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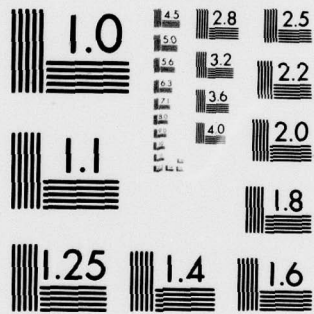
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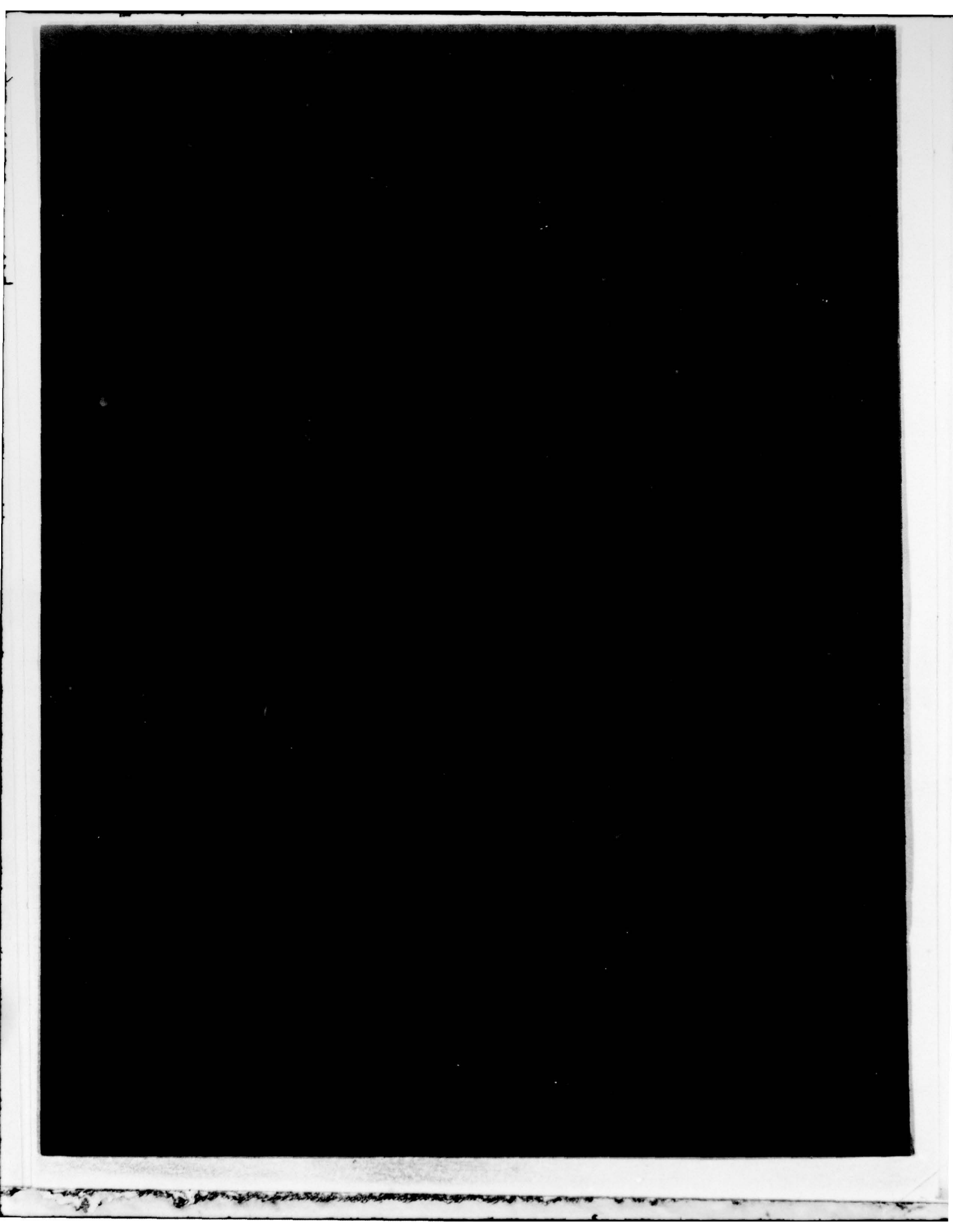


