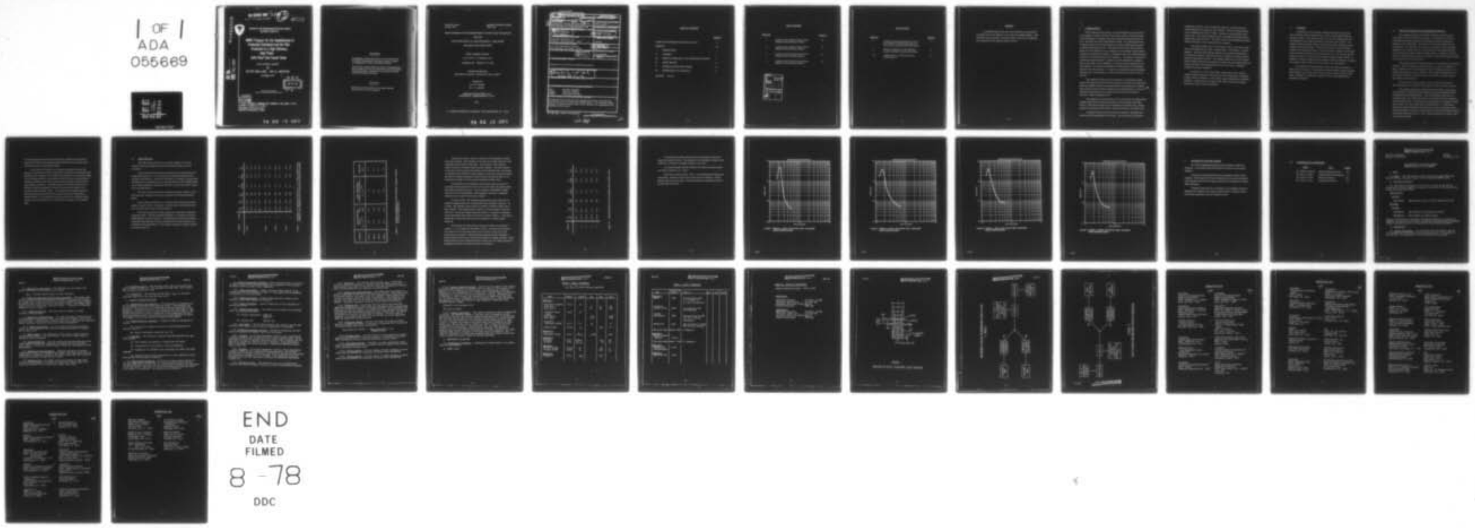
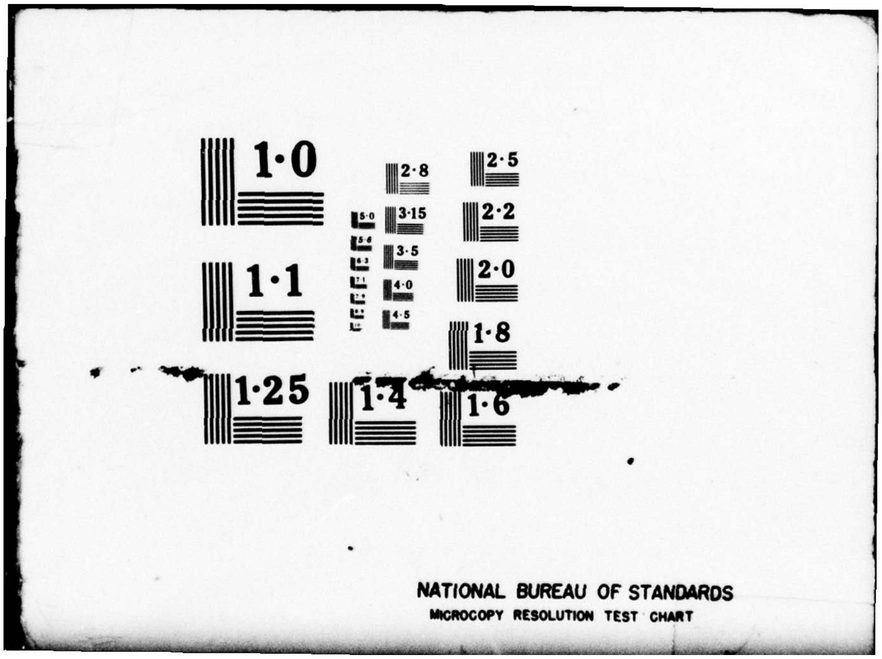
AD-A055 669 MICROWAVE ASSOCIATES INC BURLINGTON MASS F/G 9/1
MANUFACTURING METHODS AND TECHNOLOGY PROGRAM FOR THE ESTABLISHM--ETC(U)
OCT 77 R E WALLINE, J L HEATON DAAB07-77-C-0324
UNCLASSIFIED ECOM-0324-3 NL

| OF |
ADA
055669



END
DATE
FILMED
8-78
DDC


1·0
2·8
2·5
5·0
3·15
2·2
5·6
3·5
6·3
2·0
1·1
4·0
4·5
1·8
1·25
1·4
1·6
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

A046408 + A049128

12

Research and Development Technical Report
ECOM-0324-3

MM&T Program for the Establishment of Production Techniques and the Pilot Production of a High Efficiency, High Power GaAs Read Type Impatt Diode

3 RD QUARTERLY REPORT

By

DR. R.E. WALLINE DR. J.L. HEATON

OCTOBER 1977

DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

Monitored by:
ECOM
US ARMY ELECTRONICS COMMAND • FORT MONMOUTH, NEW JERSEY 07703
CONTRACT DAAB07-77-C-0324
MICROWAVE ASSOCIATES, INC.
Burlington, Massachusetts 01803

TR-ECOM-0324-3
October 1977

REPORTS CONTROL SYMBOL
OSD-1366

MM&T PROGRAM FOR THE ESTABLISHMENT OF PRODUCTION TECHNIQUES AND THE PILOT PRODUCTION OF A HIGH EFFICIENCY, HIGH POWER GaAs READ-TYPE IMPATT DIODE

THIRD QUARTERLY REPORT

01 July 1977 to 31 September 1977

CONTRACT NO. DAAB07-77-C-0324

Distribution Statement
Distribution unlimited: Approved for public release

Prepared By
Dr. R.E. Walline
Dr. J.L. Heaton

MICROWAVE ASSOCIATES, INC.
BURLINGTON, MASSACHUSETTS 01803

FOR

U.S. ARMY ELECTRONICS COMMAND, FORT MONMOUTH, NJ 07703

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

⑱ ⑲ **REPORT DOCUMENTATION PAGE**	**READ INSTRUCTIONS BEFORE COMPLETING FORM**
1. REPORT NUMBER ECOM-0324-3	2. GOVT ACCESSION NO.
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ⑥ Manufacturing Methods ~~&~~ and Technology Program for the Establishment of Production Techniques and the Pilot Production of a High Efficiency, High Power GaAs Read-Type IMPATT Diode,	5. TYPE OF REPORT & PERIOD COVERED Third Quarterly 01 July 1977 - 31 Sept 1977
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) ⑩ Dr. Robert E. Walline Dr. John L. Heaton	8. CONTRACT OR GRANT NUMBER(s) ⑮ DAAB07-77-C-0324
9. PERFORMING ORGANIZATION NAME AND ADDRESS Microwave Associates, Inc. Burlington, Massachusetts 01803 229 400	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2769738
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Electronics Command Fort Monmouth, New Jersey 07703	12. REPORT DATE ⑪ October 1977
	13. NUMBER OF PAGES 40
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) ⑫ 35 p.	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.	
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) ⑨ Quarterly rept. no. 3, 1 Jul-31 Sep 77,	
18. SUPPLEMENTARY NOTES	
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) READ GALLIUM ARSENIDE IMPATT PROCESS CONTROL EPITAXY COMPUTER CONTROL	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An epitaxial GaAs system has been designed for growth of low-high-low (L-H-L) GaAs for use in Read-type IMPATT diodes. This epitaxial system includes a computer control system for the operation and monitoring of the epitaxial growth process.	

