RADFET development and calibration

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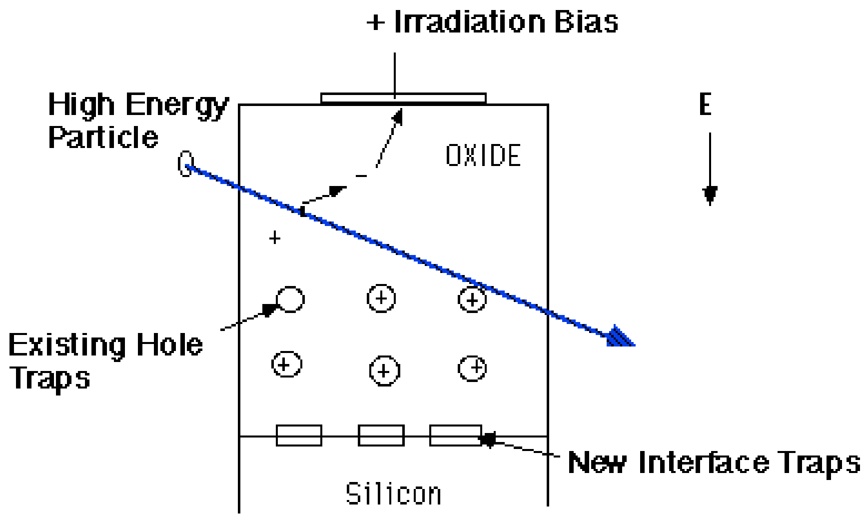
Outline:

- Basics of RADFET operation
- Overview of the work performed
- Main results:
  - Qualification tests and RADFET supply
  - RADFET calibration
  - RADFET reader improvements
- Future work

RADFET operating principle:

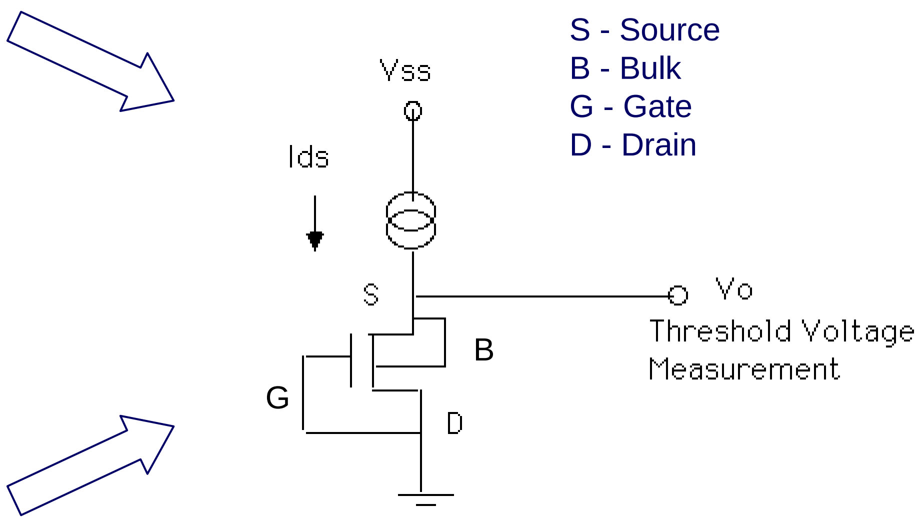


- Radiation creates electron-hole pairs
- Initial recombination of electrons and holes happens
- Non-recombined electrons leave the oxide;
  holes are trapped in the vicinity of the oxide/silicon interface
- RADFET threshold voltage (V_T) changes ($\Delta V_T \sim$ Dose)

RADFET biasing configurations:

- Irradiation (sense mode): zero current; (B, S and D grounded); G can be:
  - Grounded ($V_{IRR}=V_{GS}=0V$) (option 1)
  - Biased (typically $V_{IRR}=V_{GS}>0$) (option 2)

  Read-out mode: specified current applied to S=B; G=D grounded



- Irradiation (sense mode) and Read-out mode are the same (option 3)

RADFET advantages over other dosimeters:

- Immediate read-out without destroying the data
- Extremely small sensor chip
- Very low or zero power consumption
- Electronic signal
- Low cost (especially of the read-out electronics)

