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QUARTERLY PROGRESS REPORT NUMBER 3

1 April 1992 - 30 June 1992

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FIELD EMISSION CATHODE AND VACUUM
MICROELECTRONIC MICROWAVE AMPLIFIER
DEVELOPMENT

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I. EXECUTIVE SUMMARY

- The quality of composite material obtained from initial growth runs performed during the previous reporting period has been verified as acceptable for fabrication use
- Emitter array fabrication (vapor deposition) facilities have been completed and process control capabilities (film thickness and deposition rates) are being verified
- Automated emission testing equipment has been procured and final software development is being completed
- Suitability of the photolithography mask set has been verified and work continues to identify satisfactory resist materials and compatible etching processes
- Array capacitance modelling has been extended to include additional material property parameters and emitter geometries demonstrating the advantage of arrays based on insulating substrate materials, thin (< 1 micron) insulator layers, and the effects of emitter - gate aperture geometry parameters

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Statement A per telecon
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Availability Codes	
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II. MILESTONE STATUS

A -- Field Emitter Cathode Development

A.1. Composite Development

A.1.a. Increase composite ingot volume and die size

Start -- 1 October 91 Planned

1 October 91 Actual

Completion -- 31 March 93 Planned

A.1.b. Optimize composite growth morphology

Same as A.1.a.

A.2. Emitter Tip Geometry and Composition

A.2.a. Etching studies

Start -- 1 November 91 Planned

1 November 91 Actual

Completion -- 31 March 93 Planned

A.2.b. Emitter coatings

Start -- 1 April 92 Planned

1 June 92 Actual

Completion -- 31 March 93 Planned

A.3. Field Emitter Structure Development

A.3.a. Emitter ballasting

Start -- 1 April 92 Planned

1 July 92 Rescheduled

A.3.b. Insulator film studies

Start -- 1 December 92 Planned

1 December 92 Actual

Completion -- 31 December 92 Planned

A.3.c. Double-deposition geometry studies

Start -- 1 December 92 Planned

1 December 92 Actual

Completion -- 31 March 93 Planned

A.4. Field Emitter Array Testing

A.4.a. Test package development

Start -- 1 November 91 Planned

1 December 91 Actual

Completion -- 31 October 92 Planned

DC and rf evaluation

Start -- 1 February 92 Planned

1 July 92 Rescheduled

Completion -- 31 March 93 Planned

A.4.b. Beam analysis

Start -- 1 April 92 Planned

1 May 92 Actual

Completion -- 31 March 93 Planned

III. TECHNICAL PROGRESS

A -- Field Emitter Cathode Development

A.1. Composite Development

The growth run described in the previous Quarterly Report as being preliminarily judged acceptable has, in fact, been found to have contained a substantial quantity of composite material of acceptable quality. An additional growth run performed during this reporting period is presently being evaluated for uniformity of fiber distribution, fiber continuity and average crack-free die size. It appears that the average minimum dimension of dies with adequate integrity for processing has improved from earlier runs, and dimensions of about 6 to 8mm obtained. Objective dimensions of 1cm x 1cm have not yet been obtained.

Initial processing efforts in fabrication have not been adversely impacted by the small die size, however, as described later in this report.

A.2. Emitter Tip Geometry and Composition

The availability of composite material, as described above, has allowed initial chemical etching to proceed, and material has been successfully etched. This material is now being used for the initial lithography work on etched samples.

As an alternative to the wet chemical etching used to selectively etch the zirconia matrix material, several approaches to plasma etching have been tried, but without success. The ability to plasma etch the tungsten fibers, however, has been demonstrated, and this is being evaluated as an alternative process as described later in this report.

A.3. Field Emitter Structure Development

Detailed development of the photolithography procedures began during this reporting period. Problems with photoresist degradation by the etches traditionally used for selective removal of the tungsten fibers from the matrix outside of the intended emitting areas has been encountered. Both positive and negative photoresist materials have been evaluated in alkaline and acid etch environments without success. At this writing two additional efforts are under way. One is evaluating the possibility of using the plasma etching techniques noted above; the second will evaluate the use of an alkaline electrochemical etch. It is probable that one or both of these techniques will prove successful, and allow continuation of the process development.