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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

ADVANCED ELECTRONIC TECHNOLOGY

QUARTERLY TECHNICAL SUMMARY REPORT
TO THE
AIR FORCE SYSTEMS COMMAND

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1 FEBRUARY - 30 APRIL 1979

ISSUED 2 JULY 1979

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INTRODUCTION

This Quarterly Technical Summary covers the period 1 February through 30 April 1979. 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

Introduction	iii
DATA SYSTEMS - DIVISION 2	
Introduction	1
Digital Integrated Circuits - Group 23	3
I. Introduction	3
II. High-Speed Digital Circuits	3
III. MNOS Memory	3
IV. Analysis and Testing	4
Computer Systems - Group 28	6
SOLID STATE - DIVISION 8	
Introduction	7
Division 8 Reports on Advanced Electronic Technology	9
I. Solid State Device Research	13
II. Quantum Electronics	13
III. Materials Research	14
IV. Microelectronics	14
V. Analog-Signal-Processing Technology	15

DATA SYSTEMS
DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 February through 30 April 1979 on Data Systems. Separate reports describing other work of Division 2 are issued for the following programs:

Seismic Discrimination	ARPA/NMRO
Distributed Sensor Networks	ARPA/IPTO
Education Technology	Bureau of Mines
Network Speech Systems Technology	OSD-DCA
Digital Voice Processing	AF/ESD
JTIDS Speech Processing	AF/ESD
Packet Speech Systems Technology	ARPA/IPTO
Radar Signal Processing Technology	ARMY/BMDATC
Nuclear Safety Designs	NRC

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DIGITAL INTEGRATED CIRCUITS
GROUP 23

I. INTRODUCTION

MNOS 64K memory chips were made with no between-metal shorts and good storage and readout on 80 percent of the bits. The valence alternation pair (VAP) defect model has been applied to silicon dioxide. A new mask verification program was used to check the 64K memory masks.

II. HIGH-SPEED DIGITAL CIRCUITS

A. Parallel/Serial Converters

Parallel/serial converter circuits have been fabricated and await testing. These use the same diffusion masks as the serial/parallel circuit and new metal masks.

B. Poly-Ox Process Evaluation

Ring oscillators on a test chip have functioned with a gate delay of 280 psec per stage at a switched current of 1.2 mA. Other structures show that minority carrier lifetime in doped polysilicon decreases as the doping increases, and that depletion-layer widths in polysilicon diodes decrease as doping increases. Use of thermal silicon oxide and CVD silicon nitride which are under compressive and tensile stress, respectively, make it important in processing design to consider balancing these stresses over the front and back of the wafers to prevent bowing and eventual wafer breakage.

III. MNOS MEMORY

A. 64K-Chip Fabrication

A decoded 64K silicon chip with polyimide between-metal insulation has been fabricated in which successful storage and readout can be performed on over 80 percent of the array. Analysis of modes of failure is incomplete. Incorporation of damaged-Si guard rings around the decoding transistors has improved device characteristics and yield. Partially functioning chips on both bulk Si and SOS have been fabricated. The improved isolation and lower capacitive loading obtained on SOS indicate that better yield and performance will probably be obtained on sapphire. Electrical testing of the 64K chips indicates that a digit line dynamic pulldown, which will be implemented in the second-generation 64K chip design, is essential to eliminate parasitic contributions to the readout due to sneak paths in the memory array, and to minimize sense amplifier noise. Masks for the new 64K chip are due early in the next quarter.

B. Testing

Previously, MNOS memory testing has been done with a 150-kHz read voltage and a sense amplifier with a 1-MHz bandwidth and about 50-mV peak-to-peak noise. A new sense amplifier has been built for 1-MHz read waveforms which has 10-MHz bandwidth and about 5-mV peak-to-peak noise. A new probe card with fast drivers and the new amplifier is being designed.

C. Polyimide Insulation for Multi-level Metal

A number of 64K memory wafers have now been made using polyimide plastic as insulation between first- and second-level metal conductors. The plastic is 0.5 μm thick, permits etching of $5 \times 15\text{-}\mu\text{m}$ vias, has very good adhesion to metal and oxide and good adhesion to nitride, and is not degraded by high-temperature processing. Between 20 and 30 percent of the memory chips per wafer show no between-metal shorting in extensive address bus tests, and via resistance is uniformly low with no sinter. Further development of this process for multi-level interconnect in VLSI circuits will continue.

