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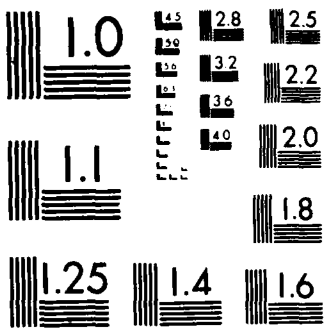

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AD-A173 246

INSTRUMENTATION FOR RESEARCH ON ULTRA-SMALL GaAs DEVICES

FINAL ~~Status~~ Report

For the period October 16,1985, through October 15, 1986

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Chief, Technical Information Division

James S. Harris
Principal Investigator

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This grant, under the DoD University Research Instrumentation Program funded the purchase of processing equipment for GaAs structures and devices This processing facility is now completed and in operation.

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Stanford GaAs Research Lab Facilities

DoD Equipment Grant AFOSR 84-0253

1.0 Introduction

Contract AFOSR 84-0253 was awarded to Stanford University as a result of a proposal submitted by Professor James Harris in response to the DoD-University Research Instrumentation Program. The goal of this proposal was to establish an advanced GaAs Heterojunction Research Laboratory to complement the recently established molecular beam epitaxy laboratory (DARPA/ONR N00014-83-K-0077) so that advanced heterojunction device structures and small-scale ICs could be fabricated and characterized at Stanford. This Air Force award and the DARPA/ONR award have been the foundation to build the Heterojunction Research facility. This foundation has provided leverage to attract substantial equipment contributions from manufacturers and additional clean room facilities from Stanford University. The net result is an Advanced GaAs Research Laboratory with facilities greater than double the AFOSR and DARPA/ONR capital investment. In this report, we summarize the capabilities of the major pieces of equipment in the laboratory to provide a picture of the overall capability and then list the specific pieces of equipment purchased under this contract plus equipment and facilities purchased by Stanford as the cost-sharing part of the contract.

The Stanford Advanced GaAs Research Lab is an entirely new facility. It is a 1,500 square-foot laboratory consisting of 175 feet^2 of class 100 clean room for optical lithography 550 feet^2 of class 1000 clean room for etching, evaporation, deposition wet/dry 750 feet^2 of class 10,000 clean room for molecular beam epitaxy. Localized class 10 work areas are obtained by the use of laminar downflow, wet and dry benches for critical operations in each of the clean rooms. The lab now has the equipment necessary to investigate both new electronic materials and develop new high-speed and optoelectronic devices. This equipment includes both fabrication tools such as: MBE, ion implantation, rapid thermal annealing, submicron contact lithography, reactive ion etching, plasma-enhanced insulator deposition and e-beam evaporation, as well as characterization tools, such as: photoluminescence, Hall effect, DLTS, electrochemical profiling, I-V and DC device probe characterization. Additional facilities outside the Advanced GaAs Research Lab, but available to students to complement their research work include the e-beam mask facility (MEBES), microwave network analyzer, scanning tunnel microscope and ultra-fast electro-optical sampling.

The major process facilities in the Advanced GaAs Research Facility are summarized below.

2.1 Molecular Beam Epitaxy

Molecular beam epitaxy (MBE) has proven to be the most versatile and important epitaxial technology in the past decade for the investigation of new electronic devices. MBE is capable of producing high-quality epitaxial layers with control over interfaces where doping and/or composition changes occur on a scale of <10Å.

Our lab contains two Varian - Gen II MBE systems interconnected by a transition tube. One system was funded by DARPA/ONR, while the second was a Varian corporate donation. The growth chambers have 3-inch non-In bonded substrate heating and 16 wafer loading capability. Analysis equipment attached to the system includes a quadrupole mass spectrometer, Reflection High Energy Electron Diffraction, and beam flux monitors. The system is computer automated with an HP 9000 (donated by HP) multitasking, multiuser, UNIX operating system. This allows complex device structures to be grown with correction in software for machine nonlinearities. A multichamber processing chamber capability allows for the addition of chambers for *in-situ* metallization, focused ion beam surface treatment scanning tunnel microscopy and insulator deposition. Such a system provides both the required flexibility for for investigation of *in-situ* and maskless processing for 3D quantum devices as well as new device concepts with more conventional materials.

2.2 Photolithography

An OAI Hybraline 500 Mark III submicron contact aligner was purchased under the AFOSR contract. It is used for optical lithography. The system has the capability to run at

220 and 400 nm wavelengths and can expose both 2- and 3-inch wafers, either partial or whole wafers. We have now demonstrated 0.5 micron features with this aligner and our lithography technology. We have successfully fabricated a 17-stage complementary MODFET, ring oscillator, quantum well tunnel and detector devices, and heterojunction bipolar transistors using the mask aligner.

An automated Headway EC101 photoresist spin-develop station is used for depositing both positive/negative resist. HEPA filtered pre-/post-bake ovens are utilized. The photolithography lab is better than Class 100, and local work stations over the aligner and resist processing yield a Class 10 environment. All of the sinks and HEPAs were purchased by Stanford as part of the cost sharing. This clean environment is critical to fabricate the type of small geometry structures that are now under investigation.

2.3 E-Beam Evaporator

A Temescal Model BJD-1800 e-beam evaporator purchased under the AFOSR contract is used to deposit metal films for device contact and circuit interconnects. It has two e-guns, a double turret, and five pockets. Utilizing an Inficon Sentinel III thickness monitor, highly accurate co-evaporations are possible. The system is cryopumped to 1E-8 torr allowing high-quality films to be evaporated. The system design is optimized to do liftoff processing of metallization and ohmic contacts. The evaporator has been used to fabricate HJBTs, complementary MODFETs and quantum well devices. The e-gun power supply and Inficon Thickness Monitor were purchased by Stanford as part of the cost sharing.