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

229 400

TABLE OF CONTENTS

		Page No.
REPORT DOCUMENTATION PAGE (DD Form 1473)		ii
ABSTRACT		vii
I.	INTRODUCTION	1
II.	SUMMARY	3
III.	SYSTEM CONSTRUCTION AND EXPERIMENTAL RESULTS	4
IV.	DEVICE RESULTS	6
V.	PROGRAM FOR THE NEXT QUARTER	16
VI.	IDENTIFICATION OF PERSONNEL	17

APPENDIX: SCS-481

LIST OF FIGURES

Figure No.		Page No.
1	Doping versus Depth for Wafer 4819-1 Measured using Finished Diodes.	12
2	Doping versus Depth for Wafer 4825-1 Measured using Finished Diodes.	13
3	Doping versus Depth for Wafer 4826-1 Measured using Finished Diodes.	14
4	Doping versus Depth for Wafer 4828-1 Measured using Finished Diodes.	15

LIST OF TABLES

Table No.		Page No.
I	Summary of Evaluation Results of L-H-L Read IMPATTs from Epitaxial GaAs Prepared in the Computer Controlled System	7
II	Material Parameters for the Epitaxial Crystals Utilized for Diode Fabrication	8
III	IMPATT Results for PHS Diodes from Crystal 4819-1	10

ABSTRACT

An epitaxial GaAs system has been designed for the growth of low-high-low (L-H-L) GaAs for use in Read-type IMPATT diodes. This epitaxial system includes a computer control system for the operation and monitoring of the epitaxial growth process.

I. INTRODUCTION

The purpose of this program is the establishment and verification of techniques to reduce the labor and increase control of processes used in the preparation of epitaxial GaAs and subsequent fabrication of Read-type, Low-High-Low (LHL) GaAs IMPATT diodes. The reduced labor and increased control will be demonstrated by improved manufacturing yields at reduced manufacturing cost. The mechanism by which these improvements are to be obtained is the automation of the epitaxial crystal growth process with appropriate feedback mechanisms which will regulate process variables in accordance with actual conditions. The system is required to control and respond rapidly to variation in wafer temperature, exposure time of the wafer to this temperature, the flow rate of the dopant and epitaxial gases, the chemical composition of these gases and the interrelationship of all these factors. In addition, the epitaxial crystal evaluation (routine) will be eliminated and crystal evaluation (non-routine) will be reduced.

The engineering effort will be restricted to the epitaxial crystal growth and epitaxial crystal evaluation required to produce high-efficiency, Read-type IMPATT diodes plus sample diodes to demonstrate the progress. The success of these control programs will be demonstrated by a pilot line production demonstration of the required X-band diode as defined in SCS-481, dated 23 December 1974.

The epitaxial crystal evaluation will productionize the measurement methods specified for dislocation density of the substrates and buffer layers, doping and uniformity of the substrates and buffer layers, doping profile of the epitaxial LHL crystal, and the thickness of the buffer layer.

A suitable X-band test cavity shall be designed, fabricated and used to test the performance of the diode. The cavity shall incorporate proper bias circuitry, shall provide easy access to the diode and fast interchangeability of diodes for quick testing. Parts and materials shall be in accordance with MIL-P-11268. Forced air or water cooling shall not be used. The output terminal shall be a standard waveguide terminal mating with flange UG-39/U. The cavity used to test engineering samples shall be identical to that supplied with the samples.

The required wafer yield is fifty percent (50%) of the wafers grown shall have eighty percent (80%), minimum area 3.0 cm^2/wafer, of usable material. The term usable defines material which meets specifications for dislocation density, doping profile and is capable of producing diodes meeting specification SCS-481. The required diode yield is forty percent (40%) of diodes produced and selected at random from any usable wafer and tested shall meet the cited specification for output power, operating frequency and power efficiency.

In addition, for the X-band diode, performance curves shall be supplied showing typical min-max excursions for capacitance, breakdown voltage, thermal resistance, output power, power efficiency and operating frequency. Diode design and process flow charts covering all process steps for the product shall be detailed.

II. SUMMARY

Construction of the computer controlled epitaxial GaAs system was completed and the computer control system was interfaced with the epitaxial system. The epitaxial system is in its final configuration with the exception of the bubbler controller for the $AsCl_3$ etch bubbler. The bubbler controller for this bubbler was received in poor condition and was returned to the manufacturer. A mass flow controller is being utilized instead of the bubbler controller. The impact of this change is not material to the successful operation of the system since it is used only for the pre-growth etch and is not used during the actual epitaxial crystal growth. In addition, the input signals of the two different units are identical, allowing the computer control system to be connected in the same fashion.

The computer controlled epitaxy system was operated during the latter part of the quarter. The computer controlled epitaxy system prepared good epitaxial L-H-L GaAs which produced devices which meet the output power, frequency and effieicncy required for the X-band IMPATT diode specified by SCS-481

III. SYSTEM CONSTRUCTION AND EXPERIMENTAL RESULTS

The epitaxial system was operated in a manual mode during the first portion of the first month of the quarter. The system is in its final configuration with the exception of the vaporizer controller which was returned to the manufacturer. This unit has not yet been returned by the manufacturer. The impact of this change is not material to the successful operation of the system since it is only used for the pre-growth etch and not used during the actual epitaxial crystal growth. In addition, the input signals of the two different units are identical, allowing the computer control to be connected in the same fashion.

The epitaxial system performed similarly to the performance previously reported. The peak shape was still too broad. As a result, a mixture of SiH_4 in hydrogen was used to replace the H_2S in hydrogen doping gas. The peak shapes appear to be much improved. The epitaxial system was shut down about the middle of the first month of the quarter to permit wiring in the computer control system.

All components of the computer control system were delivered. The components were interfaced and checked out with only minor problems.

The problems which were encountered were primarily in the nature of wiring errors in interfacing the epitaxial system to the Hewlett-Packard 9611R Remote Measurement System. The other problems which were encountered were in the interfacing of the various Hewlett-Packard equipment. These problems were: 1) the wrong cable connectors were shipped for some of the cables; 2) some cables were not supplied and; 3) wiring errors which were made at Microwave Associates on the cable connectors used to remote the laboratory cathode ray tube display and the 9611R Remote Measurement System from the computer. None of these problems were serious, and were easily corrected.

The remote measurement system and laboratory cathode ray tube display were then relocated to the epitaxial GaAs laboratory and the wiring to the computer room was completed and tested.

The wiring of the reactor to the remote measurement system (the portion of the computer control system which is located in the epitaxial GaAs laboratory) was completed. The wiring was performed in two separate stages. The gas handling portion of the epitaxial system (the mass flow controllers, vaporizer controllers and control loops) and the necessary thermocouplers were initially completed. A computer program was written to grow L-H-L structures and this program was utilized to successfully prepare L-H-L structures under computer control. The temperature controllers were then wired into the system and the entire epitaxial deposition performed by computer control. The epitaxial system controlled by the computer control system is now operational and has successfully prepared L-H-L epitaxial GaAs.

IV. DEVICE RESULTS

The first of the epitaxial L-H-L crystals prepared in the final computer controlled epitaxy system were performed toward the end of the quarter.

The evaluation diodes which are assembled are thermocompression bonded (TCB) square (7 x 7 mil) chips with a platinum Schottky barrier serving as the junction. This type of evaluation is utilized to provide quick information on the performance of the epitaxial GaAs for Read IMPATT diodes and to select material for subsequent fabrication into the high-power plated heat sink (PHS) diodes.

The device results which were obtained are shown in Table I using the device test procedures and cavity described in the Second Quarterly Report.

These ranges of efficiency are consistent with efficiencies of PHS diodes in excess of 20%. In general, the PHS diodes exhibit efficiencies 4 to 5% higher than the TCB evaluation diodes.

The various epitaxial crystals operate most efficiently at different frequency ranges. The best operating frequency is a function of the drift doping density and drift thickness. These different crystals were prepared to different specifications in order to determine the correct material to be utilized for the required device. The material parameters for these crystals are given in Table II.

