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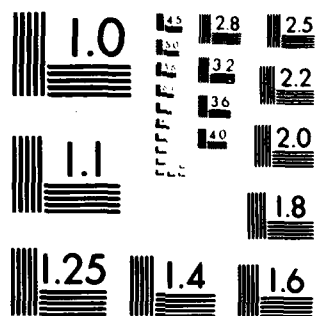
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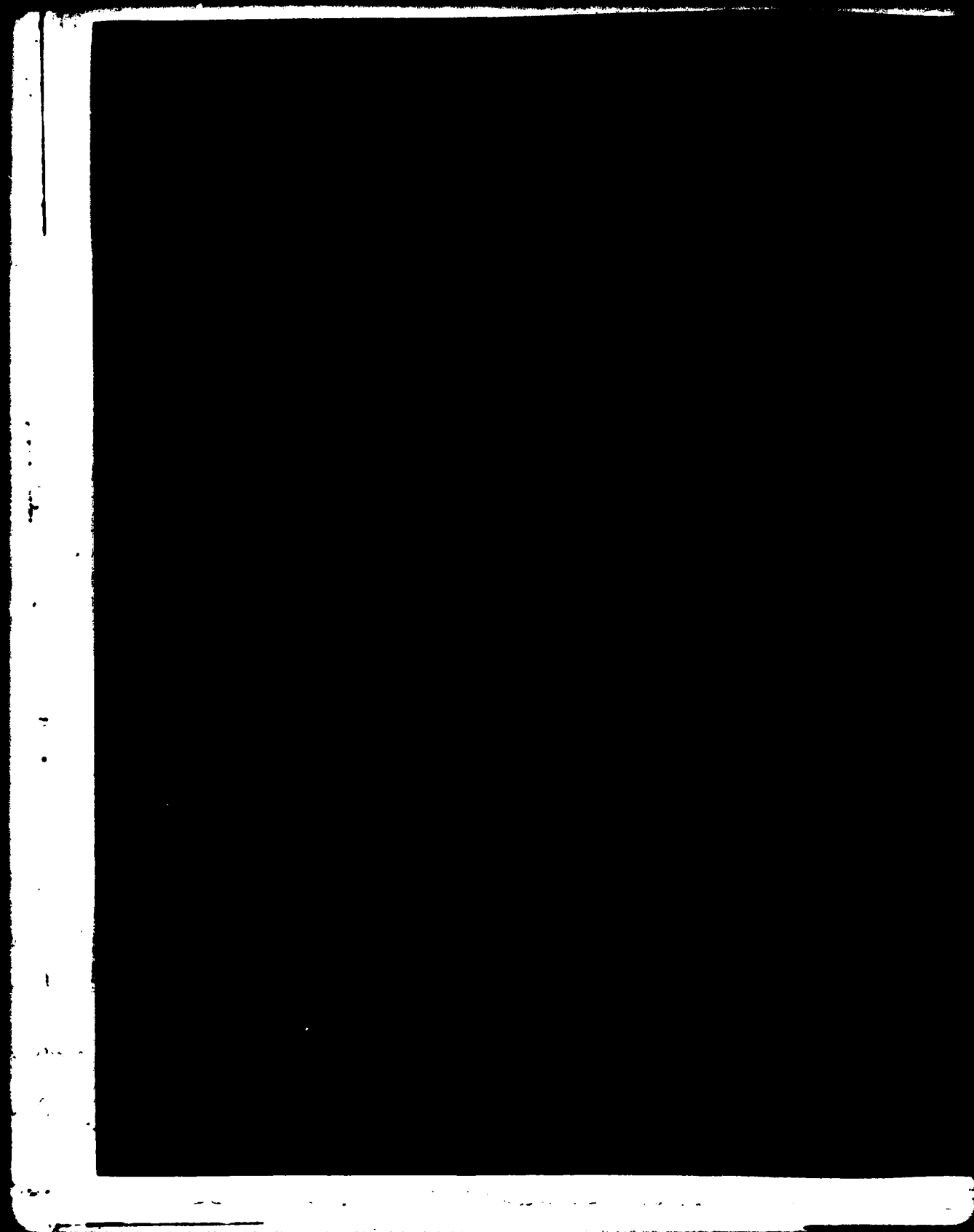
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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

