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MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING HIGH EFFICIENCY, HIGH POWER GALLIUM ARSENIDE READ-TYPE IMPATT DIODES

SEVENTH QUARTERLY PROGRESS REPORT

1 January 1977 to 31 March 1977

CONTRACT NO. DAAB07-75-C-0045

Prepared By

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ECOM
UNITED STATES ARMY ELECTRONICS COMMAND · FORT MONMOUTH, N.J.

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Group B testing of the confirmatory sample diodes was completed during the period, ending that phase of the program. All devices tested met specifications. Data is included herein.

The Read profile wafers for the pilot production diodes were fabricated and met specifications. They were delivered to the production line. Wafer characterization data is included herein,

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as well as evaluation data on the first two wafers subsequent to sample diode assembly on the production line.

The fifth X-band life test was completed. The sixth X and Ku-band life tests were also completed. Results are discussed herein.

MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING HIGH EFFICIENCY, HIGH POWER GALLIUM ARSENIDE READ-TYPE IMAPTT DIODES

SEVENTH QUARTERLY PROGRESS REPORT

1 January 1977 to 31 March 1977

CONTRACT NO. DAAB07-75-C-0045

The object of this program is to develop a capability to manufacture High Efficiency, High Power Gallium Arsenide IMPATT Diodes meeting the description and specifications of Section F of the contract and the requirements of SCS-481.

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PURPOSE

The objective of this program is to establish a capability to manufacture high-efficiency, high-power Gallium Arsenide IMPATT diodes at specified rates and yields. There are two diode types; one at X-band, and one at Ku-band which have the nominal characteristics listed below.

	X-Band	Ku-Band
Operating Frequency (GHz)	10.0 ±1.0	15.0 ±1.0
Power Output (Watts)	3.5 min.	2.5 min.
Conversion Efficiency (%)	20 min.	20 min.
Operating Junction Temperature (^{o}C)	200 max.	200 max.

Engineering effort is to be directed toward establishing production processes for both Gallium Arsenide epitaxial wafers and diode fabrication and test. The wafers are to meet the material characterization testing as specified, and the diodes must meet the detailed performance requirements outlined in SCS-481.

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1.0 INTRODUCTION

Results of Group A testing on the confirmatory sample diodes were presented in the report covering the prior period. During the present period, the Group B testing was completed. The testing was successful with the exception of two diodes lost during end-point testing subsequent to nuclear irradiation. This was due to testing error as discussed in this report.

Authorization to proceed to the pilot production phase was received from ECOM. The Read-profile wafers were grown and delivered to the production line. Six wafers of each type (X-band and Ku-band) had been scheduled for this activity, and this quantity was delivered. The wafers were accepted by incoming inspection, and some were committed for fabrication into dice. Sample diodes fabricated from the first two wafers met specifications. Production of the X-band diodes has, therefore, been initiated.

The operating life test program is continuing. During the period, the fifth X-band life test was completed and there were no failures. The sixth X-band and the sixth Ku-band tests were also completed without diode failures. Experience gained in tuning the cavities and corrections to the life test equipment, as discussed in several earlier reports, has resulted in greatly improved results in recent tests compared to those completed earlier in the program.

2.0 RESULTS AND ACCOMPLISHMENTS

2.1 Results of Confirmatory Sample Testing

The complete Group A testing on the confirmatory samples was performed during the prior period, and data was included in the Sixth Quarterly Progress Report. During the present period, the Group B testing was completed. The devices tested met all of the specifications with the exception of two devices which failed during end-point testing after exposure to nuclear irradiation. The failures were due to operator error during retest caused by improper tuning sequence. The other devices subjected to the same test showed no performance degradation, verifying that the devices are resistant to nuclear irradiation. Twenty-two each of X-band and Ku-band devices were delivered. The remaining three devices of each type are radioactive and are stored at a Raytheon facility. They are available for inspection or test. An X-band and a Ku-band test cavity were delivered with the confirmatory sample diodes.

The Group B testing consisted of the following sequence of tests:

1. Operating Life Test (9 diodes of each type)

	X-Band	Ku-Band	
Oscillator Frequency	10.0 ±1.0	15.0 ±1.0	GHz
Oscillator Output Power (min)	3.5	2.5	Watts
Oscillator Efficiency (min)	20	20	%
Junction Temperature (max)	200	200	^{o}C
Ambient Temperature	25 ±3	25 ±3	^{o}C
Test Duration	1000	1000	Hours

2. Storage Life - Nonoperating (9 diodes of each type)

Ambient Temperature:	200°C
Test Duration:	1000 Hours

3. Nuclear Radiation Exposure (3 diodes of each type)

Power Level:	10 KW
Exposure Time:	7 Minutes
Gamma Exposure:	1.2×10^5 rads (Silicon)
Neutron Exposure:	1.04×10^{13} n/cm^2, 1 Mev Si damage equivalent

4. Shock, Vibration, Accelerating, Hermeticity (4 diodes of each type)

Shock MIL-STD-750, Method 2016

500 G, 1 ms
1/2 Sine Pulse 3 planes
5 shocks per plane

Vibration MIL-STD-750, Method 2056

20 G
50 - 2000 - 50 Hz
3 planes - 4 cycles/plane
3 minutes/cycle

Acceleration MIL-STD-750, Method 2006

20,000 G
3 planes
1 minute/plane

Hermeticity MIL-STD-750, Method 1071, Condition H

4 Hours @ 60 psi Helium
1×10^{-8} atm cc/sec. maximum

Test results for the Group A and Group B testing are included in Appendix A.

2.2 Pilot Production Run

The specification for the gallium arsenide wafers which was drafted during the course of this program and revised several times to better define the wafer characteristics was finalized during the confirmatory sample phase of the program. Wafers for the pilot run were grown to these identical specifications based upon successful performance from the confirmatory samples. The specification is included in Appendix B of this report.

Six X-band wafers and six Ku-band wafers were grown and delivered for fabrication of the pilot run diodes. A listing of the key wafer characteristics is given in Table 2-1. The wafers were subjected to a quality control incoming inspection procedure prior to acceptance for production line use and all of the wafers were accepted. All of the wafers met the requirement of 80% usable area, the usable area being at least 3.0 cm^2. Actually, 100% of the wafer surface was considered device grade material. Two X-band and two Ku-band wafers were committed for dice fabrication. The balance was held in storage for future use.

The two X-band wafers have been completely processed. A sample of the resulting dice was selected for diode assembly and electrical evaluation. The results are given in Table 2-2 for wafer 41415B and in Table 2-3 for wafer 41410C. It may be seen by comparison of this data with the data in Appendix A (for the confirmatory samples) that the pilot run wafers are quite similar to the confirmatory sample wafers.

