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# 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



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RADIATION EXPERIMENTS AND MONITORS

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The research reported was made possible through the support and sponsorship of the US Government through its European Research Office of the US Army. This report is intended only for the internal measurement use of the contractor and the US Government

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# SUMMARY

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- 2. BRIEF TECHNICAL BACKGROUND
- 3. PROGRAM PLAN
- 4. RADFET FABRICATION SPECIFICATION

5. CONCLUSIONS

#### 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

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The European Research Office of the US Army has recently signed a contract with Radiation Experiments and Monitors (REM) and evaluation British firm. for the supply 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 collaborate in the evaluation of RADFET principle, will 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 articles ( see, for example "Broad Range Dosimetry with several Leuko Dye Optical Waveguides", Nuc. Inst and Meth., 190, 365 -(1981) ; and "Measuring Gamma and Neutron Doses in a 368 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 Unit at the Industrial 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 ).

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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.

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# 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

in previous RADFET work by REM, the technology used will be λs the metal-gate silicon pMOS transistor technology which has been established at Southampton University Microelectronics Centre.... (" Standard Aluminium Gate MOS Process (Nov 1977), Southampton The first batches were made for REM in 1978 using p-Channel"). existing transistor process and have been modified only with an 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 The design rules are based electron-beam evaporation. OD 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 а 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 ( e.g. catheters ) and yields a large number from a probes The pattern contains four dosimeter transistors wafer. , 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

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PARAMETER	SYMBOL	DEVICE H	DEVICE L	UNITS
Oxide Thickness ( nominal )	đ	0.7	0 <b>.2</b>	micrometres
	d òx	·	_	
Threshold Voltage	v <sub>T</sub>	10.0	4.0	volts
Responsivity				
at +12V	r(+12)	6500	700	mV / krad (Si)
at OV	r( 0 )	400	140	mV / krad (Si)

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

DOSE RANGE	RADFET TYPE	OXIDE THICK- NESS dox ( µm )	EXPOS- URE MODE	RESPON- SIVITY r (mV/krad)	OPER. LOVR. DOSE VALUE LDV (rads)	RANCE UPPR. DOSE VALUE UDV (rads)
	TOT 205	0.05	v_0 v	5	104	10 <sup>7</sup>
HICH	TOT 205 TOT 201	0.05 0.12	۸ <sup>1</sup> 0 ۳1,	10 60	10 <sup>3</sup> 10 <sup>3</sup>	10 <sup>6</sup> 10 <sup>6</sup>
	TOT 202	0.20	۸ <sup>I</sup> o	200	10 <sup>2</sup>	10 <sup>5</sup>
MEDIUM	TOT 201	0.12	v <sub>I</sub> +	300	10 <sup>2</sup>	105
	TOT 203	0.50	۸ <sup>I</sup> O	300	10 <sup>2</sup>	10 <sup>5</sup>
	TOT 202	0.20	v <sub>I</sub> +	1,000	10	104
LOW	TOT 302	0.20	v <sub>I</sub> +	1,000	10	104
	TOT 302	0.90	٩ <sup>1</sup> 0	1,300	10	10 <sup>5</sup>
	TOT 303	0.50	v <sub>I</sub> +	4,000	1	104
V. LOW	TOT 302	0.90	۳ <sub>I+</sub>	11,000	0.5	10 <sup>3</sup>

Definitions\_

Exposure Modes: V<sub>I</sub>+ : irradiation with + voltage on gate electrode V<sub>I</sub>O : irradiation with gate shorted to substrate Operating LDV : threshold-voltage shift exceeds 10 mV Range : UDV : threshold voltage shift approaches 10V

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