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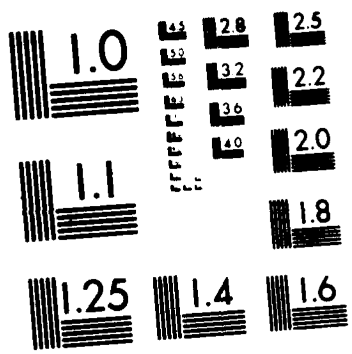

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PERIODIC REPORT NO

REM - FM - 87 - 1

FIRST PERIODIC REPORT:

PROGRAM PLAN AND FABRICATION SPECIFICATION FOR THE "SUPPLY OF EXPERIMENTAL RADFET DOSIMETERS"

by

ANDREW HOLMES - SIEDLE

JUNE TO JULY 1987

United States Army

EUROPEAN RESEARCH OFFICE OF THE US ARMY

London England

CONTRACT NUMBER DAJA45 - 87C - 0029

RADIATION EXPERIMENTS AND MONITORS

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The first periodic report is a technical planning document setting out test procedures plus a fabrication specification for p-channel Metal - Oxide - Silicon dosimeters, of an experimental type known as RADFETs.

Keywords Metal Oxide Semiconductor, Field Effect Transistor, Radiation Sensitivity, Great Britain

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CONTENTS

SUMMARY

The first periodic report on contract DAJA45 - 87C - 0029 is a technical planning document setting out several test procedures plus a fabrication specification for p-channel Metal - Oxide - Semiconductor dosimeters . These are of an experimental type known as Radiation - Sensitive - Field - Effect Transistors (RADFETs). Three lots are to be made in order to assess the feasibility of large-scale manufacture and the use of RADFETs by the US Army for tactical dosimetry.

1. INTRODUCTION

The European Research Office of the US Army has recently signed a contract with Radiation Experiments and Monitors (REM) , a British firm, for the supply and evaluation of radiation-sensitive field-effect transistors (RADFETs). The Army wishes to establish the feasibility of large-scale manufacture of these devices , for use in tactical dosimetry. In the present contract, the US Army and REM, a company formed to develop the RADFET principle, will collaborate in the evaluation of quantities of the RADFET fabricated in commercial runs.

This report initiates the technical planning of the contract and presents a task schedule and fabrication specifications.

2. BRIEF TECHNICAL BACKGROUND

The background to the development of the RADFET by REM and other workers is given in a recent review by the author of this report (Andrew Holmes-Siedle and Len Adams, "RADFET : A Review of the Use of Metal - Oxide - Silicon Devices as Integrating Dosimeters", Radiation Physics and Chemistry, 28 , (2) 235 - 244 (1986)). It was found by the author that ionising radiation dose could be measured by electronic tracking of the buildup of positive charge produced in oxide films by radiation.

The dosimetric measurement is in the form of a very convenient remotely-readable, non-destructively readable low voltage signal; the device is very small, can be merged with silicon digital integrated circuits and requires very low power and mass. The technique was developed with funding from the European Space Agency and is now in use on European and US satellites. With recent increases in sensitivity, the technique became of interest for special personnel dosimetry for military purposes, known as "tactical dosimetry". This field has been studied by the US Army Electronics Command for many years and studies of the performance of RADFETs are in progress at Fort Monmouth, N.J. Methods of tactical dosimetry have been reviewed by Stanley Kronenberg in several articles (see, for example "Broad Range Dosimetry with Leuko Dye Optical Waveguides", Nuc. Inst and Meth., 190 , 365 - 368 (1981) ; and "Measuring Gamma and Neutron Doses in a Battlefield Environment" (publication unknown, 1986).

It is of great interest at present to compare the potentialities of the various methods available for tactical dosimetry, including those quoted above, in order to determine which will be the most useful in miniature dosimeters, which can be carried by combat troops and others in a war zone.

In the present contract, the US Army and REM, a company formed to develop the RADFET principle, will collaborate in the evaluation of quantities of the RADFET fabricated in REM's commercial runs.