2.4 RIE - PECVD

A Plasma Therm Wafer Batch Series 500 Reactive Ion Etch and Plasma Deposition System was purchased. It is used to deposit $Si0_2$, Si_3N_4, polysilicon and to etch GaAs, AlGaAs and aluminum. The system is equipped with a rotary vane roots blower, and turbo pump. It has an argon sputter clean capability for pre-cleaning surfaces prior to deposition to obtain good adherence and optimum films. A computer-controlled Princeton Applied Research Model 1461 optical multichannel analyzer (OMA) is used for endpoint detection and to develop new selective etch processes.

The OMA is capable of real-time multi-species monitoring of the plasma discharge in the Reactive Ion Etcher. This capability, in conjunction with the introduction of monolayer AlAs marker layers during MBE growth allows us to etch with angstrom resolution. The RIE/PECVD and OMA were purchased with cost sharing by the Semiconductor Research Corporation and Stanford, while the controlling computer was donated by Intel Corporation.

2.5 Characterization Facilities

Extensive device and material characterization facilities have been established in the GaAs Laboratory. A Micromanipulator submicron probe station was purchased under the AFOSR contract. It is used in conjunction with an HP 4145 semiconductor parameter analyzer donated by Hewlett Packard and a 1 GHz oscilloscope donated by Tektronix to provide both DC and initial RF device characterization. Additional capabilities established outside the AFOSR contract include: deep level transient spectroscopy, Hall effect, photoluminescence, electrochemical profiling, ellipsometry and nanospec and alphastep film-thickness measurements.

3.0 Purchased Equipment

This section includes the budget page, with specified capital items, from the AFOSR contract, a list and the cost of actual items purchased on the contract and a similar list of all items purchased by Stanford as the cost-sharing part of the contract.

3.1 Proposal Budget

A. Proposed Equipment and Budget

1. E-Beam Evaporation System

   Proposed Source: CHA Industries

   Contact: Steve Hogue (415)363-8011

   Proposed Model: SE600 with CTI Cryogenic Pumping, 4 gun Airco Temescal e-beam source and supply and Inficon Thickness Monitor — $105,000

2. Si_3N_4-SiO_2 Insulator Plasma Deposition System

   Proposed Source: Technics, Inc.

   Contact: John Levin (408)946-8700

   Proposed Model: PDIIa — 45,000

3. High Resolution Mask Aligner

   Proposed Source: OAI

   Contact:

   Proposed Model: — 55,000

4. Semiconductor Probe Station

   Proposed Source: Rucker and Krolls

   Contact: Phillis Brown (415)969-2369

   Proposed Model: 2 Model 260 with stereo zoom microscopes and manipulator bases — 15,800

Capital Budget	220,800
6.5% California Sales Tax	14,352
Total Capital Budget	235,152

5. Clean Room Facility
   Renovate ~1200 ft^2 of lab space and install work stations and existing fume hoods in McCullough Bldg. — 60,000

Total Budget including Clean Room	295,152
Proposed University Cost Sharing	65,152
Requested DoD Funding	$230,000

Grantee is authorized to acquire the following items of permanent equipment. Title to the equipment shall vest in the Government at the time of acquisition. Title to the equipment shall subsequently vest in the Grantee ninety days after delivery and acceptance of the permanent equipment except if the Government advises the Grantee (prior to the expiration of the ninety days) that it wishes to retain title. If the Grantee obtains title under this provision, the Grantee agrees that no charge will be made to the Government for any depreciation, amortization or use charge with respect to such items under any existing or future Government grant or contract. Variation from these items require the prior written permission of the Contracting Officer.

Item	Estimated Charge To Grant
E-Beam Evaporation System	$105,000
Insulator Plasma Deposition System	$ 45,000
High Resolution Mask Alignor	$ 55,000
Semiconductor Probe Station	$ 15,800
Clean Room Facility	$ 60,000

At any time during the performance of the grant period, including at the completion of the period, the Grantee shall inform the Contracting Officer in writing of any Grant funds in excess of the amount actually needed for the acquisition of the equipment specified in the Grant. Disposition of such excess funds will be as determined by the Contracting Officer

3.2 Equipment Purchased Under AFOSR-84-0253

EQUIPMENT	VENDOR	COST
UV Contact Mask Aligner	OAI	57,168
Probe Station	Micromanipulator	15,800
RIE/PECVD	Plasma Therm	63,340
E-beam Evaporator	Temescal	98,286
	Total	234,594

3.3 Equipment Purchased Under Cost Sharing

EQUIPMENT	VENDOR	COST
Wet benches	PV Enterprise	$ 3,642
Wet benches	PV Enterprise	7,420
HEPA filter oven	Blue M	487
Aligner accessories	OAI	13,215
Wet benches	PV Enterprises	6,405
HEPA Hood	PV Enterprises	10,183
Refrigerator	American Scientific	898
HEPA Hood	PV Enterprises	12,245
Probe	Micromanipulator	3,841
Photoresist Spinner	Headway Research	12,444
HEPA filter oven	Blue M	5,403
Microscope	Micromanipulator	2,500
Water system	Arrowhead Industrial	5,056
RIE Accessories	Plasma Therm, Inc.	16,624
RIE Accessories	Plasma Therm, Inc.	3,884
Clean room	Matheson Gas Products	3,084
Water system	Arrowhead Industrial	2,528
E-gun supply	Temescal	18,133
Thickness Monitor	Temescal	4,472
Desiccator	Terra Universal	2,118
		$134,582

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