IAA-CU-13-04-07

The Importance of a Dosimeter in the NANOSATC-BR2

Vinicius Deggeroni[*], *Tiago Bremm*, Ezequiel Echer**, Alisson Dal Lago**,*
*Otávio Cupertino Durão **, Nelson Jorge Schuch **.*

The NANOSATC-BR2 is the first nanosatellite of the INPE-UFSM Brazilian NANOSATC-BR program intended to have the capability of measuring the amount of space radiation with a dosimeter. The purposes of the mission associated with NANOSATC-BR2 are to qualify human resource for the space area; to develop the technological capacity of the partner institutions and to improve the researches on Geospace phenomena and mainly on the Solar-Terrestrial Physics and Space Weather Science and Applications related to the South Atlantic Magnetic Anomaly (SAMA) and the Equatorial Electrojet. A bibliographic review of the main results published on the topic area is done, focusing on the study of the dosimeter RFTDAT_CC10 type RADFET (Radiation-Sensing Field-Effect Transistor). In order to act individually on each circuit, checking the efficiency of the protection system upsets caused by the incidence of energetic particles emanating from space, the dosimeter is responsible for making the measurement of this radiation, verifying the energy level radiation limit and serviceability of equipment present in the nanosatellite. The objective in this work is to detail the characteristics of the dosimeter, and the possible analysis to be performed with this instrumentation, which is paramount in the study of the radiation environment in the SAMA region.

---

[*] Southern Regional Space Research Center – CRS/INPE – MCTI, in collaboration with the Santa Maria Space Science Laboratory – LACESM/CT – UFSM, Santa Maria, RS, Brasil.

**National Institute for Space Research – DGE/CEA/INPE – MCTI, São José dos Campos, SP Brasil.

I. Introduction

In space the high energy radiation is found due to solar energetic particle emissions or galactic cosmic rays, which are composed mainly of energetic protons. The earth's atmosphere and magnetic field block most of this radiation, preventing exposure of the life forms at the surface of the planet while also protecting electronic instruments that, when operated under ionizing radiation, suffer adverse effects on their performance.

Through the NANOSATC-BR Program, a second nanosat is already being developed by the Partnership INPE-UFSM. The first Brazilian Cube Sat satellite, the NANOSATC-BR1, is a 10x10x11.3 cm. cube weighing less than 1.33 kg. It is named NANOSATC-BR2 as the second Brazilian Nano satellite, which is a 2U cubesat, (10x10x22.6 cm), permitting a more ambitious mission than the NANOSATC-BR1, with three major objectives: academic/capacity building, scientific and technological development.

The scientific objectives of this mission are to monitor the Earth's Ionosphere with a Langmuir probe, and to measure the Geomagnetic Field intensity with a fluxgate magnetometer, XEN-1210. Furthermore, the payload will have a RFTDAT_CC10 dosimeter type RADFET (Radiation -Sensing Field-Effect transistor) measuring the radiation upon the satellite. The importance of collect radiation data at an altitude of 600km is to submit these electronics components to extreme situations and monitor its components individually using the dosimeter installed on NANOSATC-BR2.

It also covers the fact that we have data on the space radiation of the South Atlantic Magnetic Anomaly (SAMA), a region with very low values of magnetic field and enhanced precipitation of energetic particles from the radiation belt. Thus the monitoring of space radiation over the SAMA region, especially at the upper atmosphere heights, is very critical to several space system operations. This should be studied to improve telecommunications in Brazil, where it has serious effects due to the location of the anomaly in services such as GPS. The dosimeter measurements would give us information about space and time variation of radiation in this region.

II. Radiation Effects

When an ionizing energetic particle of cosmic radiation passes through an electronic component, will form an ionization path. This will allow the formation of free charges in the semiconductor in the satellite. Part of these charges can be immediately collected by the device's electric field, causing a current pulse in the circuit. The rest of the charge will migrate, slowly recombining or constrained in defects of the crystal structure or even in the device's interface, remaining there for a long period, changing its electrical characteristics. In electronic circuits these effects appear as a permanent or transitory change of the parameters on the electrical components of the circuit to malfunction or even a complete failure and not operability.