3. PROGRAM PLAN

3.1 INTRODUCTION

The immediate objective of the program is to fabricate three separate process lots of the same RADFET and make measurements to demonstrate the degree of uniformity achieved with respect to dosimetric performance. The goal of the program is to achieve a good estimate of the possibility of practical large-scale production of RADFETs for tactical dosimetry.

The fabrication of RADFETs on this project will be on the usual commercial basis. That is, REM will commission fabrication runs at the Industrial Unit of the Southampton University Microelectronics Centre , Southampton, England. The samples withdrawn for the US Army sponsored study will form only a part of the run concerned. Thus, commercial samples from the same run will be available for later purchase. REM will perform evaluations of the RADFET performance and the US Army Electronics Command will perform further independent tests as required.

A number of special dosimeter structures, specified by the US Army, will be made by REM. These consist of silicon and polymeric absorbers, mounted around a RADFET chip, within its encapsulating package. The structures specified are expected to affect the neutron responsivity of the device.

3.2 TASK SCHEDULE

The bar chart shows the schedule agreed with the US Army. Three fabrication runs take place with intervals between them of about three months for evaluation and discussion. It is recognised that time is of the essence in this program and, if it appears possible to reduce the period between runs, this will be done after consultation.

3.3 EVALUATION

3.3.1 ELECTRICAL

The evaluation of each run will begin with the probe mapping of about 4 wafers with respect to the electrical parameters, including:

Threshold Voltage (extrapolated to zero current)

Threshold Voltage (at 10 microamperes)

Source - Drain Breakdown Voltage

Transconductance

RADFET Stability Tests (REM / Southampton Series).

3.3.2 RADIATION

At least 10 devices from each wafer will be mounted on headers and exposed to cobalt - 60 gamma rays according to a test schedule as follows :

Dose (rads)	Irradiation Bias (V)
10	3 to 5 samples with gates biassed
20	during irradiation at +10V and an
50	equal number with gates grounded
100	during irradiation will be exposed
200	to the total dose values shown,in
500	stepwise mode, with dosimetric
1000	measurements at each step.
RT Anneal, 48 hrs.	

For the room-temperature (RT) anneal, the devices will be left in the shorted condition.

3.4 SAMPLES FOR US ARMY EVALUATION

To avoid unnecessary costs, RADFET samples for evaluation by the US Army will be supplied in two forms:

(a) about 150 from each lot will be mounted in semiconductor encapsulations in the usual way. Present costings are based on a low-cost chip carrier employing plated gold tracks, Al or gold wire leads as required, and FR-5 epoxy/fiberglass substrate.

(b) to make further samples available for mounting at the US Army's own laboratory facilities, over 1,000 devices per lot will be supplied in the form of segments of wafers, sawn to include about 100 repeat units or "starts" per segment. This will save money by giving the Army the freedom to commission the exact packaging required after the dosimeter packaging requirement has been worked out.

(c) USAECOM at Fort Monmouth has requested other special samples. The description is quoted from the contract document:

" Five to eight groups .. of five to eight identical units. The following are examples of the devices required :

(1) 5 identical devices fabricated by placing directly on top of the p-MOS a layer of 1mm thick silicon. Gold can be used.

(2) 10 identical devices fabricated by placing directly on top of the p-MOS, a layer of silicon, but eliminating all gold in the package.

(3) 10 identical devices the same as above but with no gold and in place of the silicon a 2mm thick layer of polyethylene directly above the p-MOS."

4. FABRICATION SPECIFICATION

4.1 BASIC TECHNOLOGY

As in previous RADFET work by REM, the technology used will be the metal-gate silicon pMOS transistor technology which has been established at Southampton University Microelectronics Centre.... (" Southampton Standard Aluminium Gate MOS Process (Nov 1977), p-Channel"). The first batches were made for REM in 1978 using an existing transistor process and have been modified only with respect to the oxide growth stages and the scaling up of wafer size from 2 inches to 3, then 4 inches and the inclusion of electron-beam evaporation. The design rules are based on 10-micrometre channel lengths. Junctions are diffused from boron nitride sources. Oxides are grown late in the process after stripping previous oxide films.