D. Plasma-Deposited Insulation for Multi-level Metal

Work continued on the plasma deposition of low-temperature nitride and oxide films in order to obtain a more conformal coating of the memory chip's first-level metal pattern. 6000- and 8000- \AA SiO_2 films have been deposited on 64K MNOS memory wafers. The process utilized a 1.5-percent silane mixture in argon and nitrous oxide, a total pressure of 2300 μm , and a substrate temperature of 300°C. The deposition rate was 1200 $\text{\AA}/\text{min}$. The wafers were processed through second-level etch and 75 percent of the chips had no between-metal shorts. The results indicate that a 6000- \AA plasma-deposited SiO_2 layer provides satisfactory coverage of the first-level metal. In addition, the low deposition temperature minimizes the degradation of the chip's damaged-silicon isolation.

During these studies, a second cause of gate-to-select-line shorts was found. The second-level busses were connected by thin strips of aluminum which remained on the SiO_2 -coated walls of the first-level metal after plasma etching. A brief wet etch was sufficient to remove the metal.

IV. ANALYSIS AND TESTING

A. VAP Defects in Silica

The valence alternation pair (VAP) concept of defect centers has been applied to amorphous silicon dioxide (a- SiO_2). The defect centers are a singly bonded nonbridging oxygen and a triply bonded bridging oxygen. The VAP model of defects in a- SiO_2 is consistent with experimentally observed properties such as negative bias instability and Anderson localization in MOS devices, electron and hole trapping in the oxide, and growth or radiation-induced optical absorption and luminescence in the oxide. The concept of VAP defects thus would appear to offer a natural explanation of many of the defect properties of a- SiO_2 .

B. Neon-Damaged Silicon

More accurate measurements of conductivity as a function of temperature in neon-damaged silicon confirm the previously reported model of this material. The thermal activation energy of conductivity is 0.56 eV, half the bandgap of silicon.

C. MOS Test Program

The TIC system MOSCAP test program has been revised to provide more accurate data for MOS capacitors. The impurity concentration is now determined from a measurement of the minimum capacitance by a method suggested by J. R. Brews.* The measured C-V curve may

*J. R. Brews, *Solid-State Electron.* 20, 607 (1977).

also be used to produce a plot of dopant concentration against distance from the oxide. The program computes and plots a theoretical C-V curve and this is used in conjunction with the measured C-V curve to determine the flat band voltage and Q_{SS} . A plot of interface state density may also be obtained.

D. Mask Analysis

The mask design verification program is now operational on the IBM 370 computer. The program provides the user with a general set of mask primitives which permit design rule checking and design verification. Mask primitives are divided into three categories: spacing, logical, and input/output. Spacing operations consist of single-mask interior dimension check, single-mask figure-to-figure spacing, dual-mask figure-to-figure spacing, and dual-mask enclosure checks. The logical operations are union, intersection, and negation. Input/output operations include primitives to read/write magnetic tape and disk. The mask program was employed to check the 64K MNOS memory chip mask set. A total of 23 separate tests were run. Several mask errors were found which had gone undetected despite considerable manual checking.

COMPUTER SYSTEMS
GROUP 28

One of the measures of demand for interactive computing service is the average number of users logged on over the course of the working day. In the previous quarter, the daily average was 85. In this quarter, the daily average has jumped to nearly 95.

In order to service this kind of growing demand, several different actions have been taken. The most significant effort was the evaluation of proposals for a more powerful system. It is expected that this will lead to a selection and installation during the next quarter. The algorithm for dispatching daytime batch jobs for processing has been changed to select on the basis of least estimated run time. This will not, of course, increase total throughput, but it will provide better response to the interactive user. Also, the entire schedule balance between the interactive (VM) and batch (VS) systems has been modified and extended on an ad hoc basis in response to changes in the load. Whenever available, more efficient software has been provided. One such item, installed in the past quarter, is a new Fortran compiler that includes several optimization levels which produce significantly more efficient run-time code.