III. Importance of the Dosimeter

The radiation belt trapped particles are very energetic (~MeV), thus causing major damage to satellites with orbits inside the magnetosphere (Fig. 1), when compared with the damage caused by cosmic rays at geostationary satellites.

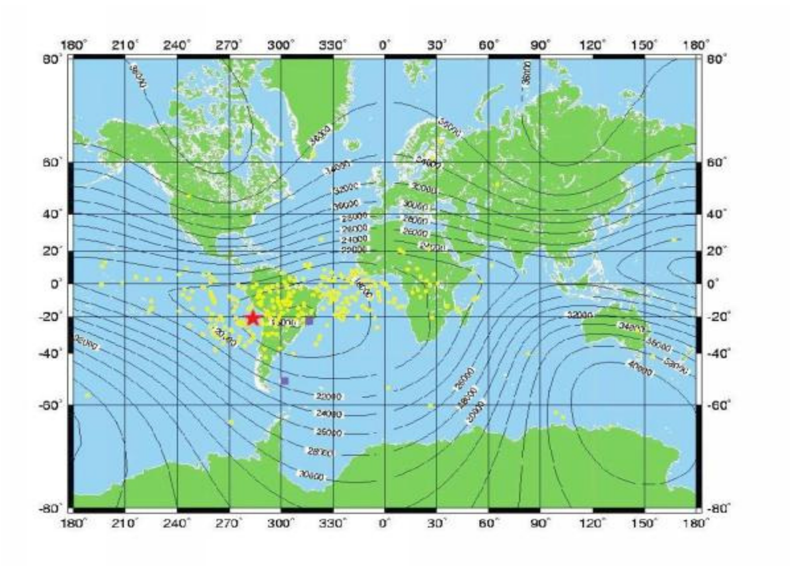

Fig.1. - Many low orbit satellites had problems on the South Atlantic Magnetic Anomaly - SAMA. In the figure, a Red

Star Shows Where the NASA MODIS Satellite presented problems on June 15, 2001, remaining inoperative for 16 days. The yellow dots represent the locations where the TOPEX satellite, whose orbit is 1000 km, had problems from 1992 to 1998. The contours represent the total intensity of the Terrestrial Magnetic Field at an altitude of 1000 km, highlighting the South Atlantic Magnetic Anomaly - SAMA. [1]

The satellites that pass over the Brazilian territory, especially in polar orbits, are at greater risk of damage due to the action of ionizing radiation, reducing its reliability. Thus, it becomes necessary to develop integrated programs of research and monitoring to determine the dynamics and forecast more accurately the radiation environment on the Territory South of Brazil.

With the dosimeter is possible to monitor the radiation doses that affect satellites, particularly on SAMA, improving the study of the dynamics of the radiation and its correlation with the Earth's magnetosphere. It will undoubtedly contribute to decision-making, including the development of optimization in construction projects and protection, which increases in the lifetime of satellites and spacecraft at a cost of tens to hundreds of millions of dollars, besides contributing to generate a database of incident radiation.

IV. DOSIMETER RFTDAT_CC10

Radfet characteristics:

Radiation-sensitive MOSFETs – (Metal-Oxide semiconductor field effect transistor) are enhancement pMOS transistors carrying a thick gate oxide.