4.2 SPECIAL REM CHIP DESIGN

The REM masks give the opportunity for two thicknesses of oxide to be grown on different areas and for thin metal to be deposited over the sensitive areas. Oxide films are grown to special schedules, intended to give controlled response to ionising radiation and high stability to charge drift of various kinds.

The RADFET devices will be of the TOT500 design, which employs a new commercial mask pattern designed by REM. The chip is of small size (less than 1 x 1 mm), so that it can fit inside small probes (e.g. catheters) and yields a large number from a wafer. The pattern contains four dosimeter transistors , two identical pairs, of low ("L") and high ("H") responsivity values, by virtue of different oxide thickness values. One member of a pair can be used for temperature compensation. The fact that two responsivity values are available on the same chip increases the dynamic range of the device.

The twelve wire bonding pads of the TOT500 chip are laid out in an order which is suitable for the pin geometries and chip carrier geometries used by REM (these normally require the order "source - gate - drain - body" in the pads , in order to fit some existing socket pinouts).

Oxide thickness values and other commercially sensitive features of the mask will be revealed to the US Army in confidence as required.

4.3 PROCESSING

In order to achieve reproducibility, the fabrication process parameters in the three lots will be maintained as close as possible to the standard REM process.

4.4 RESPONSIVITY VALUES

The target values for responsivity are shown in Table 1, and are based on the experience gained in fabricating the devices described in Table 2. These are not contractual requirements but technical targets, based on "worst case processing" assumptions for the oxide thickness values stated. REM reserves the right to alter the process parameters as a part of final mask design optimisation.

5. CONCLUSIONS

This report has initiated the technical plannning for a new contract to supply experimental RADFET dosimeters to the US Army and to evaluate a selection of the devices. The con tractor is REM, a British firm, with Southampton University, England as subcontractor. The report has presented a task statement and a specification for the fabrication processes. The groups collaborating on this project include the European Office and the Electronics Command of the US Army.

TABLE 1 : ELECTRICAL SPECIFICATIONS FOR RADFETS

PARAMETER	SYMBOL	DEVICE H	DEVICE L	UNITS
Oxide Thickness (nominal)	d_{ox}	0.7	0.2	micrometres
Threshold Voltage	V_T	10.0	4.0	volts
Responsivity				
at +12V	r(+12)	6500	700	mV / krad (Si)
at 0V	r(0)	400	140	mV / krad (Si)

TABLE 2 : REM pMOS RADFET PERFORMANCE : EXISTING BATCHES 1986
TYPICAL RESPONSES

DOSE RANGE	RADFET TYPE	OXIDE THICKNESS d_{ox} (µm)	EXPOSURE MODE	RESPONSIVITY r (mV/krad)	OPER. RANGE	
					LOWR. DOSE VALUE LDV (rads)	UPPR. DOSE VALUE UDV (rads)
HIGH	TOT 205	0.05	V_I0	5	10^4	10^7
	TOT 205	0.05	V_I+	10	10^3	10^6
	TOT 201	0.12	V_I0	60	10^3	10^6
MEDIUM	TOT 202	0.20	V_I0	200	10^2	10^5
	TOT 201	0.12	V_I+	300	10^2	10^5
	TOT 203	0.50	V_I0	300	10^2	10^5
LOW	TOT 202	0.20	V_I+	1,000	10	10^4
	TOT 302	0.20	V_I+	1,000	10	10^4
	TOT 302	0.90	V_I0	1,300	10	10^5
V. LOW	TOT 303	0.50	V_I+	4,000	1	10^4
	TOT 302	0.90	V_I+	11,000	0.5	10^3

Definitions

Exposure Modes: V_I+ : irradiation with + voltage on gate electrode
V_I0 : irradiation with gate shorted to substrate

Operating Range : LDV : threshold-voltage shift exceeds 10 mV
UDV : threshold voltage shift approaches 10V