Several different facets of graphic output are being investigated. Installation planning and training for the Information International COMp80 system is in progress, and an RFI for a hard-copy processor has been released. The installed Interdata/Ramtek color display system has been brought up to a point where reliability is reasonably stable. Requirements for a better system are being developed. An IBM-developed 3277 display station attachment for Tektronix 4000 series terminals is being investigated. This feature uses the 3277 high-speed communications line and buffer to service Tektronix devices at speeds of the order of one-hundred times those in current use. For an interactive user working with a series of complex displays, this is an important upgrade.

A Laboratory APL user group has been formed to exchange information and plan for new features. Communications have been enhanced by the activation of a newsletter facility which operates under APL. Although not yet released for public use, a batch-processing capability for APL has been developed. After successful testing, it will be provided as a regular service.

SOLID STATE
DIVISION 8

INTRODUCTION

This section of the report summarizes progress during the period 1 February through 30 April 1979. 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 DOE.

A. L. McWhorter
Head, Division 8

I. Melngailis
Associate Head

DIVISION 8 REPORTS
ON ADVANCED ELECTRONIC TECHNOLOGY

15 February through 15 May 1979

PUBLISHED REPORTS

Journal Articles

<u>JA No.</u>			
4829	ν_3 Mode Absorption Behavior of CO ₂ Laser Excited SF ₆	T. F. Deutsch S. R. J. Brueck	J. Chem. Phys. <u>70</u> , 2063 (1979)
4843	Infrared Laser Photochemistry of Silane	T. F. Deutsch	J. Chem. Phys. <u>70</u> , 1187 (1979)
4888	Collision Induced Predissociation in Photoassociated Hg ₂	D. J. Ehrlich R. M. Osgood, Jr.	Chem. Phys. Lett. <u>61</u> , 150 (1979)
4890	p-n Junction Diodes in InP and In _{1-x} Ga _x As _y P _{1-y} Fabricated by Beryllium-Ion Implantation	C. A. Armiento J. P. Donnelly S. H. Groves	Appl. Phys. Lett. <u>34</u> , 229 (1979)
4899	Preparation of Sn-Doped In ₂ O ₃ (ITO) Films at Low Deposition Temperatures by Ion-Beam Sputtering	J. C. C. Fan	Appl. Phys. Lett. <u>34</u> , 515 (1979)
4907	Emission Cross Section and Flashlamp-Excited NdP ₅ O ₁₄ Laser at 1.32 μ m	M. M. Choy* W. K. Zwicker* S. R. Chinn	Appl. Phys. Lett. <u>34</u> , 387 (1979)

Meeting Speeches

<u>MS No.</u>			
4654	Advances in GaAs Schottky Diode Submillimeter Heterodyne Receivers and Radiometers	P. E. Tannenwald	Proc. AGARD Conf. No. 245, Millimetre and Submillimetre Wave Propagation and Circuits, Munich, Germany, 4-8 September 1978, p. 17-1
4760	Gap-Coupled InSb/LiNbO ₃ Convolver Operating at 77 K	F. J. Leonberger R. W. Ralston S. A. Reible	1978 Ultrasonics Symposium Proceedings (IEEE, New York, 1978), pp. 238-242
4767	An Acoustoelectric SAW/CCD Device	D. L. Smythe R. W. Ralston B. E. Burke E. Stern	1978 Ultrasonics Symposium Proceedings (IEEE, New York, 1978), pp. 16-19

* Author not at Lincoln Laboratory

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MS No.

4798	GaInAsP/InP Lasers and Detectors for Fiber Optics Communications at 1.1-1.3 μm	J.J. Hsieh	Proc. IEEE Intl. Electron Devices Mtg., Washington, D.C., 4-6 December 1978, pp.628-629
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UNPUBLISHED REPORTS

Journal Articles

JA No.

