anneal. The results can be explained by a model which assumes that the proton bombardment creates both deep donor and deep acceptor levels.

The ion implantation of Se, Si, Be, Mg, Cd, and Fe in InP was investigated. Implantation of Fe was found to be quite effective in creating high-resistivity layers in n-type InP. A multi-energy Fe implant in n-type InP ($n \approx 4 \times 10^{16}$ $cm^{-3}$) followed by annealing at 725°C for 15 min. yielded layers with a resistivity $\approx 10^7$ Ω-cm.

A high distribution coefficient impurity, identified as silicon, was shown to be a key problem in achieving the goal of growing high-purity InP layers by liquid-phase epitaxy (LPE). We found that not only is the Si concentration of as-received In too high, but also the LPE growth solution can be contaminated with Si through direct or indirect contact with quartz if a strongly reducing gas such as dry $H_2$ is present in the growth tube.

## II. QUANTUM ELECTRONICS

A simple miniature room-temperature pulsed $NdP_5O_{14}$ laser excited by a small Xe flashlamp has been made, with threshold energies of a few hundred millijoules. Output energies of 4.5 mJ have been obtained with less than 1 J input, and further improvement is expected.

Efficient second-harmonic generation has been achieved in $AgGaSe_2$. Using a $CO_2$ laser with a 0.5-nsec pulse length, a second-harmonic energy conversion efficiency of 33 percent was observed.

The second harmonic generated by a $CdGeAs_2$ crystal pumped by a passively Q-switched $CO_2$ laser has been scattered from a remote topographic target and the return signals detected. This system can be used for differential absorption measurements of the concentrations of atmospheric constituents.

Grating tuning of the optically pumped $O^{13}CS$ and $C_2H_2$ lasers has been demonstrated. From the measured 53 laser lines of the $O^{13}CS$ laser, the band center for the laser transition has been determined.

The second vibrational overtone absorption spectrum of the $\nu_3$ mode of $SF_6$ has been measured using a 1-m grating spectrometer. Only a single Q-branch transition was observed.

Infrared double-resonance and saturation techniques have both been used to measure the V-T relaxation of the $\nu_3$ mode of $CH_3F$ in dilute solution in the cryogenic hosts liquid $O_2$ and



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liquid Ar. With the double-resonance technique, a relaxation time of 375 ± 35 nsec was found in liquid $O_2$, while in liquid Ar the relaxation time was 1.30 ± 0.15 μsec. An induced $\nu_3 \rightarrow 2\nu_3$ absorption was observed in the double-resonance measurement; the observed anharmonicity is in good agreement with the gas-phase literature value.

The previously developed rotation-vibration interaction model for the widths of two-photon resonances in liquid media has been used in an analysis of recently reported results for the temperature dependence of the Raman linewidth in liquid $N_2$. The results indicate that this process contributes significantly to the observed linewidths.

Heterodyne radiometry with blackbody sources was used to determine the sensitivities of GaAs Schottky-diode submillimeter receivers. At 500 μm, an NEP of $2 \times 10^{-18}$ W/Hz was measured for the system.

## III. MATERIALS RESEARCH

A vertical gradient-freeze technique has been developed for growing single crystals of Ni-doped $MgF_2$ which will be used to determine whether this material can be used as a tunable source of near-infrared laser radiation. Crystals of excellent optical quality, as determined by interferometer evaluation, have been grown in self-sealing graphite crucibles in a tungsten-element resistance furnace.

To assist in the development of near-infrared lasers and detectors utilizing $Ga_xIn_{1-x}As_yP_{1-y}$ layers lattice-matched to InP substrates, the alloy compositions of such layers have been determined by electron microprobe analysis, and the emission wavelengths of lattice-matched $Ga_xIn_{1-x}As_yP_{1-y}$/InP double-heterostructure diode lasers have been measured at 300 and 77 K. Over the entire lattice-matching range, the composition data are well represented by $x = 0.40y + 0.067y^2$, and the laser photon energies at 300 K are given by $h\nu$ (eV) $= 1.307 - 0.60y + 0.03y^2$.

## IV. MICROELECTRONICS

The optimum channel-stop implants and field oxide growth conditions have been determined for the MOS transistors which will be part of the static shift register being added to the programmable transversal filter to control the binary multiplication. An optimum value for channel doping was found to be $3.8 \times 10^{16}$ cm$^{-3}$, which could be achieved by implanting boron at 200 keV at a dose of $1 \times 10^{13}$ cm$^{-2}$. The 0.8-μm-thick field oxide was grown by a steam oxidation for 4 hr at 1000°C, followed by an 1100°C gate oxidation in dry $O_2$ plus 3% HCl for 18 min., followed by a 15-min. $N_2$ anneal. This process yielded an acceptably small flatband voltage of −4 V.

Several wafers of the 100- × 400-cell CCD imaging devices for the GEODSS (Ground Electro-Optical Deep Space Surveillance) Program have been fabricated incorporating an integral light shield over the input and output shift registers. A total of 12 of 84 devices have passed a DC probe test and will be dynamically evaluated. Devices which pass the dynamic test will be used to assemble a 2-chip prototype hybrid imaging array.

A two-level interconnect system has been developed for fabricating hybrid integrated circuits on alumina substrates. Sputtered aluminum is used for both metallization levels, and insulation between levels is provided by either sputtered or low-temperature CVD $SiO_2$. Substrates for two complex, multi-chip hybrid circuits have been fabricated by this process – one an 8-bit multiplier utilizing 8 microprocessor chips and the other a 16-chip CCD sensor array. Best results were obtained using a CVD oxide and a 99.5% alumina substrate polished to 1- to 2-μ-in. surface finish.

## V. SURFACE-WAVE TECHNOLOGY

A process has been developed for fabricating polyimide-membrane x-ray-lithography masks with membrane thicknesses ranging from 0.5 to several micrometers. Thin membranes are required so that they are relatively transparent to soft x-rays. The process produces large-area rugged x-ray masks suitable for use at the 13.3-Å $Cu_L$ wavelength as well as at the 44.7-Å $C_K$ and 8.34-Å $Al_K$ wavelengths.

The first results have been obtained with a new acoustoelectric surface-acoustic-wave device, the integrating correlator. The basic operation of the device is similar to a correlation receiver. An array of Schottky diodes held in close proximity to a $LiNbO_3$ delay line provides mixing of two counter-propagating surface waves, and each diode integrates the mixer product over time. Integration times of 50 msec or more have been achieved. For a device with a bandwidth of 20 MHz, this provides a potential correlation gain in excess of 50 dB.

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