ADVANCED ELECTRONIC TECHNOLOGY

QUARTERLY TECHNICAL SUMMARY REPORT
TO THE
AIR FORCE SYSTEMS COMMAND

1 AUGUST - 31 OCTOBER 1979

ISSUED 18 JANUARY 1980

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LEXINGTON

MASSACHUSETTS

INTRODUCTION

This Quarterly Technical Summary covers the period 1 August through 31 October 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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**DATA SYSTEMS
DIVISION 2**

INTRODUCTION

This section of the report reviews progress during the period 1 August through 31 October 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
Restructurable VLSI Technology	ARPA/IPTO

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DIGITAL INTEGRATED CIRCUITS GROUP 23

I. INTRODUCTION

Characterization of 64K MNOS memory chips was advanced through improvements to the tester. Bit map displays of complete chips were generated. A test chip for restructurable logic devices was designed.

II. MNOS MEMORY

A. 64K-Chip Fabrication

First-generation 64K memory masks revised to eliminate transistor gate buss shorting, and second-generation 64K memory masks for silicon-on-sapphire were received and wafer runs were initiated for both.

B. 64K-Chip Testing

An improved off-chip drive and sense circuit board was completed which operates at higher frequency (250 kHz) and has lower sense amplifier noise. A sense circuit was built to convert memory sense signals to ones and zeros which are then fed to a storage oscilloscope for a display of a chip's bit map. The 64K-chip tester can now be operated from the computer-controlled test system. Sense signals are digitized and sent to the computer for detailed analysis. At present, data from 6000 bits can be handled in one set. Programs have been written to plot distributions of CV threshold voltages and capacitance change for the one and zero states. Numbers of good and bad storage locations are tabulated.

C. Damaged-Silicon Isolation

Preliminary experiments indicate that lateral spreading of the damaged-silicon (dSi) isolation region during neon implantation may limit the use of dSi isolation in the MNOS memory to digit linewidths not less than about 1.0 μm .

D. Polyimide Insulation for Multi-level Metal

Polyimide between-metal insulation is now used routinely on the 64K MNOS memory, replacing CVD oxide. A very low incidence of metal-to-metal shorts has been experienced, with recent test devices showing three shorts per 500,000 crossings at 40 V across 0.8- μm -thick polyimide. Work with three levels of conductors has demonstrated good 1.25- μm -wide via contacts, few shorts, and leveling of the underlying metal topography good enough to permit 1.5- μm -geometry definition on the third level of metal.

III. RESTRUCTURABLE LOGIC DEVICES

A process has been designed which will produce p-channel metal-gate MNOS and MOS transistors and NPN bipolar transistors on one chip. The principal design constraint is the high breakdown voltage required for writing the MNOS transistors. This process uses selective oxidation, self-aligned implants, and polysilicon emitters. A process-evaluation chip has been designed which contains a large number of MNOS, MOS, and NPN transistors, process and parameter monitor devices, and a small section of an Electrically Programmable Logic Array.

IV. PROCESSING AND ANALYSIS

A. Poly-Ox Process Development

Measurements on walled-emitter poly-ox transistors indicate that reduced arsenic emitter implantation dose rate minimizes wafer heating and the partial self-annealing which causes emitter-base junction leakage and hence lower beta.

Computer simulation of the poly-ox fabrication process shows that a higher-energy boron channel stop implant is more effective in preventing surface inversion than that currently used. Even though the higher energy yields a peak concentration deeper into the silicon, the segregation, diffusion, and oxidation coefficients are such that less boron will be incorporated into subsequent oxides and the final surface concentration will be higher for the deeper implant.

Recent literature suggests that a higher oxidation temperature may be preferable in growth of recessed oxide structures such as that used in the poly-ox process. The higher temperatures lead to more favorable sidewall profiles and reduced stress in the silicon adjacent to the oxide. Incorporation of this change in computer process simulation does not indicate any trouble as far as dopant profiles are concerned. However, other possible side effects, such as wafer warpage or crystal slip, have to be determined by experiment.

B. Process Control

Improvements in furnace gas distribution facilities, wafer cleaning, and wafer handling techniques are being implemented to reduce wafer contamination by copper, iron, and nickel. Junction leakage and minority-carrier-lifetime measurements indicate that some wafers were contaminated to the extent that gettering techniques such as back-side implantation were ineffective. A major source of these heavy metals was found to be the metal tools used to handle wafers between the acid cleaning and high-temperature processes. Design of an exhaust enclosure to contain piping used for HCl furnace cleaning is completed and the enclosure is being fabricated. Installation of piping for the new system has begun.