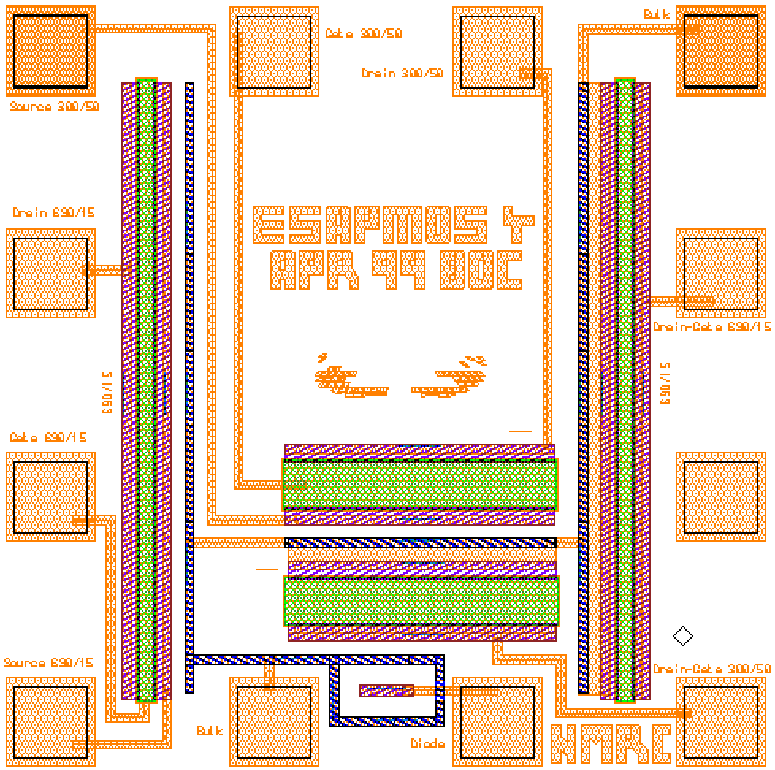
Applications:

- Nuclear industry and research
- Space dosimetry
- Radiotherapy
- Personal dosimetry [?]

Overview of main project tasks:

- Supply of RADFETs:
  - Flight samples for imminent space missions
  - Experimental samples for space missions and other ESTEC needs
- RADFET characterisation and calibration
- RADFET reader improvement

ESAPMOS4 RADFET chip:



- Chip size: 1mm x 1mm
- Contains four RADFETs:
  - two 300/50 devices
  - two 690/15 devices
- Chip types (gate oxide):
  - 100 nm
  - 400 nm
  - 400 nm Implanted (IMPL)
  - 1 µm
  - 1 µm Implanted (IMPL)

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RADFET qualification:

- Wafer lot acceptance
  - Construction analysis of RADFET die with SEM and cross-section
- Validation of the assembly
  - Construction analysis (package)
  - Residual Gas Analysis
  - Bond pull test
  - Die shear test
- Assembly and screening
- Life test
  - Burn-in 1000 hr at 125 degrees

Process flow:

Item No.	Description	Completed
1	Wafer Lot Acceptance	Yes
2	Validation of Assembly	Yes
3	Visual inspection to Space Level	Yes
4	Pre-cap CSI, including sample bond pull and die shear	Yes
5	Temperature cycling	Yes
6	Acceleration 30KG	Yes
7	Particle Impact Noise Detection (PIND) condition A	Yes
8	Pre electrical test and datalog at ambient	Yes
9	240hr power burn-in at 125C	Yes
10	Post electrical test and datalog at ambient	Yes
11	Electrical test and datalog at –55°C	Yes
12	Electrical test and datalog at +125°C	Yes
13	Fine & Gross Seal Tests	Yes
14	External visual	Yes
15	Life test: - Sample 10 units - Electrical test and datalog at ambient - Burn-in 1000hr at 125°C - Electrical test and datalog at ambient - External visual	Yes

RADFET supply:

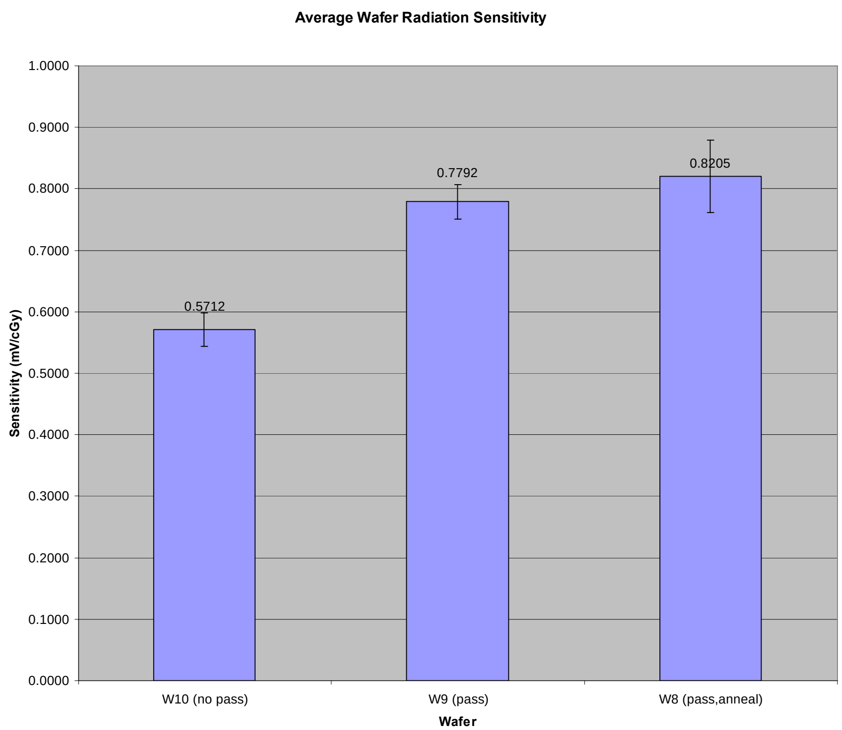
- Flight samples:
  - 4 parts for Proba-II
  - 16 parts for Alphasat
  - 20 parts for GlobalStar
  - 16 parts for O3B (TAS)
  - 6 parts for BepiColombo
- Experimental samples:
  - 12 parts for Proba-II
  - 40 parts for high ion irradiations in Juvaskyla
  - 20 parts for Alphasat
  - 20 parts for GlobalStar

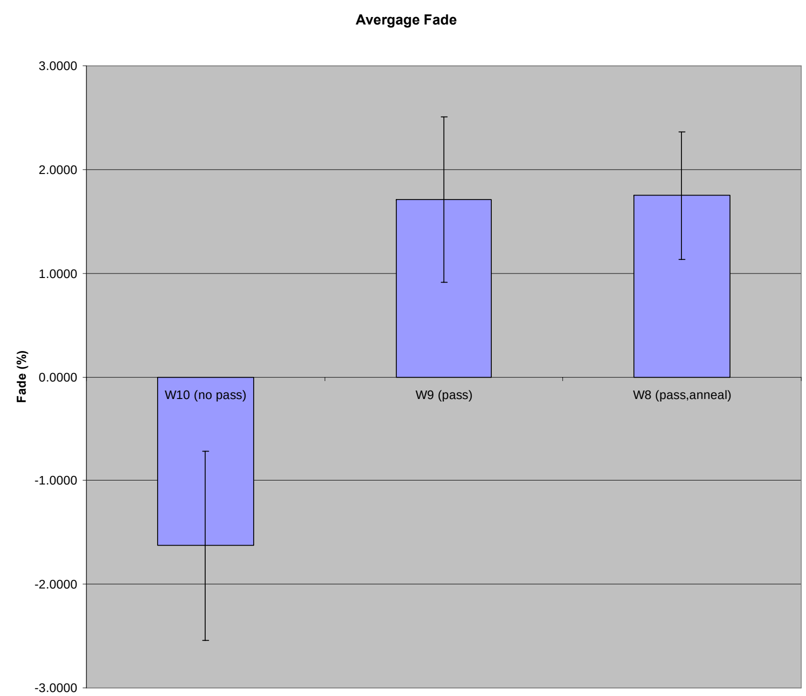
Difficulties encountered:

- Originally chosen RADFET batch exhibited V_T shift during packaging in 14-pin ceramic packages
- Observed behaviour was not always consistent
- Detailed tests have shown that the batch in question indeed exhibited a V_T shift owing to a high temperature process during hermetical packaging
- Moisture ingression is most probable culprit
- Storage of RADFET wafers is critical
- RADFET wafers are not passivated – this makes problem worse
- Passivation could improve things, however…

Passivation (Si_3N_4) and sensitivity/fading:

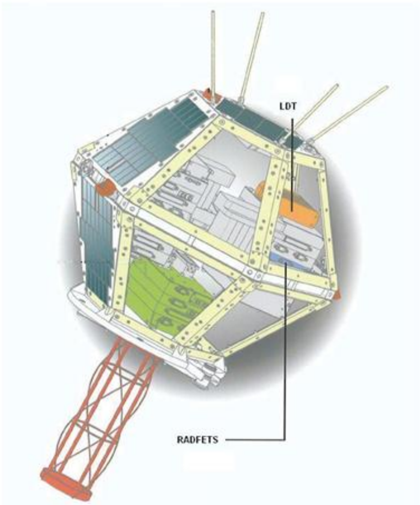
- No effect of passivation to pre-irradiation I-V curves
- Effects emerging during and after irradiation

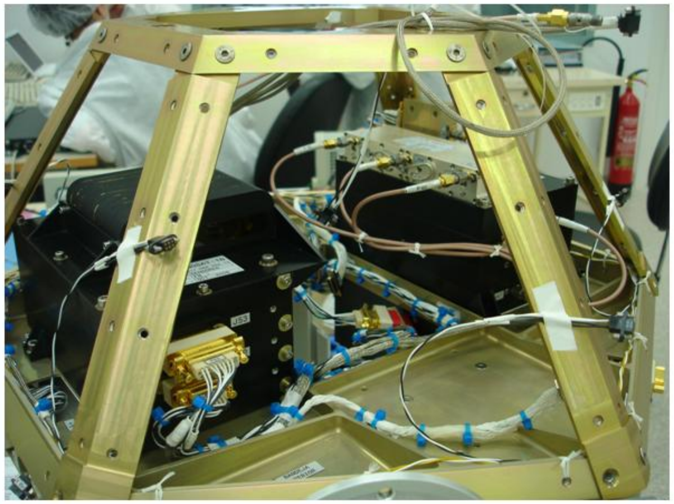




RADFETs on NANOSAT 1B:

Orbit type	Heliosynchronous; 98º inclination; 690 km height
Orbital period	98 minutes
Orbits per day	14.7
Life time	Minimum 3 years. Up to 5 years
Mass	20 kg
Length	50 cm





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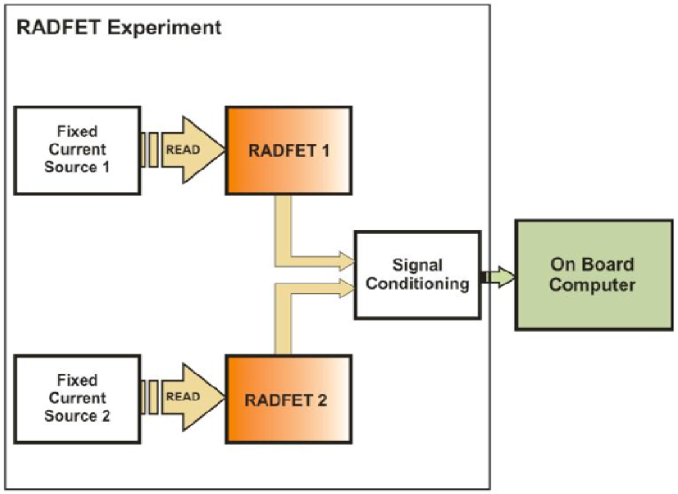
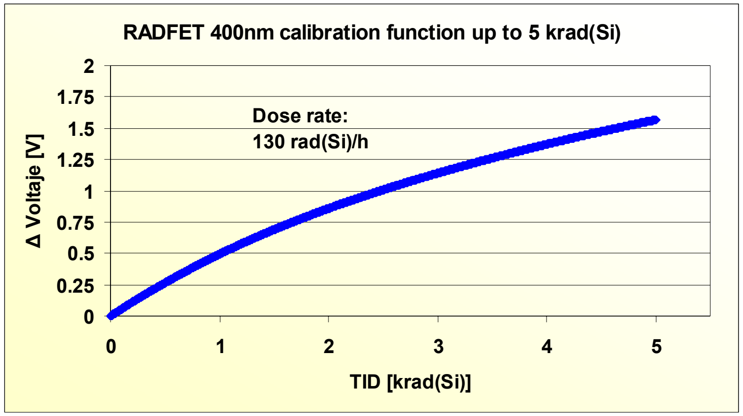
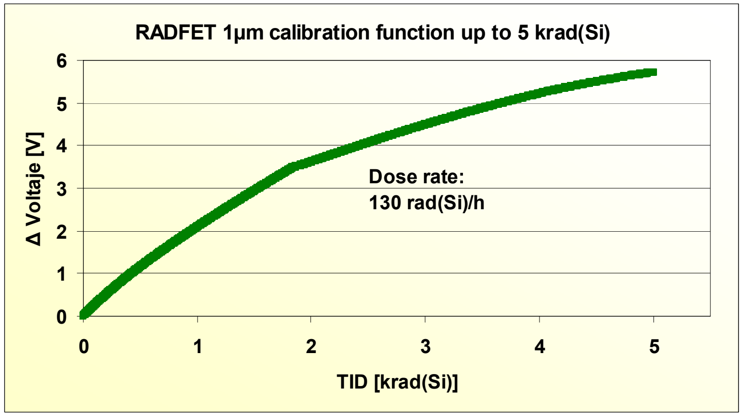
RADFET board set-up and calibration:







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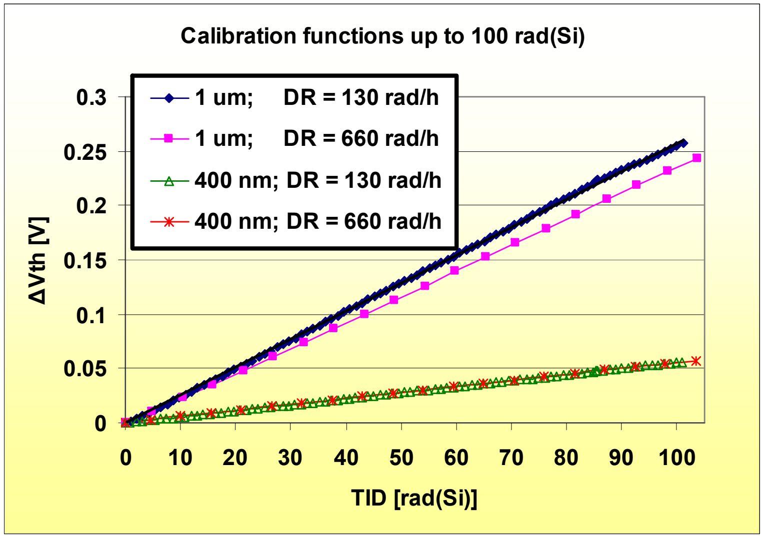
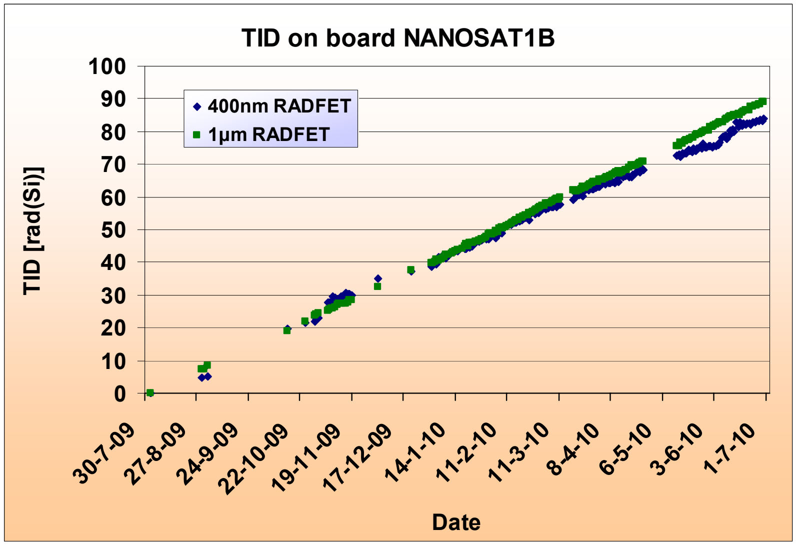
Precise calibration and total dose:





RADFET reader improvements:

- Current RADFET automated read-out system:
  - Passive board (in the radiation room)
  - Controller board (in the radiation room, shielded)
  - PC with application SW (in the control room, RS-232 connection)

- Proposed modifications:
  - Change cable between passive and controller board to facilitate placing controller board in the control room
  - Change connection between controller board and PC to USB to avoid problems with USB/RS-232 adapters
  - Introduce single mains supply (currently two adapters)
  - Overhaul application software

Proposed future work:

- Improvement of the RADFET reader
- Additional flight and experimental samples
- Further RADFET characterisation
  - Irradiations (Co-60, protons)
  - Passivation solutions (nitride, CVD oxide, polyamide)