4685	Lasers	H.J. Zeiger	Accepted by <u>The Encyclopedia of Physics</u>
4853	High Resolution Double Resonance Spectroscopy of SF_6	P.F. Moulton A. Mooradian	Accepted in <u>Laser Induced Processes in Molecules</u> (Springer-Verlag - to be published)
4871	MBE Techniques for IV-VI Optoelectronic Devices	H. Holloway* J.N. Walpole	Accepted by J. Cryst. Growth
4881	Zn-Diffused, Stripe-Geometry, Double-Heterostructure GaInAsP/InP Diode Lasers	J.J. Hsieh	Accepted by IEEE J. Quantum Electron.
4891	Alkali-Metal Resonance-Line Lasers Based on Photodissociation	D.J. Ehrlich R.M. Osgood, Jr.	Accepted by Appl. Phys. Lett.
4901	Synthesis and Crystal Growth of CdGeP_2	P. Vohl	Accepted by J. Electron. Mater.
4902	Anomalous Noise Behavior in Wide Bandwidth Photodiodes in Heterodyne and Background-Limited Operation	D.L. Spears R.H. Kingston	Accepted by Appl. Phys. Lett.
4920	Ion-Implanted, Laser-Annealed GaAs Solar Cells	J.C.C. Fan R.L. Chapman J.P. Donnelly G.W. Turner C.O. Bozler	Accepted by Appl. Phys. Lett.
4929	Tunable Infrared Lasers	A. Mooradian	Accepted by Rep. Prog. Phys.
4931	A SAW/CCD Accumulating Correlator	D.L. Smythe R.W. Ralston E. Stern	Accepted by Appl. Phys. Lett.

* Author not at Lincoln Laboratory.

JA No.

4933	Planar Guarded Avalanche Diodes in InP Fabricated by Ion Implantation	J. P. Donnelly C. A. Armiento V. Diadiuk S. H. Groves	Accepted by Appl. Phys. Lett.
4936	FM Mode-Locked $\text{Nd}_{0.5}\text{La}_{0.5}\text{P}_5\text{O}_{14}$ Laser	S. R. Chinn W. K. Zwicker*	Accepted by Appl. Phys. Lett.
4937	Electroabsorption in GaInAsP	R. H. Kingston	Accepted by Appl. Phys. Lett.
4945	Schottky Diode Receivers for Operation in the 100-1000 GHz Range	B. J. Clifton	Accepted by Radio Electron. Eng.
4949	UV Solid-State Ce:YLF Laser at 325 nm	D. J. Ehrlich P. F. Moulton R. M. Osgood, Jr.	Accepted by Opt. Lett.

Meeting Speeches†

MS No.

4542C, D	Recent Advances in Laser Devices	A. Mooradian	Seminars: University of Toronto, Ontario, Canada, 3 April 1979; University of Rochester, Rochester, New York, 27 April 1979
4846	A Comparison of Coplanar Waveguide and Microstrip for GaAs Monolithic Integrated Circuits	A. Gopinath	Intl. Microwave Symposium, Orlando, Florida, 30 April - 2 May 1979
4883B	Solar Cells: Plugging into the Sun	J. C. C. Fan	Physics Colloquium, Boston College, Boston, Massachusetts, 14 March 1979
4894	High-Efficiency GaAs Solar Cells on Single-Crystal GaAs and Ge Substrates	J. C. C. Fan C. O. Bozler	1979 Photovoltaic Solar Energy Conf., Berlin, West Germany, 23-26 April 1979
4898	Interband Magneto-Optical Studies in $\text{In}_{1-x}\text{Ga}_x\text{As}_y\text{P}_{1-y}$ Alloys	K. Alavi* R. L. Aggarwal* S. H. Groves	American Physical Society Mtg., Chicago, 19-23 March 1979
5000	Magnetic Phase Dependence of Ni Reaction with CO	R. S. Mehta* G. Dresselhaus* M. S. Dresselhaus* H. J. Zeiger	

* Author not at Lincoln Laboratory.