CRYSTAL	DIODE	V_B (V)	V_{op} (V)	I_{op} (mA)	P_o (watts)	f_o (GHz)	η (%)
4819-1	1	20.2	44.6	380	3.0	10.0	17.8
	2	19.5	45.2	280	2.2	10.2	17.8
	3	21.7	44.8	308	2.6	10.3	18.4
	4	22.1	45.8	296	2.3	10.8	16.9
4825-1	3	27.2	44.6	368	2.8	11.3	17.1
	5	27.5	45.2	370	3.0	11.5	18.0
4826-1	4	32.5	46.8	338	3.2	11.7	20.2
	5	32.6	47.6	370	3.7	11.4	20.7
4828-1	3	30.7	46.4	300	2.7	12.6	19.3
	5	31.1	45.4	240	2.3	13.0	20.6

TABLE I SUMMARY OF EVALUATION RESULTS OF L-H-L READ IMPATTS FROM EPITAXIAL GaAs PREPARED IN THE COMPUTER CONTROLLED SYSTEM

CRYSTAL	PEAK PARAMETERS Height $(n \times 10^{-17})$	Depth (μm)	DRIFT PARAMETERS CARRIER CONCENTRATION $(n \times 10^{-15})$	THICKNESS (μm)
4819-1	4.8	0.35	5.8	5.4
4825-1	5.7	0.34	8.5	6.3
4826-1	5.8	0.26	10.0	4.7
4828-1	6.0	0.27	8.0	5.3

TABLE II MATERIAL PARAMETERS FOR THE EPITAXIAL CRYSTALS UTILIZED FOR DIODE FABRICATION

Within each crystal, there is a variation of the breakdown voltage from diode to diode. This variation is the result of a slight variation of the integrated charge density of the peak. This variation is the result of slight variations in the peak height and peak position. The peak position is the result of the original peak position of the epitaxial layer, the amount of epitaxial GaAs removed by sputter etching to clean the surface and locate the peak for optimum performance and the amount of platinum which is reacted with the GaAs to form the reacted platinum Schottky diode.

The variation of the breakdown voltage from crystal to crystal is caused by larger variations from run to run in peak height and peak position than within an epitaxial crystal. These variations of breakdown voltage from run to run do not translate to corresponding variations in operating voltage as can be seen from the data in Table I.

For each crystal, the evaluation diodes were square chips and are subject to damage during the chip fabrication and assembly processes. As a result, after bonding, these diodes are etched to provide a sharp breakdown voltage. This etching process leads to an area variation in the evaluation lot. This area variation manifests itself as a variation in operating current and output power such as seen in the results in Table I. The smaller diodes have a lower capacitance and thus operate at a slightly higher frequency.

The efficiency for these devices appears to follow the breakdown voltage, i.e., the higher the breakdown voltage, the higher the efficiency. This feature can be seen more clearly from the data in Table III for PHS diodes from crystal 4819. These data would indicate that the integrated charge density of the peak in some of these diodes is slightly too high. Those devices which have the lowest breakdown voltage have the greatest amount of undepleted peak with a resultant decrease in efficiency.

DIODE	V_B (V)	V_{op} (V)	I_{op} (mA)	P_o (watts)	f_o (GHz)	η (%)
2	24.0	42.7	423	4.5	10.9	24.9
3	23.0	40.7	439	4.0	10.7	22.4
4	20.5	39.7	500	4.3	11.2	21.7
5	23.2	41.1	461	4.3	10.9	23.7
6	22.4	40.0	433	4.0	11.2	23.1

TABLE III IMPATT RESULTS FOR PHS DIODES FROM CRYSTAL 4819-1

The breakdown voltage variation does not translate to the same operating voltage variation. The variation of the breakdown voltage (± 8%) results in a variation of operating voltage of only ± 4%.

The carrier density profiles obtained from these evaluation diodes are shown in Figures 1,2,3, and 4.

The first of these crystals - 4819 - was processed into plated heat sink diodes. Results of these devices were shown in Table III. These devices meet the output power, operating frequency and efficiency for the X-band diode of SCS-481.

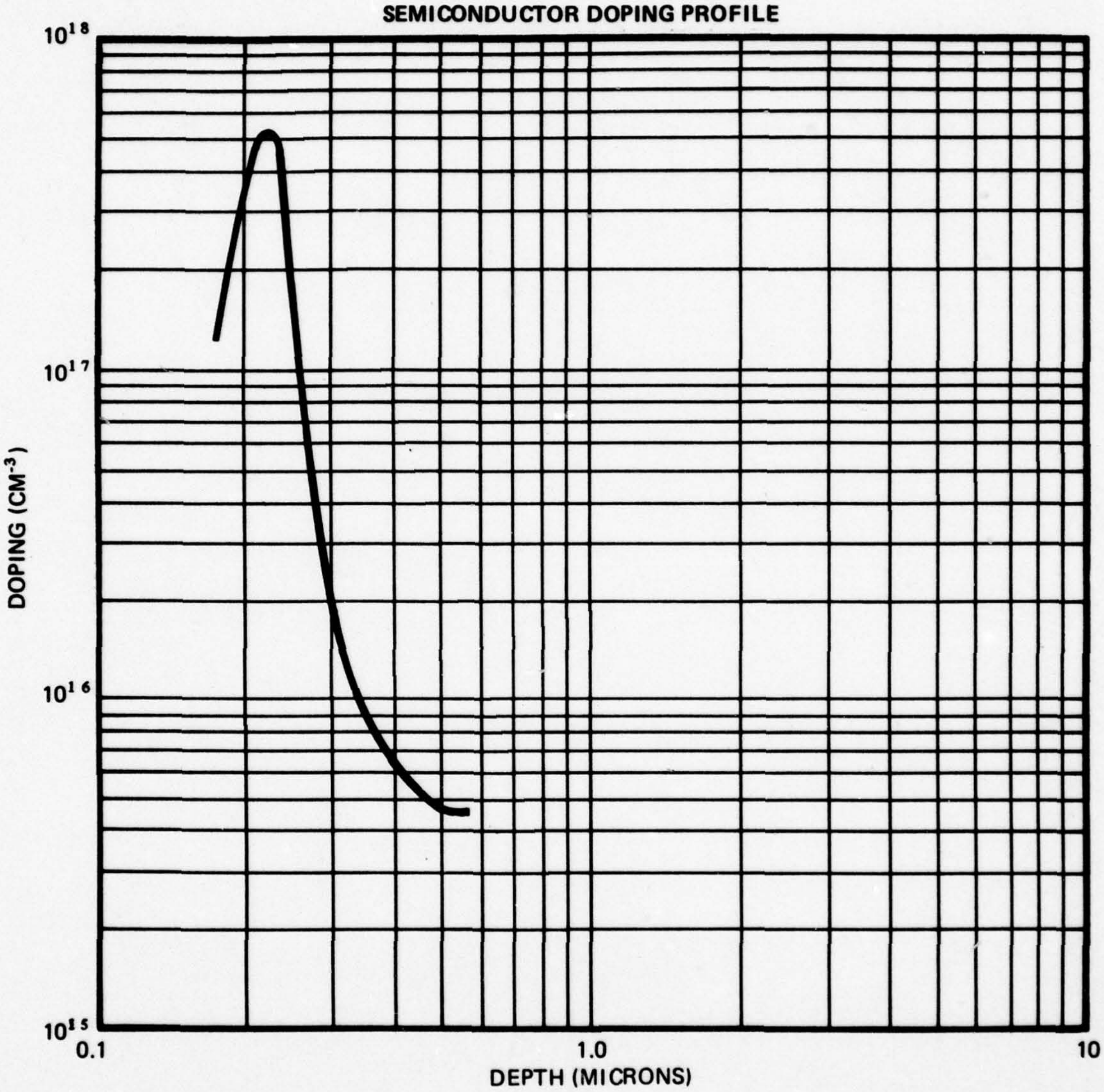


FIGURE 1. DOPING vs. DEPTH FOR WAFER 4819-1 MEASURED USING FINISHED DIODES.