Characteristics profile maps were made for each of the wafers as described in previous reports. A map of the Breakdown Voltage for each (Figures 2-1 and 2-2) is sufficient to show the uniformity on the wafers. This further verifies that at least

Table 2-1

Read Wafers Supplied for Pilot Run

Wafer No.		Buffer	Transit		Spike				Contact			
Series	Run	W (μm)	W (μm)	$n \times 10^{16}$ (cm^{-3})	W (nm)	$n \times 10^{16}$ (cm^{-3})	$Q^* \times 10^{12}$ (c-cm^{-3})	V^* (volts)	x_p (μm)	x_o (μm)	$n_o \times 10^{16}$ (cm^{-3})	Band
414	27A	4.8	4.2	1.1	52	40	2.4	7.7	0.24	0.19	7	Ku
	28B	4.3	3.9	1.2	52	36	2.2	7.3	0.23	0.19	8	Ku
	35B	4.2	4.0	1.0	41	55	2.4	8.3	0.23	0.19	10	Ku
	36A	4.5	4.3	1.1	42	55	2.5	8.6	0.24	0.20	10	Ku
	36B	4.5	4.3	1.0	44	52	2.4	8.4	0.25	0.20	10	Ku
	37B	4.2	3.9	1.0	41	49	2.3	7.2	0.23	0.19	11	Ku
414	10A	5.1	5.1	0.50	50	35	2.3	8.2	0.23	0.19	9	X
	10C	5.2	5.3	0.52	50	33	2.3	8.8	0.25	0.20	7	X
	11A	4.9	4.9	0.52	50	36	2.4	8.3	0.24	0.19	8	X
	13A	4.7	4.6	0.53	50	33	2.3	7.5	0.23	0.18	9	X
	15A	4.8	4.8	0.49	50	34	2.4	8.2	0.24	0.19	8	X
	15B	4.8	4.8	0.48	50	34	2.4	8.1	0.24	0.18	8	X

Table 2-2

Data Sheet - MS50371
SCS-481 Type 1
X-Band Diode

CHARACTERISTIC		B_V	C_{TO}	C_{TVR}	V_R	R_{TH}	P_o	F_o	V_{OP}	I_{OP}	η	Mech. Tun.	HAT	ΔT_j	$Q_{Ext.}$	ΔF_{RMS}	$(N/S)_{AM}$
TEST CONDITION		Ima	V=O	$V = V_R$													
UNITS		Volts	P_F	P_F	Volts	°C/W	Watts	GHz	Volts	ma	%			°C		Hz	db
LIMITS	MIN.						3.5	9			20	±250					
	MAX.							11	70	500				200	200	50	115
Serial No.	Diode I.D. Number																
	41415B-A-8	35.0		1.72	25	14.3	3.5	9.5	57.2	270	22.7		400	196			
	9	38.5		1.89	25	14.3	3.5	9.6	57.3	270	22.6		400	196			
	10	43.0		1.90	25	13.3	3.5	9.5	58.1	265	22.7		400	183			
	11	44.0		1.75	25	--	3.5	9.7	57.3	280	21.8		400	---			
	12	42.5		1.95	25	13.1	3.5	9.5	57.1	260	23.6		400	174			
	14	38.8		1.85	25	14.3	3.5	9.6	55.8	260	24.1		400	182			
	15	40.0		1.78	25	13.8	3.5	9.7	55.8	260	24.1		400	177			
	16	43.5		1.55	25	14.1	3.5	10.1	56.4	240	25.9		400	167			
	17	40.1		1.81	25	14.0	3.5	9.8	56.6	260	23.8		400	182			
	18	43.2		1.87	25	13.3	3.5	9.6	56.7	260	23.7		400	175			
	19	44.4		1.88	25	13.0	3.5	9.7	57.4	260	23.5		400	174			

Table 2-3

Data Sheet - MS50371
SCS-481 Type 1
X-Band Diode

CHARACTERISTIC		B_V	C_{TO}	C_{TVR}	V_R	R_{TH}	P_o	F_o	V_{OP}	I_{OP}	η	Mech. Tun.	HAT	ΔT_j	$Q_{Ext.}$	ΔF_{RMS}	$(N/S)_{AM}$
TEST CONDITION		Ima	V=O	$V = V_R$													
UNITS		Volts	P_F	P_F	Volts	°C/W	Watts	GHz	Volts	ma	%			°C		Hz	db
LIMITS	MIN.						3.5	9			20	± 250					
	MAX.							11	70	500				200	200	50	115
Serial No.	Diode I.D. Number																
	41410C-A-2	42.8		1.75	25	15.2	3.5	10.0	57.4	235	25.9		380	177			
	3	42.0		1.80	25	15.1	3.5	10.0	57.0	245	25.1		380	183			
	5	42.0		1.86	25	15.7	3.5	10.0	55.5	245	25.7		380	184			
	6	42.3		1.84	25	16.1	3.5	10.0	56.7	245	25.2		380	192			
	7	42.8		1.87	25	16.1	3.5	10.0	57.1	240	25.5		380	189			
	8	42.1		1.89	25	14.8	3.5	10.0	57.1	250	24.5		380	184			
	9	40.8		1.84	25	16.8	3.5	10.0	56.6	245	25.2		380	199			