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

<u>MS No.</u>			
4928	Monolithic Integration in GaAs	R. A. Murphy	Intl. Solid State Circuits Conf., Philadelphia, 14-16 February 1979
4934	Acoustoelectric SAW/CCD Devices	D. L. Smythe	Greater Boston Chapter, IEEE Group on Sonics and Ultrasonics, Bedford, Massa- chusetts, 21 March 1979
4945	Ion Implantation in Si and III-V Compound Semiconductors	J. P. Donnelly	Joint IEEE Chapter on Micro- wave Theory and Techniques, Electron Devices, and An- tennas and Propagation, St. Louis, Missouri, 17 April 1979
4945A, B	Ion Implantation in Si and III-V Compound Semiconductors	J. P. Donnelly	IEEE Chapters on Electron Devices: Schenectady, New York, 21 March 1979; and University of Illinois, 26 April 1979
4946	Fabrication and Applica- tions of Artificial Microstructures	H. I. Smith	Seminar, Naval Research Laboratory, Washington, D.C., 22 February 1979
4946A	Fabrication and Applica- tions of Submicrometer Structures	H. I. Smith	Seminar, Harvard University, 20 April 1979
4953	The Alignment of Masks and Substrates for X-ray Lithography	D. C. Shaver D. C. Flanders	X-ray Lithography Workshop, Stanford University, California, 21 February 1979
4954	Photodiodes at 1.06 to 1.6 μm	I. Melngailis	Optical Fiber Communications Mtg., Washington, D.C., 6-8 March 1979
5004	High-Speed Electrooptic A/D Converter	F. J. Leonberger C. E. Woodward D. L. Spears	SPIE Technical Symp. East '79, Washington, D.C., 17-18 April 1979
5009	Spectroscopic Studies of Small Molecule Interac- tions with Zinc Oxide Surfaces	R. R. Gay* E. I. Solomon* V. E. Henrich H. J. Zeiger	American Chemical Society, Honolulu, Hawaii, 4 April 1979
5022	Integrated Optics: A Tutorial	S. R. Chinn	Seminar, University of Lowell, Massachusetts, 25 April 1979

* Author not at Lincoln Laboratory.

SOLID STATE
DIVISION 8

I. SOLID STATE DEVICE RESEARCH

The ionization coefficients of electrons and holes in InP have been determined from photomultiplication measurements on abrupt-junction, low-leakage, np^+ avalanche photodiodes. The ionization rate of holes β was found to be greater than that for electrons α . The ratio varies with the peak electric field E_m from $\beta/\alpha = 3.8$ at $E_m = 4.85 \times 10^5 \text{ V-cm}^{-1}$, to $\beta/\alpha = 2.7$ at $E_m = 6.37 \times 10^5 \text{ V-cm}^{-1}$.

The electroabsorption or Franz-Keldysh effect has been measured in $\text{Ga}_{0.24}\text{In}_{0.76}\text{As}_{0.52}\text{P}_{0.48}$ with an energy gap of 1.03 eV. Absorption coefficients were determined by measuring the transmission vs reverse bias through a double-heterostructure photodiode. The results are in good agreement with theory and are applicable to modulators and detectors in the 1.25- to 1.30- μm band of interest in optical-fiber transmission.

A subtraction technique has been developed to deduce the individual signals from overlapped ones in Rutherford backscattering spectra. The method eliminates one of the overlapping signals and yields the derivative of the other one, from which the two individual signals are reconstructed. When the technique was tested, good results were obtained using computer-simulated backscattering on a thin-film model which consisted of five layers of Au-Ag alloys.

An analysis of a high-speed electrooptic guided wave analog-to-digital (A/D) converter has been carried out. Design relationships are given for the electrooptic chip, the laser sampler, and the analog signal amplifier. Based on the analysis and available waveguide materials and technology, it is concluded that the development of a 6-bit 1-GS/sec converter should be feasible.

II. QUANTUM ELECTRONICS

Frequency coincidences have been determined between doubled CO_2 -laser radiation and absorption lines of CO and NO, and the anticipated energy requirements have been calculated for remote sensing of these molecules by topographic reflection using a differential absorption system. The results indicate that concentrations typical for vehicle effluent should be measurable at reasonable ranges using the mini-TEA laser as the primary source.

In order to characterize the high-performance limitations of $\text{NdP}_5\text{O}_{14}$ lasers, the dependence of the output power on duty cycle has been measured for a quasi-CW laser. No anomalous mode or spectral changes were observed under different heating or drive conditions; the CW output power limitation is explained by a thermally induced population increase in the lower laser level.

The spectroscopy of terbium-yttrium pentaphosphate crystals has been investigated to determine the potential of these materials as lasers for the blue-green spectral region. Radiative and nonradiative rates have been measured using KrF^* laser excitation.

A CW Ni:MgO laser has been operated for the first time. Nearly 6 W of output at 1.32 μm was obtained at 77 K by optical pumping with a 1.06- μm Nd:YAG laser. Temperature tuning in wavelength regions between 1.316 and 1.409 μm was observed, with quasi-CW operation possible up to a crystal temperature of 235 K.