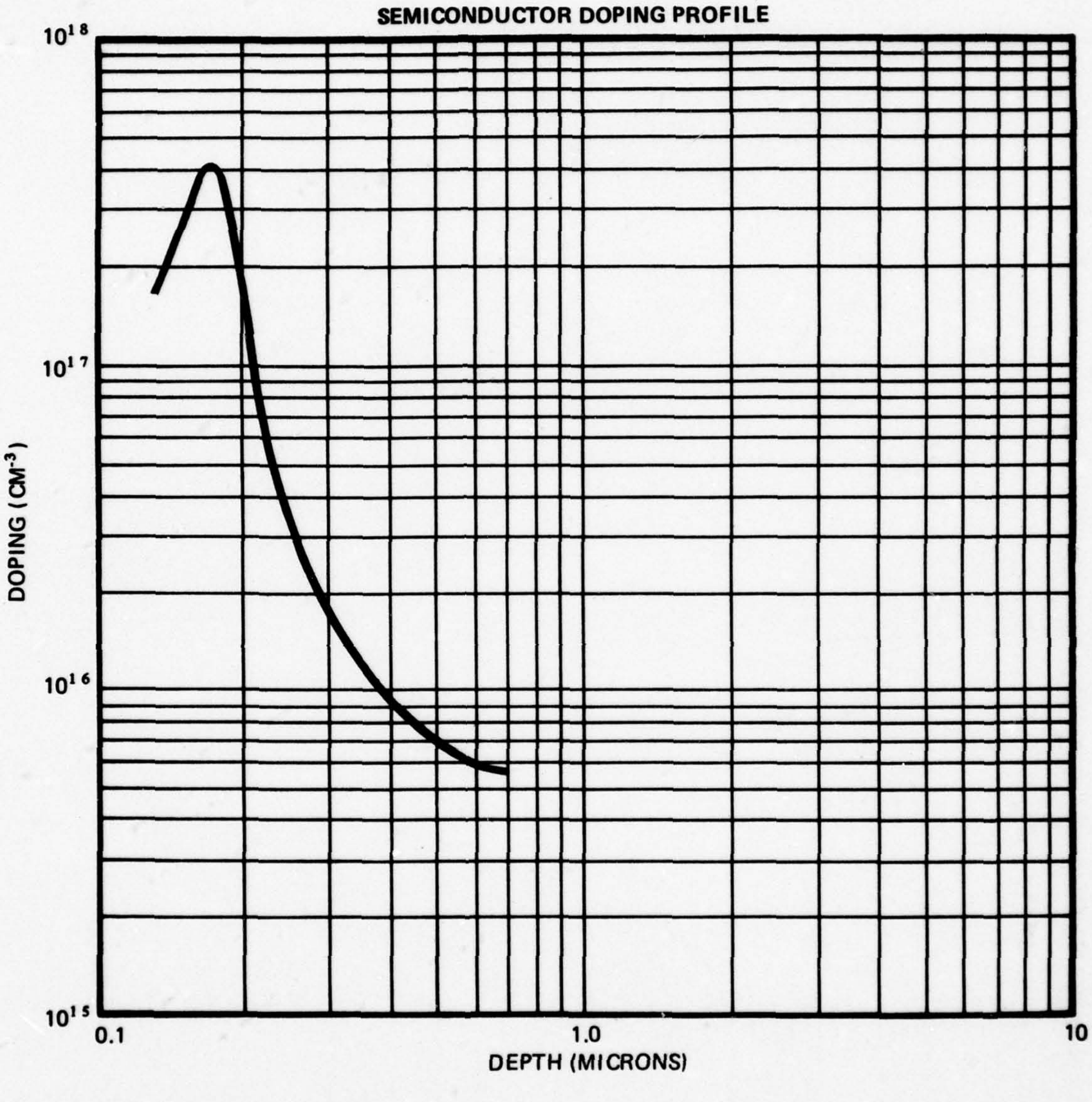


FIGURE 2. DOPING vs. DEPTH FOR WAFER 4825-1 MEASURED USING FINISHED DIODES.

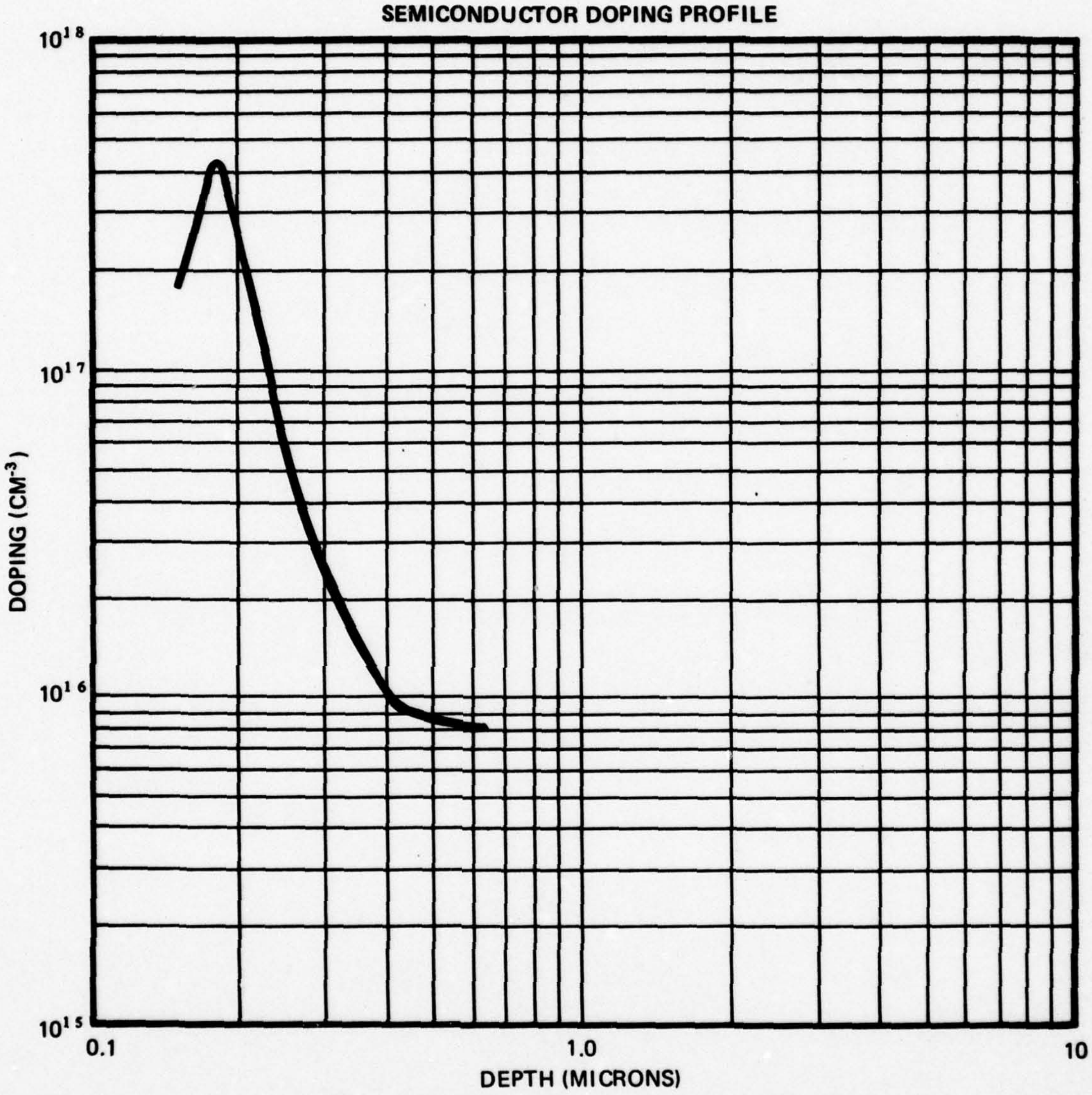


FIGURE 3. DOPING vs. DEPTH FOR WAFER 4826-1 MEASURED USING FINISHED DIODES.