C. Laser Annealing

Experiments are in process to evaluate the electrical properties of laser crystallized silicon on amorphous oxide on silicon. Experiments are also in process to activate by laser annealing base implants in bipolar transistors to eliminate the pipe problem.

D. VAP Defect Model

Recent photodepopulation experiments* have tended to confirm the valence alternation pair (VAP) defect model of charge storage in memory-type amorphous silicon nitride.

* A.V. Kordesch et al., Bull. Am. Phys. Soc. 24, 496 (1979).

COMPUTER SYSTEMS GROUP 28

The new Information International COMp80 CRT plotter, installed during this quarter, has completed its acceptance test and has taken over the production plotting load. A great deal of work has gone into system shakedown and training. While a few more bugs remain to be rooted out, there is a formal effort under way to exploit the text-processing capabilities of the COMp80. Documents created and stored on-line via the Laboratory's SCRIPT program may now be directed to the COMp80 when high-quality, camera-ready copy is required for printing. Various special fonts, including mathematical symbols, and software systems to handle them are being investigated.

Further study of the problem of implementing a high-speed bus from the central computer to remote devices has focused on different commercially available technologies for transmission rates of tens of megabits per second at distances of a few thousand feet. No single technique has been selected nor eliminated. Rather, a functional specification for the bus is being developed with the specific implementation to be selected from competing proposals.

Consulting assistance has been provided for an effort which has developed an on-line CMS (Conversational Monitor System) version of the structural analysis system, NASTRAN. The batch version is being brought up to the same level. Lincoln now has on-line and batch versions of two major structural analysis systems, NASTRAN and ICES/STRU DL.

Several system enhancements or new user facilities have been provided during this quarter. These include a PASCAL compiler from Imperial College, and a course in the language for Laboratory users. The VM/370 scheduler has been fine-tuned to yield about a 1-percent performance improvement. The APL batch system has been modified to accept input data files from previous batch APL jobs. Work on installing a new release of CMS has been slowed because its new filing system has affected many Lincoln modifications which must now be retrofitted.

**SOLID STATE
DIVISION 8**

INTRODUCTION

This section of the report summarizes progress during the period 1 August through 31 October 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, DARPA, Navy, NASA, NSF, and DOE.

A.L. McWhorter
Head, Division 8
I. Melngailis
Associate Head

DIVISION 8 REPORTS
ON ADVANCED ELECTRONIC TECHNOLOGY

15 August through 15 November 1979

PUBLISHED REPORTS

Journal Articles

<u>JA No.</u>			
4806	Rate Equations in Stimulated Light Scattering	P.L. Kelley	Phys. Rev. A 20, 372 (1979), DDC AD-A076430
4881	Zn-Diffused, Stripe-Geometry, Double-Heterostructure GaInAsP/InP Diode Lasers	J.J. Hsieh	IEEE J. Quantum Electron. QE-15, 694 (1979), DDC AD-A076459
4929	Tunable Infrared Lasers	A. Mooradian	Rep. Prog. Phys. 42, 1533 (1979)
4948	Efficient Conversion of Surface Acoustic Waves in Shallow Gratings to Bulk Plate Modes	J. Melngailis H.A. Haus* A. Lattes*	Appl. Phys. Lett. 35, 324 (1979); Erratum published in 35, 828 (1979)
4963	Spectroscopy and Lasing in $K_5NdLi_2F_{10}$ (KNLF)	A. Lempicki* B. McCollum* S.R. Chinn	IEEE J. Quantum Electron. QE-15, 896 (1979)
4966	Ionization Coefficients of Electrons and Holes in InP	C.A. Armiento S.H. Groves C.E. Hurwitz	Appl. Phys. Lett. 35, 333 (1979), DDC AD-A076467
4981	A SAW/CCD Programmable Matched Filter	R.W. Ralston D.L. Smythe E. Stern	Appl. Phys. Lett. 35, 388 (1979), DDC AD-A076468
4999	Magnetic Phase Dependence of the Nickel-CO Reaction	R.S. Mehta* M.S. Dresselhaus* G. Dresselhaus* H.J. Zeiger	Phys. Rev. Lett. 43, 970 (1979)

Meeting Speeches

<u>MS No.</u>			
4894	High-Efficiency GaAs Solar Cells on Single-Crystal GaAs and Ge Substrates	J.C.C. Fan C.O. Bozler	Proc. 1979 Photovoltaic Solar Energy Conf., Berlin, West Germany, 23-26 April 1979, p.38.

