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13 March 1992

Dr. Bertram H. Hui
Defense Advanced Research Projects Agency
Defense Sciences Office
Virginia Square Plaza
3701 North Fairfax Drive
Arlington, VA 22203-1714

DIRECTORATE FOR FREEDOM OF INFORMATION
AND SECURITY REVIEW (OASD/ISA)
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Reference: Contract MDA 972-91-C-0029
ARPA Order No. 8162
(SRI Project ECU-2743)

Subject: Quarterly R&D Status Report
Covering the Period 1 October 1991 to 31 December 1991
"Field-Emitter Arrays for RF Vacuum Microelectronics"

Dear Dr. Hui:

This report covers the first quarter of Phase I of a research and development program on the SRI Spindt-type field-emitter-array cathode with a view toward eventual applications in microwave amplifiers and is submitted in accordance with CDRL 0002AA. We began work on 1 September 1991. Goals for this first phase have been set at 5 mA total emission with a current density of 5 A/cm² for at least 1 hr and demonstrated modulation of the emission current at a frequency of 1 GHz. Our approach has been to identify methods of adapting and modifying the basic cathode structure for microwave operation and to experimentally investigate means of implementing those methods.

PROGRESS SUMMARY

Two development areas required immediate attention. The first was to find a suitable material and then develop an anode that can be used in close proximity to the cathode without causing difficulties due to outgassing and arcing. The second was to design and fabricate a cathode structure with an interelectrode capacitance consistent with the microwave applications envisioned. In addition, work has begun on improving emitter-tip geometry and packing density with a view toward minimizing driving voltage requirements. Finally, we have started development of a test vehicle for characterizing the cathodes at microwave frequencies. The microwave measurements will be made using a Hewlett-Packard 8510B network analyzer.

The plan has been to research these issues in parallel. The cathode characterization and anode materials (and processing) issues were studied using our well-established cathode arrays fabricated on silicon substrates. Easy-to-build, low-frequency, triode configurations fabricated on standard TO-5 headers were used as the test vehicles. The low-capacitance cathode structure for high-frequency work is being studied using small-area cathode structures formed on dielectric (fused quartz) substrates, and a microwave test vehicle is being designed and built.

SRI International

333 Ravenswood Ave. • Menlo Park, CA 94025 • (415) 326-6200 • TWX: 910-373-2046 • Telex: 334486 • Facsimile: (415) 326-5512

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The results to date have been that 1000-tip arrays made in our traditional way on silicon substrates have been operated with a carefully processed close-spaced nickel anode (≈ 1 mm from the cathode) at 15 mA peak emission (15 μ A average peak current per tip) using a 60-Hz driver with a peak amplitude of 80 V for over 1000 hr and continuing. (The duty cycle is 20%.) The arrays cover an area of $256 \times 256 \mu\text{m}$, giving a peak current density of 22.8 A/cm^2 . The voltage on the anode is 180 V. These results demonstrate that the anode materials and processing selected for this test were well suited to the task.

Low-capacitance cathode arrays have been fabricated on glass substrates, and although there have been difficulties with a chemical vapor deposition (CVD) process used to form the oxide dielectric layer, low-capacitance cathodes have been fabricated and operated with encouraging results. The vendor doing the CVD service for us while our equipment is being brought on-line is confident that the problems (poor adhesion and cracking) can be overcome. In spite of the difficulty with the dielectric layer, some low-capacitance cathodes were tested and, in one case, 25-mA square-wave pulsed emission was obtained from a 625-tip array covering an area $2.5 \times 10^{-5} \text{ cm}^2$ (1000 A/cm^2). The pulse width was 5 ms and the duty cycle was 5%. The cathode emission was modulated at 20 MHz during the 5-ms pulse.

A test vehicle has been designed with 450°C-bakeable, ultra-vacuum-compatible, 50-ohm cables, microstrip lines, and connectors for operation at 1 GHz and higher, and construction will begin early in the next quarter.

WORK PLANNED

Depending on deliveries, we plan to begin fabrication of the microwave test vehicle during the next period. Development of the low-capacitance cathode structure will continue, as will studies of low-voltage operation.

EQUIPMENT PURCHASES

Vacuum components for field-emission microscope apparatus were ordered.

KEY PERSONNEL

There have been no changes in key personnel.

TRAVEL SUMMARY

DARPA program review, Washington, DC, 31 October 1991.

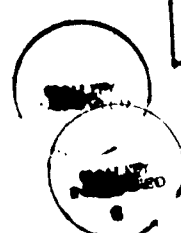
FINANCIAL SUMMARY

The following table provides the financial summary for this period.

RELATED ACCOMPLISHMENTS

No papers have yet been written on this contract.

Accession For	
NTIS	ORNL
DTIC	TAC
Unannounced	
Justification	
By	
Distribution	
Availability	
Dist	Availability
A-1	Special



**R&D STATUS REPORT
PROGRAM FINANCIAL STATUS**

		Cumulative to Date (12/31/91)			At Completion		
Element	Planned Expenditures	Actual Expenditures	Percent of Completion	Budget at Completion	Latest Revised Estimate	Remarks	
Total project	304,950	130,133	10.4	1,248,917	1,248,917		
Total	304,950	130,133	10.4	1,248,917	1,248,917		
Based on currently authorized work:					Yes	No	Amount
1. Is current funding sufficient for the current fiscal year? (Explain in narrative if "No")					√		1,010,000†
2. What is the next fiscal year's funding requirement at current anticipated levels?							238,917
3. Have you included in the report narrative any explanation of the above data and are they cross referenced?						√	

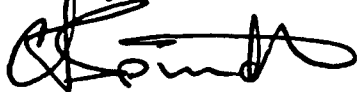
Note: Budget at completion changes only with the amount of any scope changes. (Not affected by underrun or overrun).

* All dollars include fee.

† Does not include the additional task negotiated on 25 February 1992 (\$286,825) or option (\$760,114).

Questions of a technical nature should be addressed to the undersigned at (415) 859-2993; contractual and administrative matters should be addressed to Ms. Barbara E. Camph, Group Manager, Engineering Contracts at (415) 859-4328.

Sincerely,



C. A. Spindt, Program Director
Physical Electronics Laboratory

CS:lk

cc: Mr. Thomas F. Griffin, DSO
Mr. Donald C. Sharkus, CMO

DCMAO—San Francisco
Attn: Capt. Peter L. Regan, Jr.

Defense Technical Information Center
Building 5, Cameron Station
Alexandria, VA 22304
Attn: Selections