DIE: material: Si Wafer

Mask:REM TOT600 mask (Fets Q1 And Q2, diode T And Mos capacitor C)
Die encapsulation: Black epoxy "glob" g1
Cable & connectors: commercial 6 way ffc
Diode T area: 0.05 mm^2
Capacitor C area: 0.05 mm^2

Fig.2 : Layout of the REM Dosimeter System	Length (mm)	Width (mm)	Thickness (mm)
MATERIAL:FR4CC	17	8.5	0.3
CHIP SIZE:	0.635	1.25	0.5
GATE OXIDE THICKNESS	$0.20*10^{-3}$	$0.25*10^{-3}$	$0.30*10^{-3}$

Table I. TYPE RFT-300-CC10G1

OPERATION: Dosimetry involves tracking Threshold voltage, V_T, at 10 to 500 µA, according to the NANOSATC-BR2 project necessity. Through the dimension in the layout showed in Fig.2 ,we note that the RFTDAT_CC10 fits well with the physical characteristics, because their size and it's card shape.

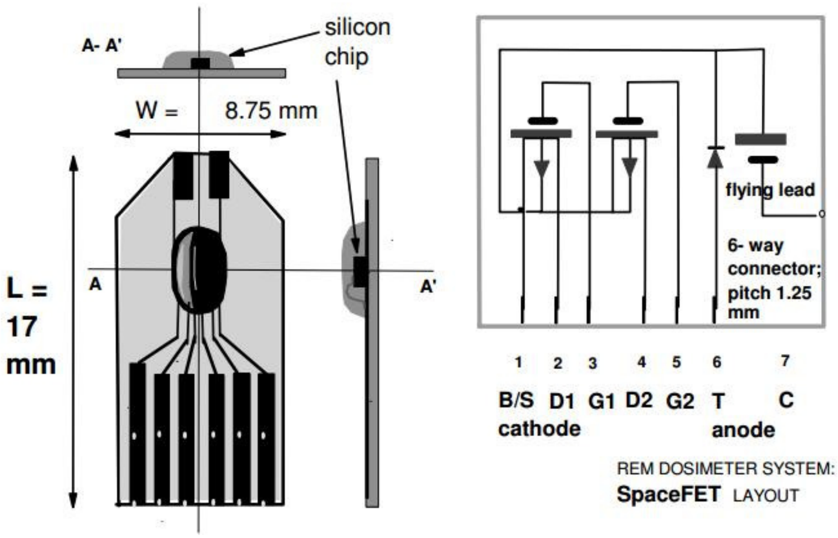

Fig.2 : Layout of the REM Dosimeter System.

PINOUT: 1. Source/Body 2. D1; 3 G1; 4 D2 ; 5 G2; 6. T (diode) 7. C (capacitor). D = drain, G = Gate REM's latest medium-responsivity silicon sensor for ionizing radiation is the TOT600, consists of a new design of dual MOSFET, a p+n diode and an MOS capacitor mounted on a dosimeter carrier (REM CC10) suitable for space and other automated vehicles. The sensor element is the smallest known solid state radiation dosimeter. This development by REM Oxford, Semefab and DST Glenrothes, in commercial partnership, of a dosimeter system, known as DOT (for "Dosimetry by Oxide Trapping") is the product of over 30 years of experience within REM. References to an extensive literature are available, with a major bibliography given in REM's "Handbook of Radiation Effects" [2,3].

Response to radiation: VT shift of the TOT601 series:

PRACTICAL DOSE RANGES FOR TOT601B	
Biased modes (VI = +9V)	10 to 100,000 cGy
Zero-bias mode (VI = 0V)	20 to 2 million cGy

Table II. The response for Vi = 0 operation is about 6 times lower but this means that the practical dose range for the is higher (see Fig. 3).