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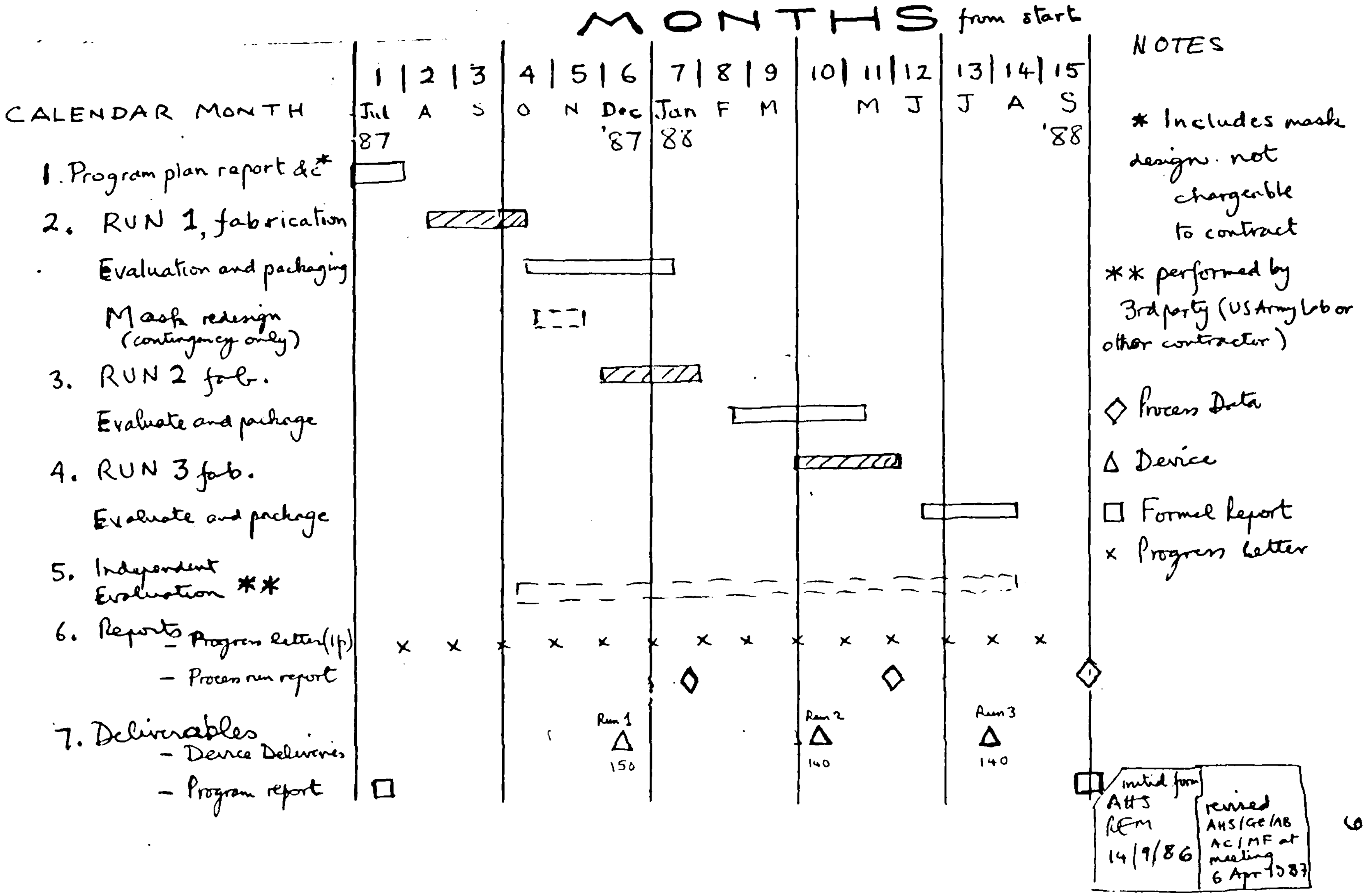

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