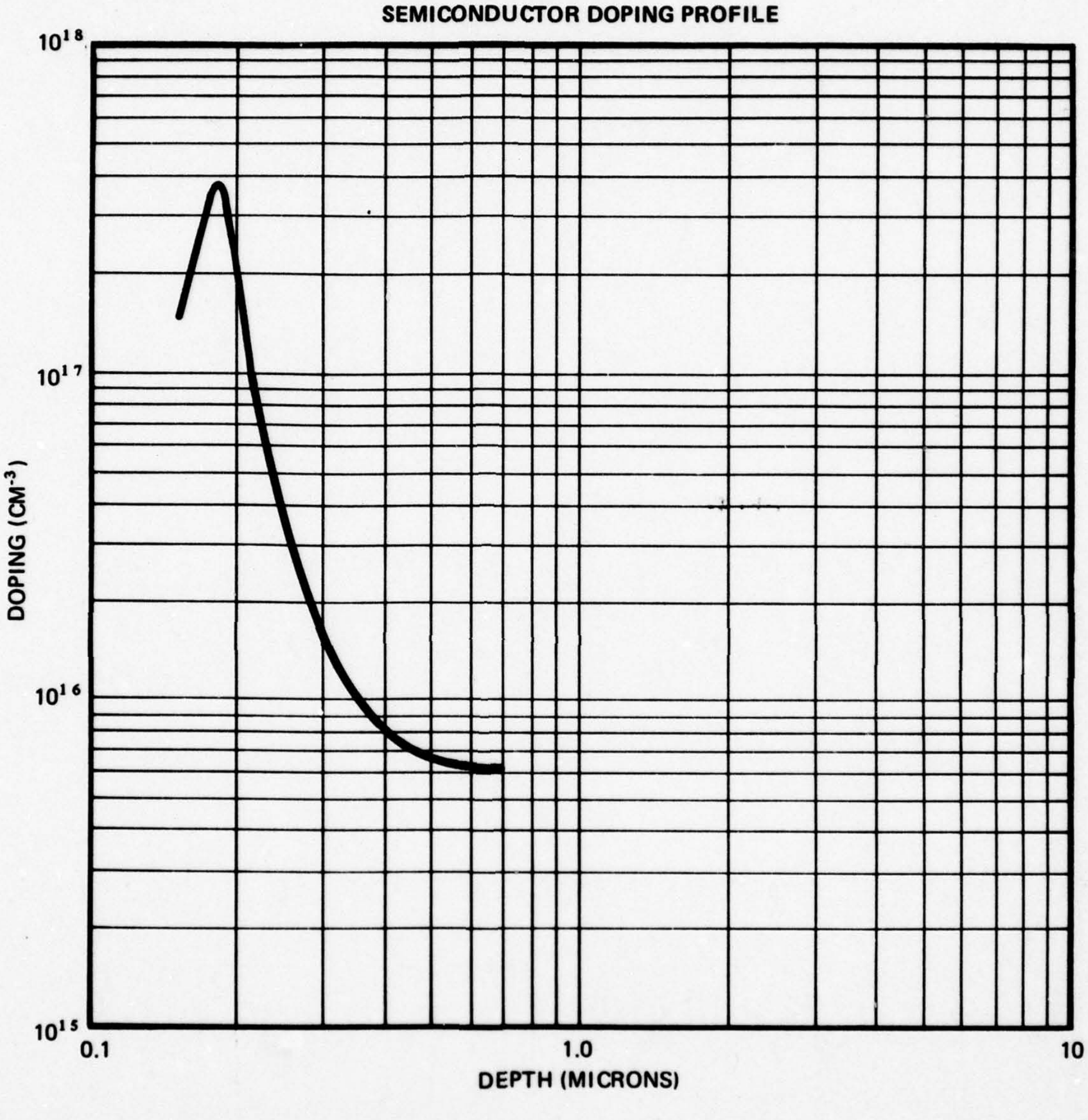


FIGURE 4. DOPING vs. DEPTH FOR WAFER 4828-1 MEASURED USING FINISHED DIODES.

D-15408

V. PROGRAM FOR THE NEXT QUARTER

The second engineering samples will be prepared, tested and delivered. It is expected that these diodes will meet all of the specifications.

Preliminary reproducibility data on the epitaxial system will be obtained. These data will be used to determine if any serious reproducibility problems exist with the epitaxy system which could then be immediately addressed.

Uniformity data will also be obtained on the epitaxial crystals to determine the variation of the carrier density profile, thickness and the doping peak parameters over the epitaxial crystal.

VI. IDENTIFICATION OF PERSONNEL

NAME	TITLE	HOURS
Dr. Robert E. Walline	GaAs Department Manager	48
Dr. John L. Heaton	IMPATT Product Line Manager	75
Mr. James E. Holtz	Materials Engineer	410
Mr. Carl N. Foose	Engineering Assistant	80

ELECTRONICS COMMAND
TECHNICAL REQUIREMENTS

SCS-481
23 December 1974

HIGH EFFICIENCY, HIGH-POWER GALLIUM ARSENIDE READ-TYPE IMPATT DIODES

1. SCOPE

1.1 Scope. - This specification covers the detailed requirements for high efficiency, high power Gallium Arsenide Read-Type IMPATT Diodes.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on the date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-S-19500	Semiconductor Devices, General Specification for.

STANDARDS

MILITARY

MIL-STD-750	Test Methods for Semiconductor Devices
MIL-STD-1311	Test Methods for Electron Tubes

(Copies of specification, standards, drawings and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the Contracting Officer).

3. REQUIREMENTS

3.1 Detail requirements. - The individual item requirements shall be in accordance with MIL-S-19500, and as specified herein. In the event of any conflict, the requirements of this specification shall govern.

3.2 Abbreviations and symbols. - The abbreviations and symbols used herein are defined in MIL-S-19500 and as follows:

Q_{ext} = external quality factor of diode oscillator

3.3 Design and construction and physical dimensions. - The diodes shall be made by epitaxial growth of Read-type profiles. The diode shall consist of a single mesa, single chip mounted in a ceramic-to-metal microwave package. The package shall be gold plated and hermetically sealed. The package shall provide means for readily heat sinking the diode. A schematic of a suitable package is shown in Figure 1.

3.3.1 Operating position. - The diode shall be capable of proper operation in any position.

3.4 Performance characteristics. - The diode performance characteristics, while operating as oscillators, shall be as specified in Tables I and II and as listed below. The performance characteristics shall apply over the specified ambient operating temperature range unless otherwise specified.

3.4.1 Process conditioning. - All units shall be process conditioned before they are subjected to the tests and examinations defined in Tables I and II (see 4.5.4).

3.5 Serial number. - The manufacturer shall assign a serial number to each device furnished to this specification. This serial number shall be sequential and non-repeating.

3.6 Interchangeability. - All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance within the requirements of this specification.

3.7 Storage life (non-operating). - Following storage at an ambient temperature of 200°C ± 3°C for 1000 hours minimum, all diodes shall meet the requirements of oscillator frequency, oscillator output power and oscillator efficiency as defined in Table III (see 4.6.5).

3.8 Operating life. - All diodes which have operated for 1000 hours minimum per the requirements of Table III shall have a power output of no less than 75 percent of the initial power output (see 4.6.6).

3.9 Mechanical tuning. - The RF output power shall not decrease below specified value in Table III. The frequency and power shall vary smoothly with no steps or jumps (see 4.6.3).

3.10 External Q. - The external quality factor, Q_{ext}, of the diode oscillator shall not be more than 200 (see 4.6.4).

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. - The contractor is responsible for the performance of all inspections specified herein. The contractor may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.2 Classification of inspection. - Inspection shall be classified as follows:

(a) First article inspection (does not include preparation for delivery) (see 4.4).

(b) Quality conformance inspection (see 4.5).

4.3 Test plan. - The contractor prepared Government-approved test plan shall contain:

(a) Time schedule and sequence of examinations and tests.

(b) A description of the method of test and procedures.

(c) Programs of any automatic tests including flow charts and block diagrams.

(d) Identification and brief description of each inspection instrument and date of most recent calibration.

4.4 First article inspection. - First article testing shall consist of the tests specified in Tables I and II. For the tests of Table I and the end point measurements of Table II, the diodes shall be operating as oscillators in the test cavity. The number of units to be subjected to each test shall be as stated in the contract. No failures will be permitted.

4.5 Quality conformance inspection. - This inspection shall be performed on samples selected from the pilot production as specified in the contract and shall consist of Group A and B inspections.