Experimental studies of the nonlinear susceptibility responsible for the tripling of CO_2 radiation in cryogenic liquids have been continued. Interference between the electronic and the

two-photon resonant vibrational contributions to the third-order susceptibility tensor for liquid CO-O₂ mixtures has been used to measure the electronic contribution. A value of 3.9×10^{-34} Asm/V³ has been obtained.

Efficient AC Kerr switching of visible radiation by infrared radiation has been demonstrated in liquid O₂. These switches are useful throughout the infrared spectral region with ultimate switching speeds of 0.1 to 0.3 psec.

The applicability of UV laser-induced dissociation to the processing of microelectronic components is being explored. Metal films with micrometer size features have been produced using a frequency-doubled argon ion laser to photodissociate metal alkyl compounds.

A submillimeter modeling system has been developed and applied to imaging and radar cross-section measurements of scaled tactical targets. The dependence of radar cross sections on transmitter/receiver polarization, resolution element size, and target aspect are being studied at frequencies of interest for a millimeter-wave radar system.

III. MATERIALS RESEARCH

By using a simple analytical model for GaAs solar cells with the n⁺/p/p⁺ shallow-homojunction structure, good fits have been obtained between computer calculations and experimental data for the external quantum efficiency and conversion efficiency of cells with different values of n⁺-layer thickness. The calculations not only yield values for material properties of the GaAs layers composing the cells, but will also permit the optimization of cell design parameters.

In experiments on the crystallization of amorphous semiconductor films by scanning with the slit image of a CW laser, several unusual phenomena have been observed which include the formation of periodic structural features on the film surface, pulsations of the film temperature during scanning, and runaway crystallization of the entire film following first contact with the laser image. By means of preliminary computer calculations of the crystallization front velocity, it has been shown that these phenomena can be attributed to the liberation of heat accompanying the amorphous-to-crystalline transformation.

IV. MICROELECTRONICS

Uniform crystallographic orientation of 500-nm-thick silicon films has been achieved on amorphous fused silica substrates by laser crystallization of amorphous silicon deposited over surface-relief gratings etched into the substrates. The gratings had a square-wave cross section with a 3.8- μ m spatial period and a 100-nm depth. The <100> directions in the silicon were parallel to the grating and perpendicular to the substrate plane.

A SAW/CCD programmable matched filter has been demonstrated. This device is capable of correlating an analog SAW signal of up to 40-MHz bandwidth and 3.5- μ sec duration against 300 samples of an analog reference previously loaded into a CCD shift register. This unique hybrid structure makes possible real-time processing of wideband inputs combined with low-speed, CCD-programmable reference patterns.

A 16-tap CCD transversal filter with tap weights programmable as 4-bit digital words has been fabricated and tested. The device has been successfully used as a programmable matched filter for a chirp signal. The matched-filter output has a dynamic range of 45 dB.

The spectral quantum efficiency of the 100- \times 400-element CCD imager being built for the GEODSS (Ground Electro-Optical Deep Space Surveillance) Program has been measured. The

imager is designed to have a maximum responsivity to an air mass 2 solar spectrum, which has a maximum photon flux at about 700 nm. The quantum efficiency averages approximately 50 percent over a midband range from 600 to 900 nm.

V. ANALOG-SIGNAL-PROCESSING TECHNOLOGY

The major sources of spurious signals in memory correlators have been identified, and techniques for their suppression have been developed. The use of a split transducer drive in combination with metal shields under the ends of the silicon strips significantly reduces undesirable bulk-wave and edge-detection signals. It has been shown that all the development goals for suppression of spurious signals can be achieved.

MNOS capacitors are being investigated for use as analog nonvolatile memory devices. Linear signal storage over a dynamic range of at least 47 dB has been demonstrated. The loss of stored charge proceeds logarithmically in time at a rate proportional to the initial stored charge; a plot of flat-band voltage vs the log of the storage time is a straight line with a slope of approximately 0.1 V/decade per volt of initial flat-band voltage. Further investigations are centered on optimizing the conduction properties of the oxide and nitride.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This Quarterly Technical Summary covers the period 1 February through 30 April 1979. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.		

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