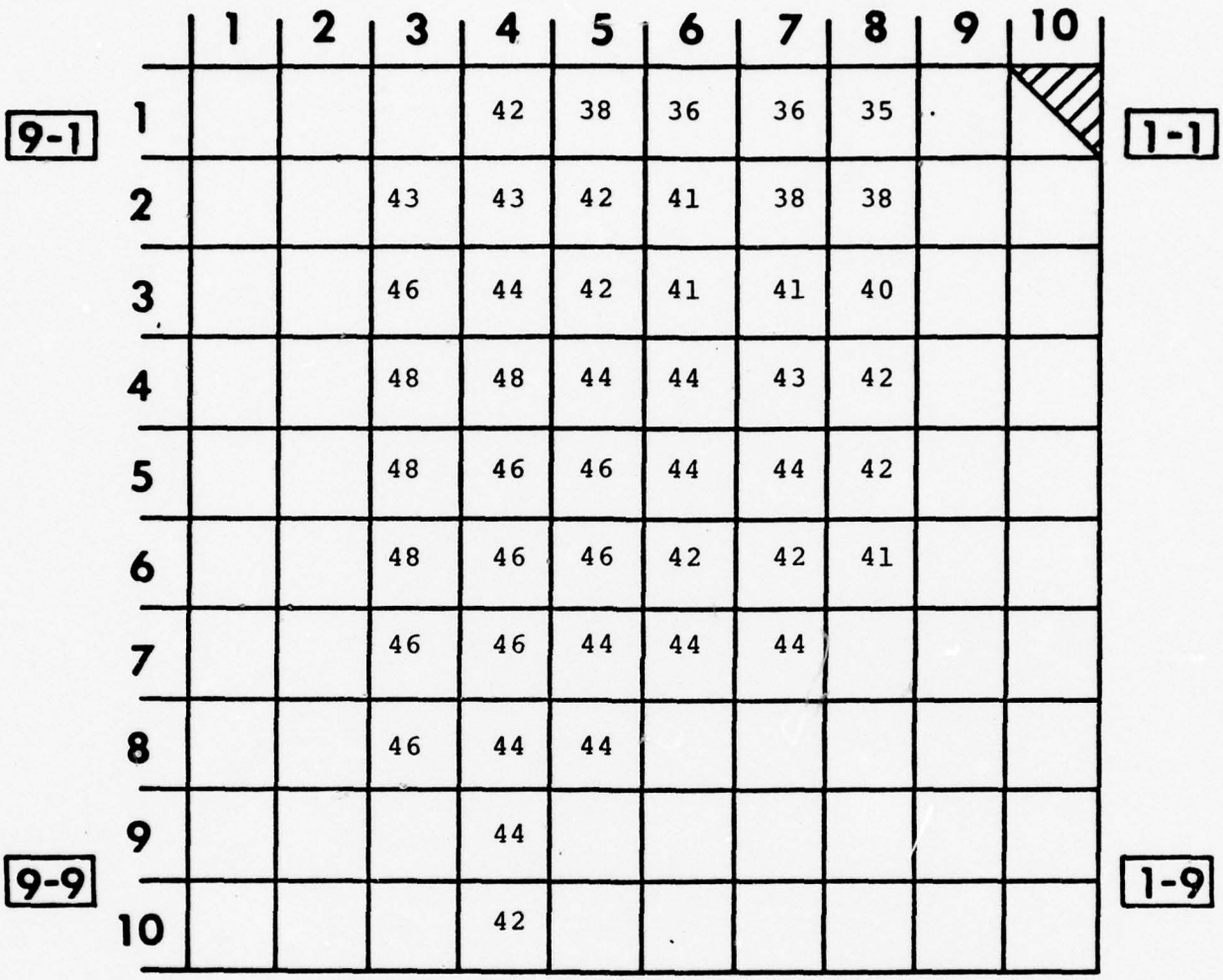


Figure 2-1 Breakdown Voltage Profile - Wafer 41415B

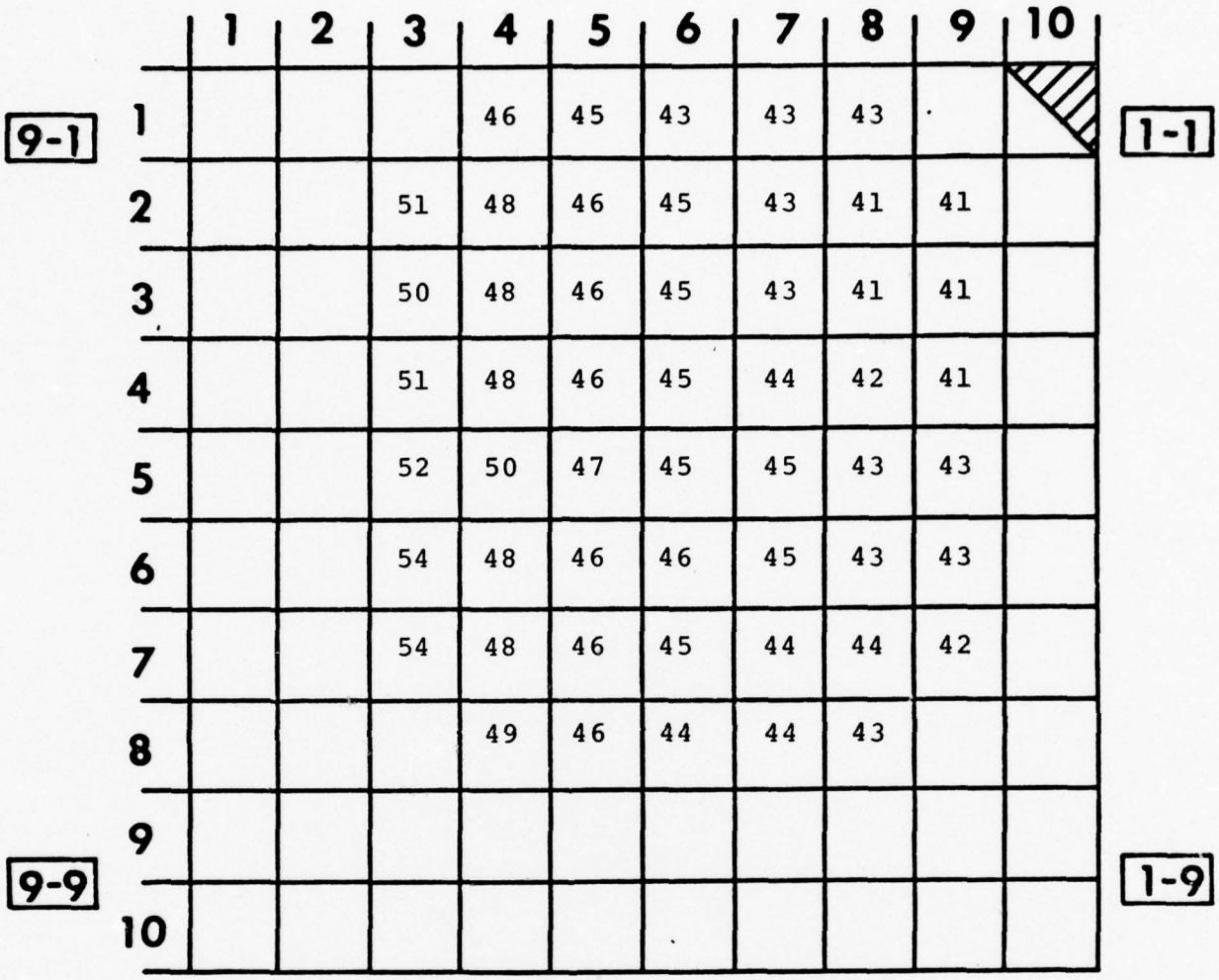


Figure 2-2 Breakdown Voltage Profile - Wafer 41410C

80% of the wafer area was usable. The uniformity of breakdown voltage depicted is a vast improvement over wafers evaluated early in the program.

Assembly of the pilot run diodes has begun using dice from these wafers, and other wafers are being processed.

3.0 DIODE OPERATING LIFE TESTS

3.1 Summary of Requirements

Operating life test requirements of this program specify that diodes periodically be subjected to 1000 hour life tests while operating as oscillators. The tests are to be initiated at the end of the first quarter and repeated quarterly for a total of seven (7) tests. The sample size for each test is five (5) diodes of each type randomly selected from a corresponding wafer. In addition, nine (9) diodes of each type are to be life tested for 1000 hours as a part of the Group B quality conformance inspection at the time of confirmatory sample testing and again at the time of pilot run sample testing.

The testing is to be conducted at an ambient temperature of 25°C with the test cavity temperature held below 75°C and the diode junction temperature not exceeding 200°C. To identify failures, the power output must be monitored with failures defined by a 25% decrease in the power output of a diode relative to its initial value. The Group B life testing will be performed with the diode operating within its rated power output, frequency, efficiency, and junction temperature specifications. The quarterly tests will be conducted in such a way as to demonstrate progress toward successfully meeting these test requirements.

Two operating life test stations, one for X-band diodes and one for Ku-band diodes, were designed and constructed to meet the operating life test requirements described. A description of the equipment was presented in the first quarterly report.

3.2 Status of Operating Life Test Program

The following is a summary of the results obtained to date during the operating life test program. Only one diode has

failed in the last three tests, and this was felt to be a circuit problem rather than a defective diode.

	X-Band		Ku-Band	
Test Number	Qty. Tested	Failures	Qty. Tested	Failures
1	5	1	5	1
2	5	1	5	5*
3	5	1	5	0
4	5	0	5	0
5	5	0	5	1
6	5	0	5	0

* System malfunction caused catastrophic failure of all devices.

3.3 Results of Tests

During the current period, the fifth X-band life test was completed and the sixth X-band and Ku-band tests were also completed. During the fifth X-band life test, the event log indicates several interruptions due to power supply shutdown. This was caused by an apparent malfunction of the circuit breaker switch. The power was quickly reset and there was no damage to the devices under test. Bias circuit oscillations were noted on one of the Ku-band diodes during the sixth test. The cavity tuning was adjusted slightly to correct the condition. There was no damage to the diode.

Upon completion of the tests, the diodes were retested for power output, efficiency, and operating frequency. In all cases, the original data was very closely duplicated.

The data for the fifth X-band test is given in Table 3-1. The data for the sixth X-band and Ku-band tests is given, respectively, in Tables 3-2 and 3-3.