4.5.1 Group A inspection. - Group A inspection shall consist of the examinations and tests specified in Table I. The diodes shall be operating as oscillators in the test cavity.

4.5.2 Group B inspection. - Group B inspection shall consist of the examinations and tests specified in Table II.

4.5.3 Group C inspection. - Group C inspections are not applicable to this specification.

4.5.4 Process conditioning. - All diodes will be stored, non-operating, under the following conditions:

(a)	Junction temperature:	225°C max 200°C min
(b)	Storage time:	168 hrs. min

4.5.5 Test cavity. - Two suitable microwave test cavities, one for each frequency band, shall be used to test the performance of the diodes.

4.6 Methods of examination and test. - Methods of examination and test shall be as specified in Tables I and II and as follows:

4.6.1 AM noise. - An AM noise measurement system as shown schematically in Figure 2 shall be used to determine the AM noise to signal ratio. The AM noise spectrum shall be measured continuously from 10 KHz to 100 KHz from the carrier as a minimum and recorded by an x-y recorder. Noise measurements shall be performed while diode oscillator is meeting the operating requirements in Table III.

4.6.2 FM noise. - An FM noise measurement system as shown schematically in Figure 2 shall be used to determine FM noise deviation. The FM noise spectrum shall be measured continuously from 10 KHz to 100 KHz from the carrier as a minimum and recorded by an x-y recorder. Noise measurement shall be performed while the diode oscillator is meeting the operating requirements in Table III.

4.6.3 Mechanical tuning. - The oscillator unit will be mechanically tuned over the required frequency range of ± 250 MHz from operating frequency.

4.6.4 External Q. - The external quality factor, Q_{ext}, of the diode oscillator shall be determined by standard injection locking techniques. A small locking signal shall be injected into the diode oscillator for measurement of locking bandwidth as a function of injected power.

4.6.5 Storage life (non-operating). - The diodes shall be stored at an ambient temperature of 200°C ± 3°C for 1000 hours minimum. These diodes shall be selected randomly from diodes which have undergone process conditioning and have successfully passed all Group A inspections. Upon completion of storage, the diodes shall be subjected to the following tests described in Table I: Oscillator frequency, oscillator output power and efficiency.

4.6.6 Operating life. - The diodes shall be tested under operating conditions in accordance with Table III for 1000 hours minimum. Power output shall be monitored continuously. The diodes subjected to the operating life test shall be selected randomly from diodes which have undergone process conditioning and have successfully passed all Group A inspections. The number of failures as a function of time shall be recorded. The test shall be conducted in an ambient temperature of 25 ± 3°C and the cavity temperature shall not exceed 75°C during this test.

4.6.7 Efficiency (RF-DC). - The RF to DC power efficiency of diodes operating as oscillators shall be determined by measuring the DC input power and using standard mathematical formulations.

$$\text{Power Efficiency (RF-DC)} = \frac{\text{Power output (RF)}}{\text{Power in (DC)}} \times 100$$

4.6.8 RF output power. - RF output power of diodes operating as oscillators shall be measured at operating frequency in accordance with method 4250, MIL-STD-1311 using a calibrated thermistor and power meter.

4.6.9 Oscillator frequency. - Frequency of diodes operating as oscillators shall be determined with a calibrated spectrum analyzer and verified with a calibrated frequency meter.

4.6.10 DC bias voltage. - DC bias voltage of diodes operating as oscillators shall be measured in accordance with method 4016, MIL-STD-750.

4.6.11 DC bias current. - DC bias current of diodes operating as oscillators shall be measured in accordance with method 4016, MIL-STD-750.

4.6.12 Nuclear radiation exposure. - Devices will be exposed to the neutron level specified below over a time period not to exceed five (5) minutes. This exposure will be conducted with the devices in a non-operating, non-biased condition and at a temperature not to exceed 40°C. Devices shall not experience temperatures in excess of 40°C prior to evaluation testing. Evaluation will be conducted in such a manner that no device will be operated for more than two (2) minutes prior to completion of the sub-group tests. These precautions are necessary to reduce the effects of high temperature annealing of the radiation induced damage.

10^{13}n/cm^2, 1 MeV equivalent (Si)

10^4 rads (Si) gamma

4.6.13 Junction temperature. - The junction temperature shall be determined as follows: The breakdown voltage of the diode shall be measured at 40°C intervals between 20°C and 200°C in accordance with method 4021 of MIL-STD-750. The breakdown voltage shall be that voltage corresponding to a reverse current of 1 mA. The diode shall then be biased under pulsed conditions in a lossy circuit to suppress oscillations thus making input power equivalent to dissipated power. Pulse width shall be sufficient (about 1 msec) for the diode to reach thermal equilibrium. The diode shall then be pulsed down to a current of 1 mA and breakdown voltage shall be measured. The pulse-down duration shall be short (several *microseconds*) to prevent cooling of the diode. From this data thermal resistance of the diode shall be determined. The junction temperature of a diode under operating conditions shall be determined from its power input, power output and thermal resistance.

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery. - Packaging and marking shall be in accordance with the contract.

6. NOTES - None.

TABLE I - GROUP A INSPECTION

$T_A = 25 \pm 3^{\circ}C$ unless otherwise specified

Test	Method	Symbol	Min	Max	Units
Subgroup 1					
Oscillator Frequency	4.6.9	fo			
Diode Type 1			9	11	GHz
Diode Type 2			14	16	GHz
Oscillator output power	4.6.8	Po			
Diode Type 1			3.5		W-CW
Diode Type 2			2.5		W-CW
Oscillator efficiency (RF-DC)	4.6.7	η	20		%
Junction Temp	4.6.13	T_j		200	°C
Subgroup 2					
Mechanical tuning	4.6.3	Δf_{mech}	± 250		MHz
Subgroup 3					
AM Noise	4.6.1	$(N/S)_{AM}$		-115	dB
FM Noise	4.6.2	Δf_{rms}		50	Hz
Subgroup 4					
DC Bias voltage	4.6.10	V_o		70	v
DC Bias current	4.6.11	I_o		500	ma
Subgroup 5					
External Q	4.6.4	Q_{ext}		200	

TABLE II GROUP B INSPECTION

Test	MIL-STD-750 Method	Details	Min	Max	Units
Subgroup 1					
Shock	2016	Non-operating; 500G, $t = 1.0$ msec, X_1, Y_1, and Z_1 orientation			
Vibration, Variable Freq.	2056	Non-operating; 20G, 50 to 2000 Hz.			
Constant acceleration	2006	Non-operating; 20,000G min, X_1, Y_1 and Z_1 orientation			
Hermeticity	1071	Test Condition H- Traces Gas Fine Leak (Helium)			
End point measurements; Table I, Subgroup 1					
Subgroup 2					
Nuclear radiation exposure	4.6.12				
End point measurements: Table I, Subgroup 1					
Subgroup 3					
Storage life (non-operating)	4.6.5				
Subgroup 4					
Operating life	4.6.6				

TABLE III OPERATING REQUIREMENTS

Ambient Temperature Range: -40°C to 65°C

Diode Type 1

Oscillator frequency	10.0 GHz ± 1.0 GHz
Oscillator output power	3.5 W-CW, min.
Oscillator efficiency (RF-DC)	20% min
Junction Temperature	200°C max

Diode Type 2

Oscillator frequency	15.0 GHz ± 1.0 GHz
Oscillator output power	2.5 W-CW, min
Oscillator efficiency (RF-DC)	20% min
Junction Temperature	200°C max