*Author not at Lincoln Laboratory.

MS No.

- | | | | |
|------|---|---|---|
| 5004 | High-Speed Electro-Optic Analog-to-Digital (A/D) Converter | F.J. Leonberger
C.E. Woodward
D.L. Spears | Proc. SPIE Vol.176: <u>Guided Wave Optical Systems & Devices II</u> (Society of Photo-Optical Instrumentation Engineers, Bellingham, Washington, 1979), pp.28-35. |
| 5027 | Shallow-Homojunction GaAs Solar Cells | J.C.C. Fan | Proc. Conf. on Solar Cell High Efficiency and Radiation Damage, Cleveland, Ohio, 13-14 June 1979, p.227 |
| 5050 | Comparison of Surface Acoustic-Wave and Optical Signal Processing | R.C. Williamson | Proc. SPIE Vol.185: <u>Optical Processing Systems</u> (Society of Photo-Optical Instrumentation Engineers, Bellingham, Washington, 1979), pp.74-84 |

* * * * *

UNPUBLISHED REPORTS

Journal ArticlesJA No.

- | | | | |
|------|--|---|--|
| 4960 | Efficient Infrared ac Kerr Switches Using Simple Cryogenic Liquids | S.R.J. Brueck
H. Kildal | Accepted by Appl. Phys. Lett. |
| 4972 | Liquid-Phase Epitaxy | J.J. Hsieh | Accepted as Chapter in <u>Handbook on Semiconductors</u> , Vol.3, S.P. Keller, Ed. (IBM, Yorktown Heights, New York, n.d.) |
| 4973 | Tunable Submillimeter Sources Applied to the Excited State Rotational Spectroscopy and Kinetics of CH ₃ F | W.A. Blumberg
H.R. Fetterman
D.D. Peck
P.F. Goldsmith* | Accepted by Appl. Phys. Lett. |
| 4986 | R-Branch Head of the ν_3 Band of CO ₂ at Elevated Temperatures | A.S. Pine
G. Guelachvili* | Accepted by J. Mol. Spectrosc. |
| 4987 | Broadly Tunable CW Operation of Ni:MgF ₂ and Co:MgF ₂ Lasers | P.F. Moulton
A. Mooradian | Accepted by Appl. Phys. Lett. |
| 4989 | A New Cut of Quartz for Temperature-Stable SAW Dispersive Delay Lines | D.E. Oates | Accepted by IEEE Trans. Sonics Ultrason. |
| 5001 | Effects of Narrow Free-Spectral-Range Etalons on Mode-Locked Lasers | S.R. Chinn | Accepted by Opt. Commun. |

*Author not at Lincoln Laboratory.

JA No.

5004	Atomic Transition Lasers Based on Two-Photon Dissociation of Metal Triiodide Vapors	T.F. Deutsch D.J. Ehrlich R.M. Osgood, Jr.	Accepted by Opt. Lett.
5012	High-Speed InP Optoelectronic Switch	F.J. Leonberger P.F. Moulton	Accepted by Appl. Phys. Lett.
5014	Solid-Phase Growth of Large Aligned Grains During Scanned Laser Crystallization of Amorphous Ge Films on Fused Silica	J.C.C. Fan H.J. Zeiger R.P. Gale R.L. Chapman	Accepted by Appl. Phys. Lett.
5017	Shallow-Homojunction GaAs Solar Cells with High Resistance to 1-MeV Electron Radiation	J.C.C. Fan R.L. Chapman C.O. Bozler P.J. Drevinsky*	Accepted by Appl. Phys. Lett.
5019	Doppler-Limited Spectroscopy of the $3\nu_3$ Band of SF_6	A.S. Pine A.G. Robiette*	Accepted by J. Mol. Spectrosc.
5023	Efficient Shallow-Homojunction GaAs Solar Cells by Molecular Beam Epitaxy	J.C.C. Fan A.R. Calawa R.L. Chapman G.W. Turner	Accepted by Appl. Phys. Lett.
5026	Collisional Narrowing of HF Fundamental Band Spectral Lines by Neon and Argon	A.S. Pine	Accepted by J. Mol. Spectrosc.
5027	Development of a High Repetition Rate Mini-TEA CO_2 Laser	N. Menyuk P.F. Moulton	Accepted by Rev. Sci. Instr.
5028	Interband Magneto-Absorption of $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$	K. Alavi* R.L. Aggarwal* S.H. Groves	Accepted by Phys. Rev. B

Meeting Speeches†MS No.