Table 3-1

Fifth Operating Life Test Data - X-Band Diodes

	Diode No.	Rack Position	Resistance (^{o}C/W)	Junction Temp. (^{o}C)	Operating Voltage (Volts)	Operating Current (mA)	Power Out (Watts)	Freq. (GHz)	Dissipated Power (Watts)
Initial	41320BC2-13	1	13.5	179	57.2	260	3.5	9.4	11.4
Final					58.0	260	3.5	9.7	
Initial	41320BC2-2	2	14.3	188	57.0	260	3.5	9.7	11.3
Final					57.4	260	3.5	9.6	
Initial	41320BC2-1	3	14.5	188	55.7	265	3.5	9.7	11.3
Final					55.8	265	3.8	9.7	
Initial	41320BC2-3	4	14.0	186	56.8	265	3.5	9.6	11.6
Final					56.6	260	3.5	9.6	
Initial	41320BC2-5	5	14.2	182	55.8	260	3.5	9.3	11.0
Final					57.1	260	3.75	9.65	

Specification: P_o = 3.5 W minimum

f_o = 9-11 GHz

η = 20% minimum

T_j = 200^{o}C maximum

Table 3-2

Sixth Operating Life Test Data - X-Band Diodes

	Diode No.	Rack Position	Resistance (^{o}C/W)	Junction Temp. (^{o}C)	Operating Voltage (Volts)	Operating Current (mA)	Power Out (Watts)	Freq. (GHz)	Dissipated Power (Watts)
Initial	41319BA-5	5	12.3	153	56.6	245	3.5	9.35	10.4
Final					56.6	242	3.9	9.36	
Initial	41319BB-6	6	15.5	190	56.4	250	3.5	9.31	10.6
Final					56.8	250	3.5	9.31	
Initial	41319BB-8	7	15.6	190	55.4	255	3.5	9.30	10.6
Final					55.7	252	3.8	9.30	
Initial	41319BB-14	8	14.0	183	54.8	270	3.5	9.52	11.3
Final					55.4	270	3.5	9.54	
Initial	41319BB-5	9	12.5	185	52.5	310	3.5	9.22	12.8
Final					52.4	305	3.5	9.22	

Specification: P_o = 3.5 W minimum

f_o = 9-11 GHz

η = 20% minimum

T_j = 200^{o}C maximum

Table 3-3

Sixth Operating Life Test Data - Ku-Band Diodes

	Diode No.	Rack Position	Resistance (^{o}C/W)	Junction Temp. (^{o}C)	Operating Voltage (Volts)	Operating Current (mA)	Power Out (Watts)	Freq. (GHz)	Dissipated Power (Watts)
Initial	41328AB2-6	5	18.4	199	39.3	305	2.5	14.30	9.5
Final					39.4	302	2.5	14.29	
Initial	41328AB2-14	6	18.7	199	39.4	300	2.5	14.35	9.3
Final					39.3	302	2.5	14.30	
Initial	41328AC1-1	7	18.2	194	38.7	305	2.5	14.15	9.3
Final					38.3	305	2.5	14.13	
Initial	41328AC1-9	8	18.3	198	38.6	310	2.5	14.13	9.5
Final					38.5	315	2.5	14.10	
Initial	41328AC1-21	9	17.9	196	40.2	300	2.5	14.14	9.6
Final					41.0	290	2.5	14.18	

Specification: P_o = 2.5 W minimum

f_o = 14-16 GHz

η = 20% minimum

T_j = 200^{o}C maximum

4.0 CONCLUSIONS

The confirmatory sample phase of the program was successfully concluded.

Fabrication of the pilot run diodes has begun, and results to date are good.

The sixth life test has been completed with no failures.

5.0 PROGRAM FOR NEXT INTERVAL

During the next interval, the pilot run is scheduled to be completed. As part of the effort, a demonstration of the yields and production rates will be made for ECOM personnel. The seventh life test will be run concurrently with the pilot run assembly effort.

6.0 IDENTIFICATION OF PERSONNEL

Michael Benedek Engineer - Production Processes	144 Hours
Henri Chalifour Manager - Diode Production	120 Hours
Paul Coletti Supervisory Engineer - Dice Fabrication	112 Hours
William Labossier Research Assistant - Epitaxial Wafer Growth	88 Hours
Samuel R. Steele Senior Scientist - Manager Materials Laboratory	8 Hours
Basil Vafiades Programs Manager - MMTE Program Manager	18 Hours
Production Technicians	155 Hours
Research Technicians	139 Hours
Machinists	20 Hours

APPENDIX A

TEST RESULTS - CONFIRMATORY SAMPLE DIODES

DATA SHEET
MS50371
SCS-481 TYPE 1

CHARACTERISTIC		B_V	C_{TO}	C_{TVR}	V_R	R_{TH}	P_O	F_o	V_{OP}	I_{OP}	η	Mech. Tun.	HAT	T_J	$Q_{Ext.}$	ΔF_{RMS}	(N/S)AM
TEST CONDITION		Ima	V=O	$V=V_R$													
UNITS		Volts	P_F	P_F	Volts	°C/W	Watts	GHz	Volts	ma	%			°C		Hz	db
LIMITS	MIN.						3.5	9			20	± 250					
	MAX.							11	70	500				200	200	50	115
Serial No.	Diode I. D. Number																
81	41319B-A-1	31.7	23.1	1.88	25	13.1	3.5	9.93	49.5	270	26.2	ok	380x2	129	< 200	.43	-144
82	41319B-A-3	43.9	23.1	1.73	25	13.0	3.5	9.98	55.05	222	28.6	ok	380x2	114	< 200	.68	-144
83	41319B-A-5	47.0	25.9	1.88	25	12.3	3.5	9.94	57.4	230	26.5	ok	380x2	120	< 200	.86	-144
84	41320B-BB-14	40.5	26.4	1.88	25	12.7	3.5	9.84	55.9	246	25.5	ok	380x2	130	< 200	.97	-144
85	41319B-A-8	49.3	25.5	1.87	25	14.9	3.5	9.9	59.2	235	25.2	ok	380x2	155	< 200	.86	-145
86	41319B-A-16	46.2	24.9	1.90	25	15.2	3.5	9.82	58.5	235	25.5	ok	380x2	155	< 200	.86	-142
87	41319B-A-18	47.6	25.1	1.89	25	13.5	3.5	9.8	58.6	250	23.9	ok	380x2	150	< 200	.86	-145
88	41319B-B-3	39.5	23.6	1.90	25	15.9	3.5	9.91	52.1	245	27.4	ok	380x2	147	< 200	.68	-143
89	41319B-B-5	35.0	24.0	1.89	25	12.5	3.5	9.98	50.9	255	27.0	ok	380x2	143	< 200	.31	-144
90	41319B-B-6	45.5	25.8	1.88	25	15.5	3.5	9.83	55.4	265	23.8	ok	380x2	174	< 200	.68	-146
91	41319B-B-8	45.8	26.1	1.88	25	15.6	3.5	9.85	55.5	240	26.3	ok	380x2	153	< 200	.54	-145
92	41319B-B-14	43.9	23.5	1.85	25	14.0	3.5	9.79	56.8	240	25.7	ok	380x2	142	< 200	.77	-144
93	41319B-B-15	38.4	25.9	1.89	25	13.6	3.5	9.79	54.2	255	25.3	ok	380x2	141	< 200	.48	-145
94	41319B-B-16	47.0	25.8	1.85	25	15.3	3.5	9.88	57.5	240	25.4	ok	380x2	157	< 200	.48	-145
95	41319B-B-18	44.7	26.3	1.87	25	15.5	3.5	9.85	56.8	255	24.2	ok	380x2	170	< 200	.48	-145
96	41320B-AA-2	45.2	26.9	1.87	25	13.5	3.5	9.87	57.0	250	24.6	ok	380x2	145	< 200	.86	-142
97	41320B-AA-6	38.3	25.1	1.86	25	14.1	3.5	9.87	54.4	246	26.2	ok	380x2	139	< 200	.86	-143
98	41320B-AA-8	41.8	24.6	1.86	25	14.2	3.5	9.85	57.7	240	25.3	ok	380x2	146	< 200	1.08	-144
99	41320B-AA-10	39.1	25.2	1.87	25	15.0	3.5	9.92	54.1	255	25.4	ok	380x2	154	< 200	1.53	-146
100	41320B-AA-11	40.3	24.6	1.83	25	13.8	3.5	9.96	53.6	253	25.8	ok	380x2	139	< 200	.77	-145