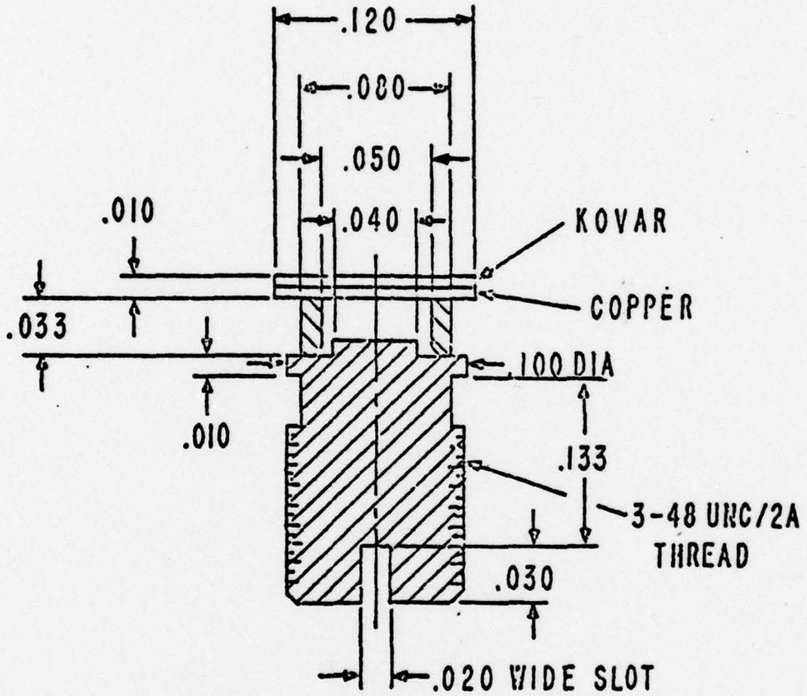


FIGURE 1

CERAMIC-TO-METAL MICROWAVE DIODE PACKAGE

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

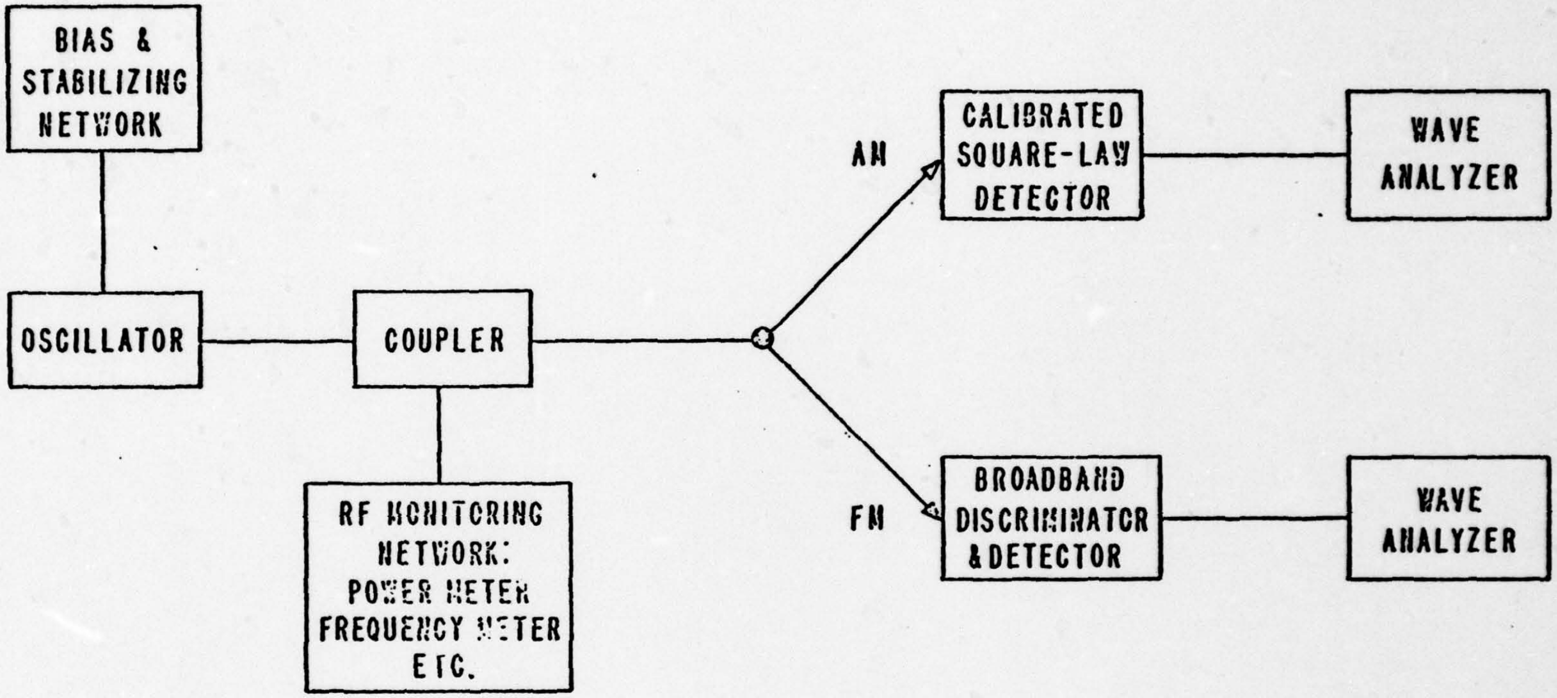


FIGURE 2

AM & FM NOISE MEASUREMENT SYSTEM (SCHEMATIC)

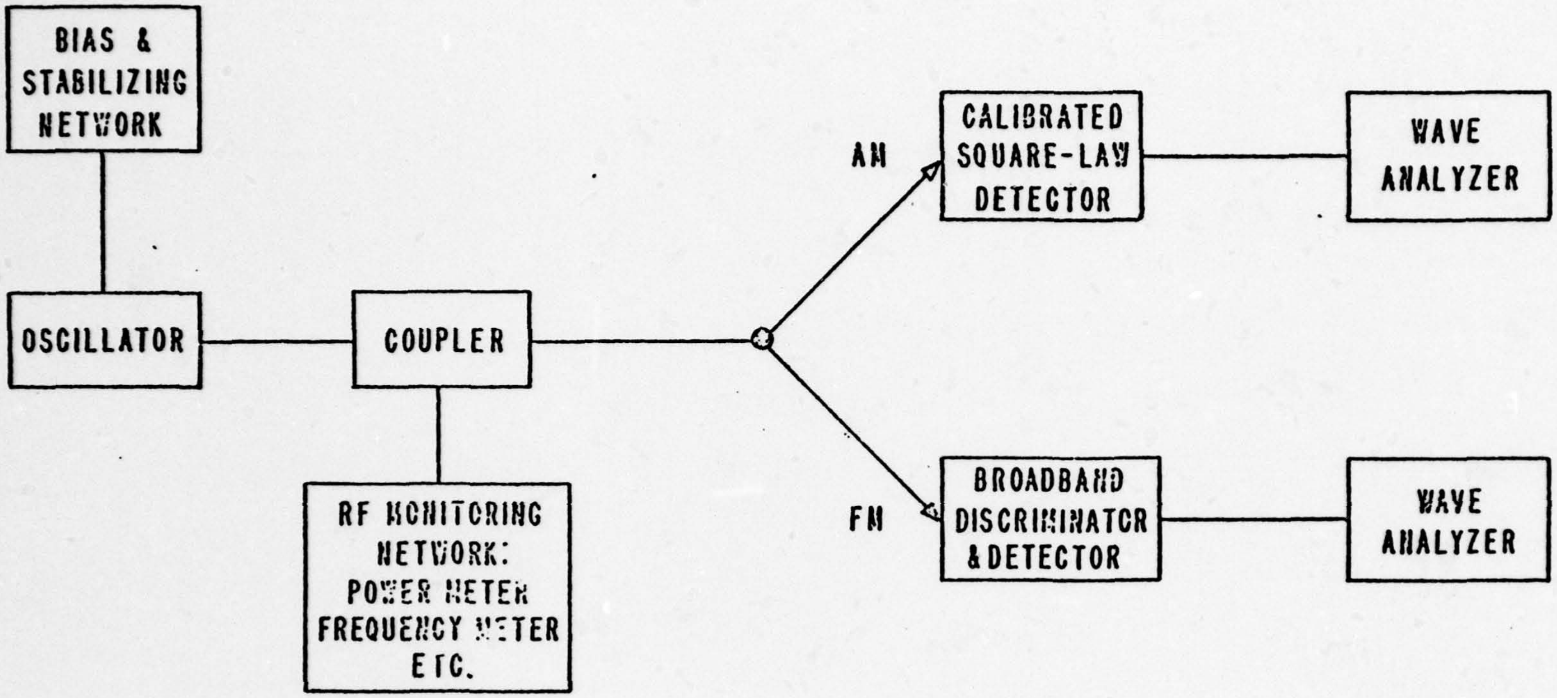


FIGURE 2

AM & FM NOISE MEASUREMENT SYSTEM (SCHEMATIC)