4530A	Precision High Resolution Molecular Spectroscopy Using a Tunable Difference-Frequency Laser Spectrometer	A.S. Pine	Infrared Symp., Philadelphia, Pennsylvania, 17 September 1979
4542E	Recent Advances in Tunable Lasers	A. Mooradian	Seminar, Bell Laboratories, Holmdel, New Jersey, 5 September 1979

* Author not at Lincoln Laboratory.

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

<u>MS No.</u>			
4612A	High Sensitivity Photodiode Heterodyne Receivers	D.L. Spears	6th Annual Mtg. of Analytical Chemistry & Spectroscopy Societies, Philadelphia, Pennsylvania, 16-21 September 1979
4740A	A High Speed CCD Digitally Programmable Transversal Filter	A.M. Chiang B.E. Burke D.L. Smythe D.J. Silversmith R.W. Mountain	5th Intl. Conf. on CCD Devices, Edinburgh, Scotland, 12-14 September 1979
4779A, B	Some Recent Developments in Laser Crystallization and Laser Annealing at Lincoln Laboratory	J.C.C. Fan	RCA Seminar Series, Princeton, New Jersey, 13 September 1979; Seminar, IBM, Yorktown Heights, New York, 14 September 1979
4802D	Vibrational Kinetics in Cryogenic Liquids and Applications to Nonlinear Optics	S.R.J. Brueck T.F. Deutsch H. Kildal R.M. Osgood, Jr.	Seminar, Memorial University, St. Johns, Newfoundland, Canada, 25 October 1979
4818A	Development and Applications of a High-Speed Electrooptic Analog-to-Digital Converter	F.J. Leonberger	3rd Rocky Mt. Symp. on Microcomputers, Colorado State University, 22 August 1979
5004A	High-Speed Guided-Wave Electrooptic Analog-to-Digital Converter	F.J. Leonberger	Seminar, Dept. of Electrical Engineering and Computer Science, M.I.T., 23 October 1979
5007	Imaging and RCS Measurements of Submillimeter Modeled Tactical Targets	J. Waldman H.R. Fetterman P.E. Duffy T.G. Bryant	25th Tri-Service Radar Symp., USAF Academy, Colorado Springs, 18-20 September 1979
5008	Surface-Acoustic-Wave Devices for Spread-Spectrum Communication	J.H. Cafarella	1979 Intl. Conf. on Solid State Devices, Tokyo, Japan, 27-29 August 1979
5029A	Metal-Atom Photodissociation Lasers	D.J. Ehrlich R.M. Osgood, Jr.	Seminar, Bell Telephone Laboratories, Holmdel, New Jersey, 26 September 1979
5029B	Collisional and Radiative Processes in Photodissociatively Produced Atoms	D.J. Ehrlich R.M. Osgood, Jr.	Seminar, Department of Physics, M.I.T., 6 November 1979
5033A	Tunable UV Solid-State Ce:YLF Laser at 325 and 309 nm	D.J. Ehrlich P.F. Moulton R.M. Osgood, Jr.	Topical Mtg. on Excimer Lasers, Charleston, South Carolina, 11-13 September 1979
5077	Two-Wavelength Optical Excitation Studies of XeBr* and Hg ₂ * Excimers	D.J. Ehrlich R.M. Osgood, Jr.	