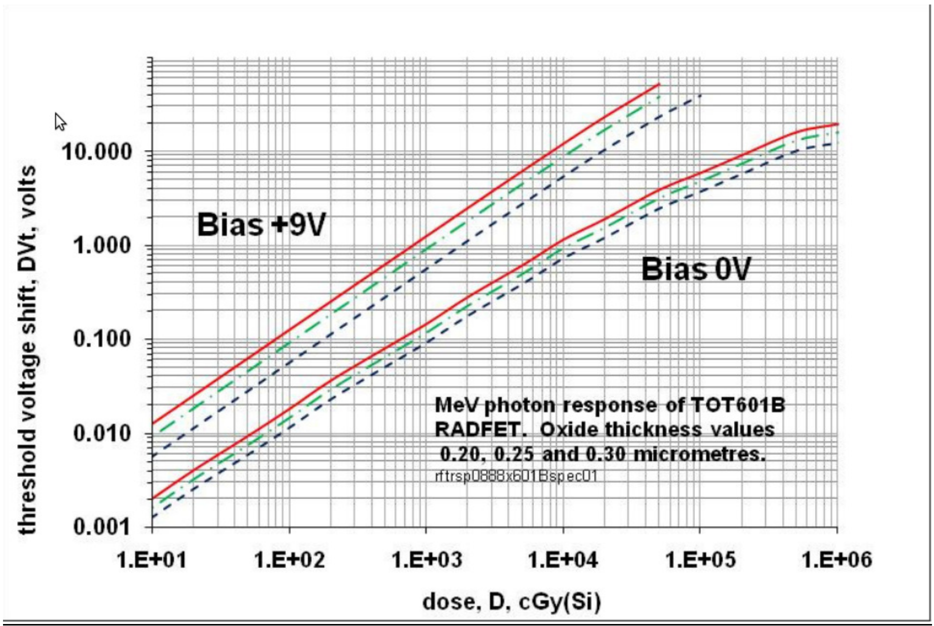

Fig. 3. Specification for shift in threshold voltage with dose of MeV photons for REM Model TOT601B RADFETs at 0V or +9V bias during exposure. Solid line: 0.30 micrometre oxide; chain dots 0.25 ; dashes 0.20. Devices with this range of response are suitable for Earth orbits and nuclear hot cells.[4]

REM RADFET TOT601B: FADE MODEL (irrad. to 1E4 cGy in 1 hr underpositive bias mode) *(See Fig. 4)*		
Anneal time	**Fade (%)**	**Remarks**
1 day	+1*	charge gain
10 day	-1	charge loss
100 day	-3	charge loss
1000 day	-5	charge loss

Table III. * "reverse annealing" a well-understood effect.

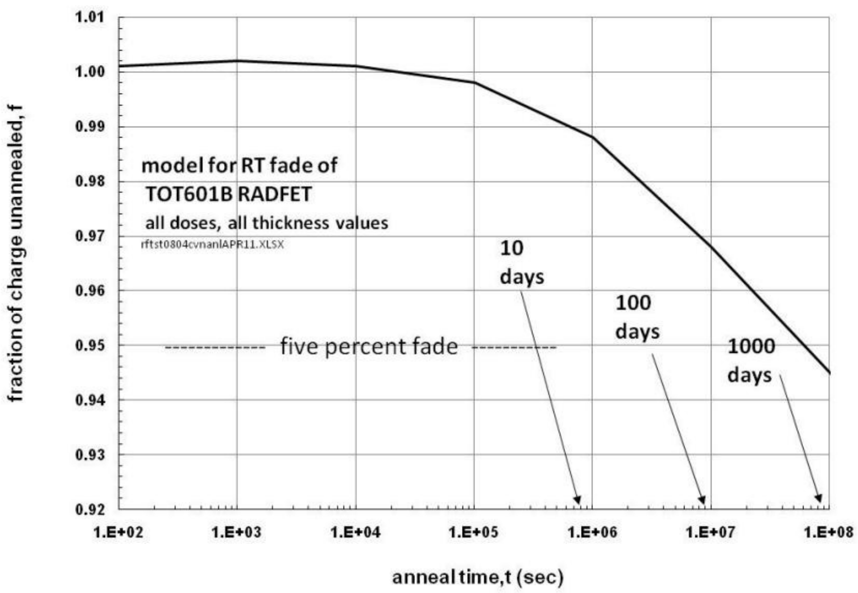

Fig. 4. Room-temperature fade or annealing curve. Typical values for all TOT601B devices (0.2 to 0.3 micrometre thickness). Irradiation in positive bias mode. A nominal figure for 100 days' anneal is 3 percent of the original Vt shift.[4,5]

The present standard rem radfet process, type tot601b, can meet the conditions of Earth orbital environments which intersect with the trapped radiation belt and can also measure conditions in high-activity hot cells.