The results of continued capacitance modelling have led to redirection of the planned efforts in fabrication. It appears that a preferred approach will use thin insulator layers, of the order of 0.5 to one micron thick, allowing fabrication of aperture diameters of the order of 0.5 to one micron with a single insulator deposition. This process is considerably simpler and easier to control than the previously envisioned double-deposition process, and is not expected to incur significant penalty in device capacitance as long as the array is fabricated on an insulating substrate such as that provided by the zirconia matrix of the composite materials being used. A substantial penalty has been shown to accrue if a conductive substrate is used.

The vapor deposition apparatus has been completed and proof testing to establish process control parameters is now in progress. It is expected that the deposition capability will be established and proven by the time the aforementioned photoresist/etchant compatibility issues are resolved. In the interim the photolithography mask set has been verified, and found satisfactory for use.

A.4. Field Emitter Array Testing

The automated emission testing system has been developed and assembled. Its operation is described in the following discussion.

For I-V characterization, the LVFE will be mounted in a cryopumped UHV system. An electrode will be mounted immediately (1-2 mm) above the LVFE to serve as a collector. Leads will be made to the collector, the cathode, and the extractor and brought outside the vacuum system via a twenty-pin electrical feedthrough. All measurements will be performed with a 386 personal computer using National Instruments Lab Windows software and GPIB hardware operated under the IEEE-488 protocol.

The cathode will be biased through a 1 meg-ohm resistor by a Kepco 0 - $\pm 1,000$ volts DC power supply the output of which is controlled by an analog signal generated by a D-to-A card in the computer. The cathode bias will be monitored with a Keithley 296 DMM which communicates directly with the computer.

The collector will be biased positively with respect to ground using dry cell batteries. The collector current will flow to ground through a Keithley 236 source-measurement unit that will transmit the value of the collector current directly to the computer.

The extractor will be connected to ground through a small resistor. A Keithley 296 DMM that communicates directly with the computer will monitor the voltage across this

resistor. This voltage will be used to measure the current flowing in the extractor circuit.

A typical I-V measurement will be performed by setting the cathode bias to 0 volts and measuring the collected current. The cathode bias will then be decreased incrementally and the collected current remeasured. By repeating this sequence a complete I-V curve can be obtained up to a predetermined value of either I (collected current) or V (cathode bias). Upon completion of this sequence, the cathode bias will either be set to 0 volts and the measurement terminated or an I-V curve will be determined in an analogous fashion to that described using increasing cathode bias increments until the cathode bias returns to 0 volts. During the measurements, the extractor current will be monitored regularly and the measurement terminated (cathode voltage set to 0 volts) if the extractor current exceeds a preset value.

IV. FISCAL STATUS

NOTE: Due to delays in Accounting as a result of Fiscal Year closeout (Georgia Tech's fiscal year corresponds to the State fiscal year, July 1 - June 30) financial information for June is not yet available. The information provided is current through the end of May 1992. Revised information through the end of the quarter will be provided as soon as it becomes available.

Expenditures this quarter (through May)	\$45,934.16
Total expenditures to date	\$182,286.58
Projected expenditures:	
7/92 - 9/92	\$119,600.00
Total Projected Cost for FY92	\$337,452.00

V. PROBLEM AREAS

- Efforts continue in the area of composite growth to reduce cracking and increase usable sample size

- Compatibility of the photoresists used in the lithography process under development with the etchants traditionally used for selective removal of the tungsten is problematical, but is being addressed by alternative etching procedures

VI. VISITS AND TECHNICAL PRESENTATIONS

A. Visits

1. Dr. Huei Pei Kuo
Hewlett-Packard
Palo Alto, California

2. Mr. Bob Duboc
Silicon Video
Cupertino, California

B. Technical Presentations

1. "Parameter Modelling of a Field Emitter Array for High Speed/High Frequency Applications", W.L. Ohlinger, D.N. Hill, R.K. Feeney, H.M. Harris and W.B. Carter, presented at the 1992 Microwave Power Tube Conference, Monterey, California, May 11-13, 1992.