DISTRIBUTION LIST

\# CY

Commander 1
Rome Air Development Center
Griffiss Air Force Base
ATTN: (EMERR) Mr. L. Gubbins
Rome, New York 13440

Commander 1
Air Force Materials Laboratory
ATTN: MATE (Ms. E. Torrance)
Electronic Branch
Wright-Patterson Air Force Base
Dayton, Ohio 45433

Advisory Group on 2
Electron Devices
201 Varick Street, 9th Floor
New York, New York 10014

Commander 2
US Army Electronics Command
ATTN: DRSEL-PP-I-PI-1
Fort Monmouth, NJ 07703

NASA Scientific & 2
Tech Information Facility
PO Box 8757
Baltimore/Washington Int'l Airport
Maryland 21240

Commander 2
US Naval Air Development Center
ATTN: Library
Johnsville, Warminster, PA 18974

\# CY

Commander 1
Rome Air Development Center
Griffiss Air Force Base
ATTN: (EMERR) Mr. Regis C. Hilow
Rome, New York 13440

AFAL (AVTA) 1
Electronic Technology Division
ATTN: Mr. Robert D. Larson, Chief
Advanced Electronics Devices Branch
Wright-Patterson Air Force Base
Dayton, Ohio 45433

National Aeronautics & 1
Space Administration
George C. Marshall Space Flight
Center
ATTN: R-QUAL-FP
(Mr. Leon C. Hamiter)
Huntsville, Alabama 35812

NSSA-Manned Space Craft Center 1
Reliability and Flight Safety Division
ATTN: Library
Houston, Texas

Commander 2
US Army Material Development and
Readiness Command
ATTN: DRCRD-RS-PE-E, DRCRE-D
5001 Eisenhower Avenue
Alexandria, Virginia 22333

Chief 1
Naval Ship Systems Command
Department of the Navy
ATTN: Code 681A2b, Mr. L. Gumina
Room 3329
Washington, DC

DISTRIBUTION LIST

CY

Commander 1
Naval Electronics Laboratory
Center
ATTN: Library
San Diego, CA 92152

Commander 1
US Naval Research Laboratory
ATTN: G. Abraham 5205
Washington, DC 20390

Commander 1
Air Research & Development Command
ATTN: RDTCT
Andrews Air Force Base
Washington, DC

Avantek 1
ATTN: Mr. Thielan
3001 Copper Road
Santa Clara, CA 95051

American Electronics Laboratory 1
Richardson Road
Colmar, PA

Centralab Semiconductor 1
4501 North Arden Drive
El Nonte, CA 91734

Commander 1
US Army Research Office
ATTN: DRXRO-IP
PO Box 12211
Research Triangle Park
North Carolina 27709

#CY

Commander 1
Department of the NAVY, ELEX 05143A
ATTN: A. H. Young
Electronics System Command
Washington, DC 20360

Commander 1
Defense Electronics Supply Center
Directorate of Engineering &
Standardization
ATTN: (DESC-ECS) Mr. N. A. Hauck
Dayton, Ohio 45401

Amelco Semiconductor 1
PO Box 1030
Mountain View, CA 94042

AIL 1
ATTN: Mr. Lou Ciaciulli
Commack Road
Deer Park, LI., New York

Alpha Industries, Inc. 1
20 Sylvan Road
Woburn, MA 01801

Rockwell International 1
Collins Radio Group
ATTN: Dr. Cheng Wen
MS 406-246
Dallas, Texas 75207

Fairchild Semiconductor Division 1
Fairchild Camera & Instrument Corp
ATTN: Mr. Robert Skurko
313 Fairchild Drive
Mountain View, CA 94040

DISTRIBUTION LIST

	# CY
Sanders Associates, Inc. ATTN: Microwave Department 95 Canal Street Nashua, NH 03060	1
Western Electric ATTN: Mr. R. Moore Marion & Vine Street Laureldale, PA	1
Hughes Aircraft Corporation ATTN: Dr. Bruce Crammer 3100 West Lomita Boulevard Torrance, CA 90509	1
Commander US Army Missile Command Redstone Scientific Info. Center ATTN: Chief, Document Section Redstone Arsenal, AL 35809	1
General Instrument Corp. Semiconductor Products Group 600 West John Street Hicksville, Long Island, NY 11802	1
Micro-Electronics Laboratory Hughes Aircraft Company 500 Superior Avenue Newport Beach, CA 92663	1
KSC Semiconductor Corp. ATTN: Mr. S. Cudletz, President KSC Way (Katrina Road) Chelmsford, MA 01824	1

	#CY
Texas Instruments Semiconductor Components Div. ATTN: Semiconductor Library PO Box 5012 Dallas, Texas	1
Varian Associates Solid State West ATTN: F. E. Rosztoczy 611 Hansen Way Palo Alto, CA 94303	1
Texas Instruments PO Box 5936, MS 105 Dallas, Texas 75222 ATTN: Central Research Labs.	1
General Motors Corporation Delco Radio Division ATTN: Box 1104 Kokomo, IN 46901	1
Honeywell, Incorporated Semiconductor Products 2747 Fourth Avenue Minneapolis, MN 55408	1
IBM Components Division ATTN: Mr. Al Kran East Fishkill, Rt. 52 Hopewell Junction, NY 12533	1
Arthur D. Little Acorn Park ATTN: Dr. H. Rudenberg 15/206 Cambridge, MA 02140	1

DISTRIBUTION LIST

CY

Commander 12
Defense Documentation Center
ATTN: DDC-TCA
Cameron Station, Building 5
Alexandria, VA 22314

Director 1
Electronic Components Laboratory
ATTN: DRSEL-TL-1J
Fort Monmouth, NJ 07703

Commander 1
Harry Diamond Laboratories
ATTN: Mr. Horst Gerlach
(DRXDO-RAA)
Connecticut & VanNess St. N.W.
Washington, DC 20438

Director 4
Electronic Components Laboratory
ATTN: DRSEL-TL-1J (Wadergin)
Fort Monmouth, NJ 07703

Office of Defense Research & Engineering 1
Communications and Electronics
Room 3D1037
Washington, DC 20330

Motorola, Inc. 1
ATTN: Mr. J. LaRue
5005 East McDowell Road
Phoenix, AZ 85008

CY

General Electric Co. 1
No. Concourse Bldg.
Syracuse, NY 13212

Director 1
US Army Production Equipment Agency
ATTN: (Mr. C. McBurney)
Rock Island Arsenal
Rock Island, IL 61201

Commander 1
US Army Materiel Development & Readiness Command
ATTN: DRCPM-NXE-D (Dr. McClung)
Nike X Project Office
Redstone Arsenal, Alabama 35809

Commander 1
US Army Missile Command
ATTN: DRSMI-IEVL (Mr. Buckelew)
Building 4500
Redstone Arsenal, Alabama 35809

MSI Electronics Inc. 1
32-34 57th Street
Woodside, NY 11377

Northrop Corporation Laboratories 1
ATTN: Library 320-61
3401 West Broadway
Hawthorne, CA 90250

DISTRIBUTION LIST

CY

Raytheon Company 1
Semiconductor Operation
ATTN: Mr. S. Weisner
350 Ellis Street
Mountain View, CA 94040

Sprague Electric Company 1
ATTN: Mr. W. C. Donelan
87 Marshall Street
North Adams, MA 01247

US Army Missile Command 1
ATTN: DRSMI-RGP
(Mr. Victor Ruwe)
Redstone Arsenal, AL 35805

Department of Defense 1
Deputy for Science & Technology
Ofc Assist Sec Army (R&D)
Washington, DC 20310

CY

Dr. Robert H. Rediker 1
Massachusetts Institute of
Technology
Building 13-3050
Cambridge, MA 02139

Raytheon Company 1
ATTN: Dr. S. F. Paik
130 Second Avenue
Waltham, MA 02154

Bell Laboratories 1
Whippany Road
ATTN: M. A. Rello, Library
Whippany, NJ 07981