DATA SHEET
MS50371
SCS-481 TYPE 1

HARACTERISTIC		B_V	C_{TO}	C_{TVR}	V_R	R_{TH}	P_O	F_o	V_{OP}	I_{OP}	η	Mech. Tun.	HAT	T_J	$Q_{Ext.}$	ΔF_{RMS}	(N/S)AM
EST CONDITION		Ima	V=O	$V=V_R$													
NITS		Volts	P_F	P_F	Volts	°C/W	Watts	GHz	Volts	ma	%			°C		Hz	db
IMITS	MIN.						3.5	9			20	± 250					
	MAX.							11	70	500				200	200	50	115
rial lo.	Diode I. D. Number																
.01	41320B-AA-12	47.1	26.7	1.85	25	13.9	3.5	9.91	58.9	245	24.3	ok	380x2	152	< 200	1.53	-141
.02	41320B-AA-13	41.5	20.5	1.86	25	14.8	3.5	9.95	58.5	235	25.5	ok	380x2	152	< 200	1.53	-147
.03	41320B-AA-17	44.2	21.1	1.93	25	14.1	3.5	9.87	58.7	235	25.4	ok	380x2	145	< 200	1.09	-143
.04	41320B-AA-19	37.8	25.2	1.91	25	14.3	3.5	10.00	53.8	250	26.0	ok	380x2	152	< 200	.68	-145
.05	41320B-AA-20	38.1	25.8	1.90	25	15.5	3.5	9.89	54.0	256	25.2	ok	380x2	162	< 200	1.08	-145

RAYTHEON

GROUP B INSPECTION
SCS-481 TYPE 1
X-BAND DIODES

SUBGROUP 1 Shock, Vibration, Acceleration, Hermeticity

CONDITIONS:

Shock	Vibration	Acceleration	Hermeticity
per MIL-STD-750 Method 2016	per MIL-STD-750 Method 2056	per MIL-STD-750 Method 2006	per MIL-STD-750 Method 1071
500G	20 G	20000 G	Test Condition H
1 ms	50-2000-50 Hz	3 Planes	4 Hours @ 60 lb He Pressure
1/2 Sine Pulse	3 Planes	1 Min/Plane	He-Leak Detector $<1 \times 10^{-8}$
3 Planes	4 Cycles/Plane		
5 Shocks/Plane	4 Min/Cycle		

CHARACTERISTIC		P_o		F_o		η		T_j	
UNITS		Watts		GHz		%		°C	
LIMITS	Min.	3.5		9		20			
	Max.			11				200	
END POINT		I	F	I	F	I	F	I	F
Serial No.	Diode I.D. Number								
81	41319B-A-1	3.5	3.5	9.93	9.96	26.2	26.7	154	151
82	41319B-A-3	3.5	3.5	9.48	10.02	28.6	28.5	140	140
99	41320B-AA-10	3.5	3.5	9.92	9.96	25.4	26.3	179	172
100	41320B-AA-11	3.5	3.5	9.96	9.96	25.8	26.6	164	158

Operator: [signature]

Date: 1-13-77

Q.C. Approved: [signature]

Date: 2.9.77

RAYTHEON

GROUP B INSPECTION
SCS-481 TYPE 1
X-BAND DIODES

SUBGROUP 2 Nuclear Radiation Exposure

CONDITIONS: Power Level - 10 KW

7 Min. Exposure

Gamma Exposure - 1.2×10^5 rads (Si)

Neutron Exposure - $1.04 \times 10^{13} n/cm^2$, 1 MeV Si Damage Equivalent (indicated by sulphur pellet dosimetry).

NOTES:

1 - The exposed devices are radioactive (Av^{198}) and they are being stored in a controlled access and storage area with Raytheon's flash X-ray facility.

2 - Device S/N AA was a control device; hence, it was not exposed to radiation.

CHARACTERISTIC		P_o		F_o		η		T_j	
UNITS		Watts		GHz		%		°C	
LIMITS	Min.	3.5		9		20			
	Max.			11				200	
END POINT		I	F	I	F	I	F	I	F
Serial No.	Diode I.D. Number								
AA	41319B-A-7	3.5	3.5	9.85	9.87	25.2	25.9	197	191
85	41319B-A-8	3.5	3.5	9.90	9.90	25.2	25.1	180	180
86	41319B-A-16	3.5	3.5	9.82	9.80	25.5	25.1	180	184
87 *	41319B-A-18	3.5	3.45	9.80	9.7	23.9	21.7	175	196

* ABOVE PERFORMANCE WAS OBTAINED PRIOR TO DEVICE "BURN-OUT". TO AVOID OVERHEATING, THE POWER TO THE DIODE WAS INCREASED TOO FAST AND TOO HIGH. THE BURN-OUT WAS TYPICAL OF OVER-DRIVEN DIODES; HENCE, NOT DUE TO THE RADIATION EXPOSURE.

Operator: [signature]

Date: 1/13/77

Q.C. ~~Approved~~ Witnessed: [signature]

Date: 1/13/77

RAYTHEON

GROUP B INSPECTION
SCS-481 TYPE 1
X-BAND DIODES

SUBGROUP 3 Storage Life

CONDITIONS:
- Nonoperating
- Ambient Temperature 200°C ±3°C
- Duration, 1040 Hours

CHARACTERISTIC		P_o		F_o		η		T_j	
UNITS		Watts		GHz		%		°C	
LIMITS	Min.	3.5		9		20			
	Max.			11				200	
END POINT		I	F	I	F	I	F	I	F
Serial No.	Diode I.D. Number								
88	41319B-B-3	3.5	3.5	9.91	9.96	27.4	26.9	172	176
93	41319B-B-15	3.5	3.5	9.79	9.86	25.3	25.1	166	167
94	41319B-B-16	3.5	3.5	9.88	9.91	25.4	25.2	182	184
95	41319B-B-18	3.5	3.5	9.85	9.85	24.2	25.0	195	188
96	41320B-AA-2	3.5	3.5	9.87	9.90	24.6	24.7	170	169
102	41320B-AA-13	3.5	3.5	9.95	9.88	25.5	26.2	177	171
103	41320B-AA-17	3.5	3.5	9.87	9.87	25.4	26.2	170	164
104	41320B-AA-19	3.5	3.5	10.0	10.0	26.0	25.3	177	183
105	41320B-AA-20	3.5	3.5	9.89	9.85	25.3	25.1	185	187

Operator: [signature]

Date: 1/26/77

Q.C. Approved: [signature]

Date: 2.9.77

RAYTHEON

GROUP B INSPECTION
SCS-481 TYPE 1
X-BAND DIODES

SUBGROUP 4 Operating Life

CONDITIONS:

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.
Ambient Temperature:	25 ±3°C

CHARACTERISTIC		P_o		F_o		η		T_j	
UNITS		Watts		GHz		%		°C	
LIMITS	Min.	3.5		9		20			
	Max.			11				200	
END POINT		I	F	I	F	I	F	I	F
Serial No.	Diode I.D. Number								
83	41319B-A-5	3.5	3.5	9.35	9.36	25.2	25.6	153	150
89	41319B-B-5	3.5	3.5	9.22	9.22	21.5	21.9	185	181
90	41319B-B-6	3.5	3.5	9.31	9.31	24.8	24.6	190	191
91	41319B-B-8	3.5	3.5	9.30	9.30	24.8	24.9	190	190
92	41319B-B-14	3.5	3.5	9.52	9.54	23.7	23.4	183	185
97	41320B-AA-6	3.5	3.5	9.70	9.70	23.9	23.0	182	190
98	41320B-AA-8	3.5	3.5	9.78	9.77	24.2	23.9	181	183
101	41320B-AA-12	3.5	3.5	9.34	9.33	22.5	22.5	192	192
84	41320B-BB-14	3.5	3.5	9.80	9.80	23.8	23.8	167	167
	-								