MS No.			
5039	High Frequency Calculations of IMPATT and TUNNETT Diodes	M. E. Elta	Seventh Biannual Cornell Electrical Engineering Conf., Ithaca, New York, 14-16 August 1979
5145	Permeable Base Transistor	C.O. Bozler G.D. Alley R.A. Murphy D.C. Flanders W.T. Lindley	
5146	Two Dimensional Numerical Simulation of the Permeable Base Transistor	G.D. Alley C.O. Bozler R.A. Murphy W.T. Lindley	
5042	Efficient Frequency Conversion Techniques for CO ₂ Lasers	H. Kildal S.R.J. Brueck N. Menyuk	Electro-Optics/Laser Conf., Anaheim, California, 23-25 October 1979
5047A, B	Third-Order Nonlinear Coefficients of Cryogenic Liquids	S.R.J. Brueck H. Kildal	Gordon Research Conf., Wolfeboro, New Hampshire, 2-6 July 1979; Annual Mtg. of Optical Society of America, Rochester, New York, 8-12 October 1979
5049	Wideband LiNbO ₃ Elastic Convolver with Parabolic Horns	R.A. Becker D.H. Hurlburt	1979 Ultrasonics Symp., New Orleans, Louisiana, 26-28 September 1979
5056	Moving Target Simulation Utilizing a SAW Variable Delay Line Incorporating Quadratic Phase Correction	D.R. Arsenault V.S. Dolat	
5057	Selective Excitation of Bulk Plate Modes	H.A. Haus* A. Lattes* J. Melngailis	
5058	Temperature Effects in Reflective Array Devices and Temperature Compensated RAC	D.E. Oates R.C. Williamson	1979 Ultrasonics Symp., New Orleans, Louisiana, 26-28 September 1979
5059	Four-Wave Interactions in Acoustoelectric Integrating Correlators	R.W. Ralston E. Stern	
5060	A SAW Accumulating Correlator with CCD Readout	R.W. Ralston D.L. Smythe E. Stern	
5061	A CCD-Programmable SAW Matched Filter	D.L. Smythe R.W. Ralston E. Stern	

* Author not at Lincoln Laboratory.

MS No.

5062	Wide Bandwidth Acousto-electric Convolvers	I. Yao S.A. Reible	1979 Ultrasonics Symp., New Orleans, Louisiana, 26-28 September 1979
5082	A Satellite-Borne SAW Chirp-Transform System for Uplink Demodulation of FSK Communication Signals	R.C. Williamson V.S. Dolat R.R. Rhodes D.M. Boroson	
5053	Wideband SAW Fourier-Transform Processor Design and Applications	R.C. Williamson	IEE Seminar on Case Studies in Advanced Signal Processing, Peebles, Scotland, 18-21 September 1979
5078	Solid-Phase Growth of Large Aligned Grains During Scanned Laser Crystallization of Amorphous Ge Films on Fused Silica	H.J. Zeiger J.C.C. Fan R.P. Gale R.L. Chapman	The Electrochemical Society, Los Angeles, California, 14-19 October 1979
5081	Integrated SAW/CCD Signal Processing Devices	D.L. Smythe	SPIE Seminar on Optical Signal Processing for C ³ I, Boston, 29-30 October 1979
5106	Comparison of Acousto-electric and Acoustooptic Signal Processing Devices	R.A. Becker S.A. Reible	
5167	Device Requirements for Spread-Spectrum Communication	J.H. Cafarella	
5082A	A Satellite-Borne SAW Spectrum Analyzer for Demodulation of FSK Communication Signals	R.R. Rhodes R.C. Williamson	IEEE Boston Chapter Mtg., MITRE Corp., Bedford, Massachusetts, 24 October 1979
5085	Density Fluctuations Generated in Simple Liquids by Intense Laser Radiation	S.R.J. Brueck L.J. Belanger H. Kildal	1979 Annual Mtg. of Optical Society of America, Rochester, New York, 8-12 October 1979
5100	Remote Sensing of CO Using Frequency Doubled CO ₂ Laser Radiation	D. Killinger N. Menyuk	
5133	Electronic Material Processing Using UV-Laser Photochemistry	D.J. Ehrlich T.F. Deutsch R.M. Osgood	
5134	Excimer Excitation of Lasers Via Bound-Free and Free-Bound Transitions	R.M. Osgood D.J. Ehrlich T.F. Deutsch	
5107B	Crystallographic and Electrical Properties of Silicon Produced by Graphoepitaxy	M.W. Geis	Texas Instruments Colloq., Dallas, 13-14 September 1979