An electrical measurement [shift of threshold Voltage] gives a relative value of dose in a silicon environment (rad or cgy(si)). The charge remains for many years. The oxide dielectric responds to all forms of particle and photon radiation in proportion to the linear energy transfer (let). Dose range varies with the gate oxide thickness and the exposure bias [3].

IX. Conclusions

The measurement of energetic charged particle environmental effects (space radiation) is fundamental for several space activities such as satellite operation and astronaut activities. The electronics for space missions must first be qualified according to their tolerance to radiation. We concluded that the RFTDAT_CC10 dosimeter logistically fits the project BR2. The inclusion of a dosimeter in the payload of the NANOSATC-BR2 satellite would enable the study and monitoring of the spatial and time variation of space radiation within the critical region of the South Atlantic Magnetic Anomaly.

X. Acknowledgements

The authors thank to the Brazilian Space Agency - AEB and to USP's LSI–Tec Association for the opportunity and grants. Also thank to Dr. Carlos Alberto Gurgel Veras, the AEB’s Director of Satellites, Applications and Development and to Dr. Nilton Morimoto for important contribution for the Program: NANOSATC-BR, CubeSats Development. The authors thank to Santa Maria Design House - SMDH, to Professors Dr. Ricardo Reis and Dr. Fernanda G. L. Kastensmidt from the Graduate Program in Microelectronics, Informatics Institute from Federal University of Rio Grande do Sul - UFRGS and to the MCTI-CNPq/INPE/PCI-PIBIC-PIBIT and FAPERGS Programs for fellowships. N. J. Schuch acknowledges to Eng. Abe Bonnema and the ISIS's Board o Directors for the grant, tutorial and logistics support at Delft for the students of NANOSATC-BR – CubeSats Development Program and to the Brazilian CNPq for grant 313865/2009-4. EE would like to thank CNPq agency for research fellowship (CNPq/PQ 301233/2011-0)

References

[1] http://core2.gsfc.nasa.gov/terr_mag/saa.html.

[2] A. Holmes-Siedle and L. Adams, "Handbook of Radiation Effects" (Oxford University Press, 2nd Edition 2002). Effects explained; Appendix D is a bibliography of research on RADFETs.

[3] data sheet RFTDAT-CC10 (REV B): Low-Fade Silicon Mosfet Dosimeter: Two Radfets, Diode & Capacitor (Lid: "Glob"). Type RFT-300-CC10G1

[4] A.G. Holmes-Siedle, "The Space Charge Dosimeter - General Principles of a New Method of Radiation Dosimetry", Nucl. Instrum. Methods 121,169 (1974). The original archival literature reference. Puts the MOSFET dosimeter in the public domain, and gives priority of invention to REM.

[5] Andrew Holmes-Siedle, Federico Ravotti and Maurice Glaser (2007). "The dosimetric performance of RADFETs in radiation test beams". NSREC07 Data Workshop, Jul. 24, 2007, Proc.Workshop Record, IEEE Cat.No. 07TH0000 (2007). Available as REM Reprint iens0701.

[6] Heirtzler, J. R., “The Future of the South Atlantic Anomaly and implications for radiation damage in space”. Journal of Atmospheric and Solar-Terrestrial Physics, pp.1701-1708. 2002.

[7] Lühr, H., S. Maus, & M. Rother, “Noon-time equatorial electrojet: Its spatial features as determined by the CHAMP satellite”, J. Geophys. Res., 109, A01306, doi:10.1029/2002JA009656. 2004.