Operator: [signature]

Date: 1/26/77

Q.C. Approved: [signature]

Date: 2.9.77

RAYTHEON

IMPATT DIODE TEST CAVITY

TYPE	THX-8000		
SERIAL NUMBER	S/N-5		
HAT SIZE	380	**HAT STYLE**	Stepped
		DIODE	MS-50371 41319B-A-7

OPERATING DATA

VOLTAGE	60.2 V	**BREAKDOWN VOLTAGE** @ I_R = 1 mA	47.1 V
CURRENT	230 mA	**CAPACITANCE-C_{TO}**	24.3 pf
POWER OUTPUT	3.5 W-CW	**CAPACITANCE-C_{TVR}**	1.88 pf
FREQUENCY	9.58 GHz	@ V_R	25 V
EFFICIENCY	25.3		

DATA SHEET
MS50372
SCS-481 TYPE 2

CHARACTERISTIC		B_V	C_{TO}	C_{TVR}	V_R	R_{TH}	P_o	F_o	V_{OP}	I_{OP}	η	Mech. Tun.	HAT	T_J	$Q_{Ext.}$	ΔF_{RMS}	(N/S)AM
TEST CONDITION		Ima	V=O	V = V_R													
UNITS		Volts	P_F	P_F	Volts	°C/W	Watts	GHz	Volts	ma	%			°C		Hz	db
LIMITS	MIN.						2.5	14			20	±250					
	MAX.							16	70	500				200	200	50	-115
Serial No.	Diode I. D. Number																
106	41328A-B1-24	23.5	10.5	1.65	15	17.5	2.5	14.31	39.0	290	22.1	ok	190	179	<200	10.1	-136
107	41328A-B2-2	23.8	11.0	1.75	15	18.2	2.5	14.45	39.0	295	21.7	ok	190	189	<200	20.2	-144
108	41328A-B2-4	23.5	10.4	1.68	15	18.3	2.5	14.44	38.7	295	21.9	ok	190	188	<200	18.0	-145
109	41328A-B2-5	23.7	11.0	1.72	15	18.6	2.5	14.31	39.0	297	21.6	ok	190	194	<200	18.0	-147
110	41328A-B2-6	23.9	9.5	1.60	15	18.4	2.5	14.30	39.5	290	21.8	ok	190	190	<200	10.1	-148
111	41328A-B2-14	24.2	8.5	1.75	15	18.7	2.5	14.42	39.3	292	21.8	ok	190	193	<200	16.0	-146
112	41328A-C1-1	24.1	10.7	1.67	15	18.2	2.5	14.07	38.6	300	21.6	ok	190	190	<200	16.0	-147
113	41328A-C1-9	24.2	10.3	1.68	15	18.3	2.5	14.34	37.8	295	22.4	ok	190	183	<200	16.0	-143
114	41328A-C1-21	25.3	8.3	1.67	15	17.9	2.5	14.14	41.6	280	21.5	ok	190	188	<200	16.0	-148
115	41328A-C2-5	24.6	88.3	1.68	15	18.8	2.5	14.38	40.4	285	21.7	ok	190	195	<200	10.1	-159
116	41328A-C2-7	22.9	10.3	1.65	15	18.7	2.5	14.2	38.8	285	22.5	ok	190	186	<200	12.7	-144
117	41328A-C2-8	22.9	10.8	1.66	15	18.5	2.5	14.1	38.2	290	22.6	ok	190	183	<200	16.0	-146
118	41328A-C2-9	22.8	10.4	1.63	15	18.9	2.5	14.2	38.3	290	22.6	ok	190	187	<200	12.7	-145
122	81844M2-2-13	19.9	9.9	1.53	15	17.0	2.5	14.24	35.0	345	20.7	ok	190	188	<200	18.0	-140
123	81844M2-2-15	20.1	9.7	1.55	15	18.1	2.5	14.43	36.1	325	21.2	ok	190	193	<200	14.3	-148
124	81844M2-2-16	22.0	8.8	1.54	15	17.6	2.5	14.60	37.7	305	21.8	ok	190	183	<200	10.1	-152
125	81844M2-2-23	23.0	9.2	1.58	15	18.7	2.5	14.50	36.9	320	21.1	ok	190	200	<200	16.0	-138
126	81844M2-3-8	20.8	10.0	1.56	15	17.0	2.5	14.40	36.8	320	21.0	ok	180	185	<200	16.0	-146
127	81844M2-3-9	19.9	10.0	1.57	15	16.8	2.5	14.38	36.1	320	21.7	ok	190	177	<200	15.0	-146
128	81844M2-3-23	19.0	8.9	1.50	15	17.5	2.5	14.80	35.5	340	20.8	ok	180	191	<200	18.0	-131

DATA SHEET
MS50372
SCS-481 TYPE 2

CHARACTERISTIC		B_V	C_{TO}	C_{TVR}	V_R	R_{TH}	P_o	F_o	V_{OP}	I_{OP}	η	Mech. Tun.	HAT	T_J	$Q_{Ext.}$	ΔF_{RMS}	(N/S)AI
TEST CONDITION		Ima	V=O	$V \approx V_R$													
UNITS		Volts	P_F	P_F	Volts	°C/W	Watts	GHz	Volts	ma	%			°C		Hz	db
LIMITS	MIN.						2.5	14			20	±250					
	MAX.							16	70	500				200	200	50	-115
Serial No.	Diode I. D. Number																
129	81844M2-4-1	21.0	8.3	1.60	15	17.6	2.5	14.58	37.1	310	21.8	ok	190	183	<200	22.6	-142
130	81844M2-5-4	21.5	9.4	1.62	15	18.0	2.5	14.33	37.7	320	20.9	ok	190	170	<200	18.0	-148
119	81844M2-1-2	19.5	8.8	1.50	15	17.6	2.5	14.35	35.7	345	20.3	ok	190	198	<200	18.0	-148
120	81844M2-1-8	22.4	9.5	1.57	15	18.0	2.5	14.60	38.1	305	22.3	ok	200	182	<200	18.0	-143
121	81844M2-1-10	21.8	9.3	1.52	15	16.8	2.5	14.27	36.3	320	21.5	ok	195	178	<200	18.0	-141

RAYTHEON

MS-50372
GROUP B INSPECTION
SCS-481 TYPE 2
X-BAND DIODES

SUBGROUP 1 SHOCK, VIBRATION, ACCELERATION, HERMETICITY

CONDITIONS:

Shock	Vibration	Acceleration	Hermeticity
Per MIL-STD-750 Method 2016	Per MIL-STD-750 Method 2056	Per MIL-STD-750 Method 2006	Per MIL-STD-750 Method 1071
500G 1 ms 1/2 Sine Pulse 3 Planes 5 Shocks/Plane	20G 50-2000-50 Hz 3 Planes 4 Cycles/Plane 4 Min/Cycle	20000G 3 Planes 1 Min/Plane	Test Condition H 4 hrs @ 60 lb. He Pressure He Leak Detector <1 x 10^{-8}

CHARACTERISTIC		P_o		F_o		η		T_j	
UNITS		Watts		GHz		%		°C	
LIMITS	Min.	2.5		14		20			
	Max.			16				200	
END POINT*		I	F	I	F	I	F	I	F
Serial No.	Diode I.D. Number								
115	41328A-C-2-5	2.5	2.5	14.38	14.16	21.7	21.7	194	194
116	41328A-C-2-7	2.5	2.5	14.2	14.16	22.6	22.4	185	186
117	41328A-C-2-8	2.5	2.5	14.1	14.05	22.5	22.1	184	188
118	41328A-C-2-9	2.5	2.5	14.2	14.18	22.5	22.8	188	185

Operator: [signature]

Date: 3/15/77

Q.C. Approved: C. Mazza

Date: 3.18.77

*I-Initial
F-Final

RAYTHEON

MS-50372
GROUP B INSPECTION
SCS-481 TYPE 2
X-BAND DIODES

SUBGROUP 2 NUCLEAR RADIATION EXPOSURE

CONDITIONS: Power Level - 10 KW
7 minute exposure
Gamma Exposure - 1.2×10^5 rads (Si)
Neutron Exposure - $1.04 \times 10^{13} n/cm^2$, MeV Si damage equivalent (indicated by sulphur pellet dosimetry).