<u>MS No.</u>			
5120, A	X-Ray Lithography - A Review and Assessment of Future Applications	H.I. Smith D.C. Flanders	SEMICON/EAST, Boston, 20 September 1979; 26th Natl. Vacuum Symp., New York, 2-5 October 1979
5135	Narrow-Gap Semiconductor Detectors and Lasers	I. Melngailis	Summer School on Narrow-Gap Semiconductor Physics and Applications, Nimes, France, 13-15 September 1979
5155	The Impact of Submicrometer Structures on Future Integrated Electronics	H.I. Smith	EASCON '79, Washington, D.C., 8-11 October 1979
5181	Analog Signal Processing Techniques: SAW and CCD Devices	R.C. Williamson	
5188	Applications of Artificial Microstructures to Optics	H.I. Smith	Seminar, Dept. of Electrical Engineering and Computer Science, M.I.T., 16 October 1979

SOLID STATE DIVISION 8

I. SOLID STATE DEVICE RESEARCH

An InP optoelectronic switch, which may be better suited for high-speed analog-signal-processing applications than previously reported Si and GaAs switches, has been fabricated and demonstrated. In experiments using CW mode-locked Nd:YAG lasers, the switches have exhibited an on-state impedance of $\sim 45 \Omega$ for 40 pJ/pulse of incident laser energy.

Self-sustained pulsations in light outputs, which are similar to those occurring in AlGaAs, have been observed for several GaInAsP double-heterostructure lasers. The rate of incidence of pulsations in GaInAsP lasers is much lower and their occurrence does not appear to be increased by aging, in marked contrast to AlGaAs lasers.

Low-frequency gains of up to 700 and reduced dark currents have been achieved at 1.15- μm wavelength with a modified version of the inverted-mesa GaInAsP/InP avalanche photodiode structure described previously. In the new structure, carriers are photogenerated in the GaInAsP but are swept into the InP, where they are multiplied in the high-field region of the n-p⁺ junction of the InP.

The effect of implant temperature on the electrical characteristics of InP implanted with various ions has been investigated. For the heavy impurities, Cd and Se, and for the intermediate-mass n-type impurity Si, the highest activation was achieved for implant temperatures $>150^\circ\text{C}$; for the light-impurity Be, the activation was slightly higher for room-temperature than for heated implants; for the intermediate-mass p-type impurity Mg, the effects were dependent on dose.

A vector formulation has been used to obtain the relationship between the change of $\text{Ga}_x\text{In}_{1-x}\text{As}_y\text{P}_{1-y}$ lattice parameter and the change in composition. It is believed that this technique is potentially useful in the development of lattice-matched $\text{Ga}_x\text{In}_{1-x}\text{As}_y\text{P}_{1-y}$ /InP double-heterostructure lasers.

II. QUANTUM ELECTRONICS

Preliminary single-ended remote sensing measurements of atmospheric NO concentrations have been carried out with a differential absorption LIDAR system. Observations were made out to a range of 1.4 km despite high water-vapor absorption interference effects, and average NO concentrations of 100 to 200 ppb were observed using a target at a range of 480 m that was located adjacent to a major traffic roadway.

The doubling efficiency in CdGeAs_2 was found to be limited by a saturation mechanism with a response time faster than 8 nsec, and the maximum doubling efficiency was found to increase linearly with crystal length for crystals up to 15 mm. A maximum second-harmonic energy of 340 mJ has been observed at 5.3 μm from an 11 $\times$ 13 $\times$ 21-mm AR-coated crystal.

An experimental and theoretical investigation of the coupling of laser radiation to acoustic waves and thermal diffusion modes of liquids has been carried out. Electrostrictive coupling sets the geometry-dependent lower limit on the absorptivities that may be detected using acoustic and thermal lensing techniques.

Photodissociately pumped atomic resonance-line lasers have been shown to be effective sources in quantitative chemical analysis for detection of trace concentrations of metal atoms.

Measurements with a modified analytic flame spectrometer have yielded detection limits of 1 and 10 ppb, respectively, for Na and Tl in aqueous solutions.

UV laser-induced etching of GaAs and InP has been demonstrated, using a gas-phase photolysis of halogenated methanes. A resolution of $\sim 1 \mu\text{m}$ has been achieved. A pulsed ArF UV laser has also been used to produce ohmic contacts on p-InP; the process involves a combination of deposition by photolysis of $\text{Cd}(\text{CH}_3)_2$ gas and laser heating of the substrate.

The previously developed Schottky-diode corner-reflector heterodyne mixers have been studied at low temperatures. Total system noise temperature of 3800 K (DSB), or an NEP of $5.3 \times 10^{-20} \text{ W/Hz}$, has been achieved.