NOTES:

1) The exposed devices are radioactive (Av^{198}) and they are being stored in a controlled access and storage area with Raytheon's flash X-ray facility.

2) S/N 120 shorted before optimum Po, η and Fo were obtained. Short caused by faulty tuning sequence.

CHARACTERISTIC		P_o		F_o		η		T_j	
UNITS		Watts		GHz		%		°C	
LIMITS	Min.	2.5		14		20			
	Max.			16				200	
END POINT*		I	F	I	F	I	F	I	F
Serial No.	Diode I.D. Number								
119	81844M2-1-2	2.5	2.5	14.35	14.34	20.3	20.1	198	200
120	81844M2-1-8	2.5	2.45	14.60	14.70	22.3	21.8	182	186
121	81844M2-1-10	2.5	2.45	14.27	14.28	21.5	20.9	178	184

Operator: [signature]
Date: 1/12/77

Q.C. Approved: C. Mazza
Date: 3.18.77

*I-Initial
F-Final

RAYTHEON

MS-50372
GROUP B INSPECTION
SCS-481 TYPE 2
X-BAND DIODES

SUBGROUP 3 STORAGE LIFE

CONDITIONS: Non-operating
Ambient Temperature: 200°C ±3°C
Duration: 1040 Hours

NOTE 1: RF measurements were done in the standard Ku-band cavity.

CHARACTERISTIC		P_o		F_o		η		T_j	
UNITS		Watts		GHz		%		°C	
LIMITS	Min.	2.5		14		20			
	Max.			16				200	
END POINT*		I	F	I	F	I	F	I	F
Serial No.	Diode I.D. Number								
122	818444M2-2-13	2.5	2.5	14.24	14.18	20.7	20.7	188	188
123	81844M2-2-15	2.5	2.5	14.43	14.34	21.2	21.2	193	193
124	81844M2-2-16	2.5	2.5	14.60	14.41	21.8	21.8	183	183
125	81844M2-2-23	2.5	2.5	14.50	14.36	21.1	21.1	200	200
126	81844M2-3-8	2.5	2.5	14.40	14.30	21.0	21.0	185	185
127	81844M2-3-9	2.5	2.5	14.38	14.30	21.7	21.7	177	177
128	81844M2-3-23	2.5	2.5	14.80	14.76	20.8	20.8	191	191
129	81844M2-4-1	2.5	2.5	14.58	14.46	21.8	21.5	183	186
130	81844M2-5-4	2.5	2.5	14.33	14.15	20.9	20.9	170	170

Operator: [signature]
Date: 1/15/77

Q.C. Approved: C. Mazza
Date: 3.15.77

*I-Initial
F-Final

RAYTHEON

MS-50372
GROUP B INSPECTION
SCS-481 TYPE 2
X-BAND DIODES

SUBGROUP 4 OPERATING LIFE

CONDITIONS:

Oscillator Frequency:	15.0 GHz ±1 GHz
Oscillator Output Power:	2.5W-CW Min.
Oscillator Efficiency (RF-DC):	20% Min.
Junction Temperature:	200°C Max.
Ambient Temperature:	25 ±3°C

NOTE 1: RF measurements were done in the RF life test cavities.

CHARACTERISTIC		P_o		F_o		η		T_j	
UNITS		Watts		GHz		%		°C	
LIMITS	Min.	2.5		14		20			
	Max.			16				200	
END POINT*		I	F	I	F	I	F	I	F
Serial No.	Diode I.D. Number								
106	41328A-B-1-24	2.5	2.5	14.30	14.30	20.9	20.9	191	191
107	41328A-B-2-2	2.5	2.5	14.39	14.53	20.6	20.6	200	200
108	41328A-B-2-4	2.5	2.5	14.40	14.38	20.9	21.1	198	196
109	41328A-B-2-5	2.5	2.5	14.29	14.30	21.1	21.1	199	199
110	41328A-B-2-6	2.5	2.5	14.30	14.29	20.9	20.9	199	199
111	41328A-B-2-14	2.5	2.5	14.35	14.30	21.2	21.2	198	198
112	41328A-C-1-1	2.5	2.5	14.15	14.13	21.2	21.2	194	194
113	41328A-C-1-9	2.5	2.5	14.13	14.10	20.9	20.7	198	200
114	41328A-C-1-21	2.5	2.5	14.14	14.18	20.7	21.0	196	193

Operator: [signature]

Date: 3/15/77

Q.C. Approved: C Mazza

Date: 3 18 77

*I-Initial
F-Final

RAYTHEON

IMPATT DIODE TEST CAVITY

TYPE	THK-8000		
SERIAL NUMBER	S/N 5		
HAT SIZE	190	HAT STYLE	Flat
		DIODE	41328A-C-2-3

OPERATING DATA

VOLTAGE	40.0 V	BREAKDOWN VOLTAGE @ I_R = 1 mA	25.0
CURRENT	280 mA	CAPACITANCE-C_{TO}	8.4
POWER OUTPUT	2.5 W-CW	CAPACITANCE-C_{TVR}	1.54
FREQUENCY	14.36	@ V_R	15 V
EFFICIENCY	22.3		

NOTE: The sliding short may be replaced with a precision short for smoother operation in repetitive diode testing.

RAYTHEON

IMPATT DIODE TEST CAVITY

TYPE			
SERIAL NUMBER			
HAT SIZE		HAT STYLE	
		DIODE	

OPERATING DATA

VOLTAGE		BREAKDOWN VOLTAGE @ I_R = 1 mA	
CURRENT		CAPACITANCE-C_{TO}	
POWER OUTPUT		CAPACITANCE-C_{TVR}	
FREQUENCY		@ V_R	
EFFICIENCY			

NOTE: The sliding short may be replaced with a precision short for smoother operation in repetitive diode testing.

APPENDIX B

SPECIFICATION
GaAs EPITAXIAL WAFER READ PROFILE PEM DIODE

APPLICATION		REVISIONS			
NEXT ASSY	USED ON	LTR	DESCRIPTION	DATE	APPROVED
		1	REVISED EXTENSIVE CHGS. SEE OBSOLETE FILE FOR PREVIOUS REV	9-11-75	
		2	PARAMETER 4.6 1.0x10^16 ±10% WAS 7.5 x 10^15 ±10% ALSO.	12/15/75	
		3	REV. EXTENSIVELY PER ENG MARK UP	12-17-76	
		4	REV. PER ENG. MARKUP	3-15-77	AC 5/3/77
		5	REV. Sheet 4, Par. 4.5 "δ" added.	6/14/77	AC 6/14/77

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ±
FRACTIONS ±
3 PLACE DECIMALS ±
2 PLACE DECIMALS ±
1 PLACE DECIMALS ±

MATERIAL:

CONTR NO.

DR	R. Silveira	3-5-77
CHK	F. Yeguhart	3-31-77
APPD	[illegible]	12-20-77
APPD	Hof. [illegible]	12-22-77
APPD		

APPROVED

BY DIRECTION OF

RAYTHEON

RAYTHEON COMPANY
LEXINGTON, MASS. 02173

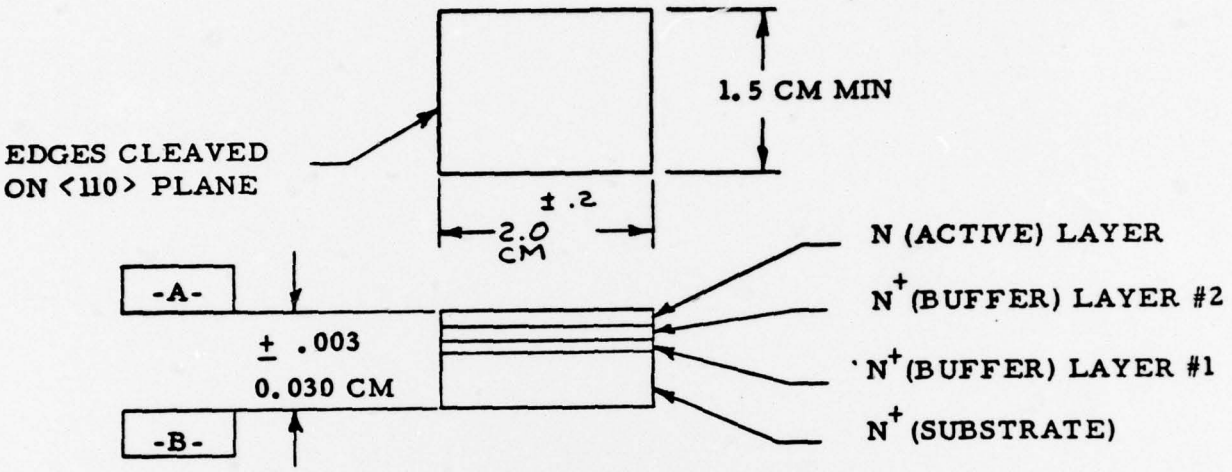
DRAWING TITLE

GaAs EPITAXIAL WAFER READ PROFILE PEM DIODE

SIZE	CODE IDENT NO.	DRAWING NO.
A	49956	892049

SCALE —— Rev. 5 SHEET 1 OF 5

10-0700 (5/68) VELLUM
10-0701 (5/68) GRID VELLUM



NOTES:

1. Usable area - 3.0 cm^2/min.

2. Fifty (50) percent of the wafers grown shall have eighty (80) percent, (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, 23 September 1974.

SIZE	CODE IDENT NO.	DRAWING NO.
A	49956	892049
SCALE	REV 5	SHEET 2 of 5

SPECIFICATIONS

1. SUBSTRATE

1.1 Resistivity: 2×10^{-3} ohm-cm max.

1.2 Carrier Concentration: $1 - 4 \times 10^{18}/cm^3$

1.3 Dopant: N-Type

1.4 Etch Pit Density: $10^4/cm^2$ max.

1.5 Orientation: $2 \pm 1/2^{\circ}$ off $\langle 100 \rangle$ towards $\langle 110 \rangle$ plane.

2. BUFFER LAYER #1

2.1 Resistivity: 2×10^{-3} ohm-cm max.

2.2 Carrier Concentration: $1 - 4 \times 10^{18}/cm^3$

2.3 Dislocation Density: $1000/cm^2$ max.

2.4 Dopant: Silicon

2.5 Thickness: $4.0 - 10.0\ \mu m$

3. BUFFER LAYER #2

3.1 Carrier Concentration: $3 - 10 \times 10^{16}/cm^3$

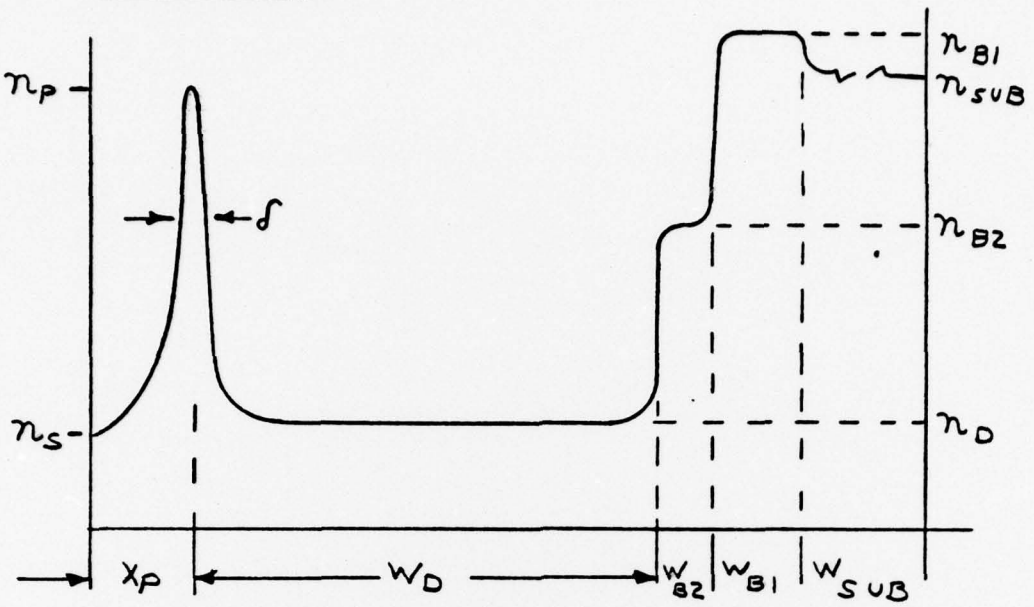
3.2 Dislocation Density: $1000/cm^2$ max.

3.3 Dopant: Silicon

3.4 Thickness: $1\ \mu m \pm 0.5\ \mu m$

SIZE	CODE IDENT NO.	DRAWING NO.
A	49956	892049
SCALE	REV 5	SHEET 3 of 5

4. ACTIVE LAYER: Per Table I



TABLE

PARAMETER		SYMBOL	PART NUMBER		UNITS
			-1	-2	
4.1	Nominal Operation Freq. Range		X-Band	Ku-Band	
4.2a	Carrier Concentration at X_o	N_o	1.0×10^{17} ref.		cm^{-3}
4.2b	Zero Bias Depletion wd.	X_o	0.20 ref.		μm
4.3	Peak Depth	X_P	$0.24 \pm .02$		μm
4.4	Total charge in spike per unit area	Q	$2.4 \times 10^{12} \pm 0.4$		$coul/cm^2$
4.5	Spike width max. at half height	δ Max.	0.06 max.		μm
4.6	Drift Space Doping	n_D	$5 \times 10^{15} \pm 10\%$	$1.0 \times 10^{16} \pm 10\%$	cm^{-3}
4.7	Active Layer Thickness	W_D	5.0 ± 0.5	4.0 ± 0.5	μm
4.8	Spike Depletion Voltage	V*	8.3 ± 1.0		Volts

SIZE	CODE IDENT NO.	DRAWING NO.
A	49956	892049
SCALE	REV 5	SHEET 4 of 5

5. SURFACE "A" FINISH

5.1 Surface "A" to be mirror-like with no hazy frosty appearance.

5.2 Surface "A" of wafer (exclusive of 1.5mm wide edge) to have a maximum of four gross defects (pits or mounts). Each defect shall be less than 1/2 mm in diameter and shall have a maximum height of 1 μm.

6. DATA REQUIREMENTS (EACH WAFER)

6.1 Identify substrate vendor and supply vendor crystal number.

6.2 Supply vendor data on 1.1, 1.2, 1.4 and best estimates on 2.1, 2.2, 2.3, 2.5, 3.1, 3.2, 3.4, 4.2 - 4.8.

SIZE	CODE IDENT NO.	DRAWING NO.
A	49956	892049
SCALE	REV 5	SHEET 5 of 5

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