III. MATERIALS RESEARCH

The diffusion of Zn and Cd into InP has been investigated in order to make a comparative evaluation of these elements as acceptor diffusants for the fabrication of GaInAsP/InP electro-optical devices. The use of Zn is found to be advantageous because p-n junctions with comparable characteristics can be obtained with lower diffusion temperatures than those required for Cd.

Scanned laser crystallization of amorphous Ge films on fused-silica substrates without surface-relief structures has produced periodic structural features that include regions of well-aligned grains with lateral dimensions up to 2 to $3 \times 100 \mu\text{m}$. The theoretical model of laser crystallization reported previously, which is consistent with the observed dependence of spatial period on substrate temperature, suggests the possibility of preparing even larger grained or perhaps single-crystal semiconductor sheets by scanning amorphous films with energy beams of high aspect ratio.

The feasibility of using molecular-beam epitaxy in the fabrication of efficient GaAs solar cells has been demonstrated. Conversion efficiencies up to 16 percent at AM1 have been obtained for shallow-homojunction $n^+/p/p^+$ cells, without a GaAlAs window, in which the n^+ , p, and p^+ GaAs layers were all grown by molecular-beam epitaxy on single-crystal p^+ GaAs substrates.

IV. MICROELECTRONICS

The permeable base transistor (PBT) has the potential for delivering gain at frequencies above those achieved by any other three-terminal device. The maximum frequency of oscillation for the first PBTs is 17 GHz, with a maximum gain of 13 dB at 4 GHz. A simulation of an optimized version of this PBT predicts a maximum frequency of oscillation of approximately 300 GHz, and a numerical study of the effects of scaling to smaller dimensions predicts a maximum frequency of oscillation approaching 1000 GHz. Fabrication of these devices combines the emerging technologies of x-ray lithography and crystal overgrowth of metal structures.

Work is in progress to improve the low-light-level performance of the CCD imager under development for the GEODSS (Ground Electro-Optical Deep Space Surveillance) Program. Measurements have been made of the dark-current noise as a function of temperature. The thermally generated charge has been reduced below 10 electrons per well for an integration time of 0.25 sec at a temperature of -60°C . This noise level is below the noise-equivalent signal that has been obtained in the output circuitry of these imagers.

A silicon CCD has been integrated with a SAW delay line to produce a CCD programmable analog matched filter. This device has a spurious response which has been identified and modeled. The response arises from the transducer-like detection of the SAW signal by the coupling finger array on the silicon chip. The output resulting from this detection is the convolution of the SAW signal with the impulse response of the coupling finger array and can be avoided by operating the filter well away from the synchronous frequency of the array.

A simple theoretical model has been developed for calculating the variation of threshold voltage both for CCDs with surface-channel inputs and with buried-channel inputs. The model emphasizes the sensitivity of threshold voltage to inhomogeneities in substrate doping or implant doping for the surface- and buried-channel cases, respectively. A smaller variation in threshold voltage for surface-channel inputs is predicted for current CCD processing, and experimental results for the two types of devices are consistent with the model, showing a factor-of-6 reduction in variation for surface-channel inputs compared with buried-channel inputs.

A monolithically integrated GaAs FET amplifier has been developed for ultimate integration into a monolithic millimeter-wave transceiver module. The amplifier has demonstrated a gain in excess of 10 dB from 2.0 to 2.6 GHz without matching at the output of the amplifier. With output matching, the amplifier has a noise figure of 4 dB with an associated gain of 11 dB at 2.5 GHz.

V. ANALOG DEVICE TECHNOLOGY

By examining theoretical calculations of the temperature coefficient of delay, it was discovered that a new cut of crystal quartz would have two orthogonal temperature-compensated SAW propagation directions as required for a temperature-stable reflective-array compressor. The existence of this new cut has been experimentally verified and the parameters of the cut — including cut angle, propagation direction, second-order temperature coefficient, and power-flow angle — have been accurately determined.

A wideband (95-MHz-bandwidth) elastic convolver which makes use of a 10- μ sec-long $\Delta V/V$ channel waveguide has been developed. This SAW device uses parabolically tapered horns to spatially compress the acoustic beamwidth and thus increase the efficiency. This scheme, with its relaxed fabrication tolerances, allows larger bandwidths than previously thought possible.

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