Radiation hardness study of semi-insulating GaAs detectors against 5MeV electrons

Andrea Šagátová[1,2], Bohumír Zaťko[3] Vladimír Nečas[1], Katarína Sedlačková[1], Pavol Boháček[3], Dávid Kubanda[1] and Marko Fülöp[2]

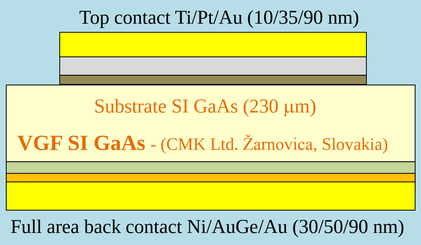
[1] *Institute of Nuclear and Physical Engineering, Slovak University of Technology, Ilkovičova 3, 812 19, Bratislava, Slovak Republic*
[2] *University Centre of Electron Accelerators, Slovak Medical University in Bratislava, Ku kyselke 497, 911 06 Trenčín, Slovak Republic*
[3] *Institute of Electrical Engineering, Slovak Academy of Sciences, Dúbravská cesta 9, 841 04 Bratislava, Slovak Republic*

Introduction

- Recent progress in radiation technology applications (nuclear power plants, hadron therapy, space applications, research accelerators) brings new requirements for the radiation hardness of used devices:
  - Electronics in the spacecraft is exposed to electrons with energies of a few MeV and fluences up to 10^{10} cm^{-2}day^{-1}sr^{-1} [1].
  - The future electron-positron collider planned in Europe [2] will be exposed to electron-positron pairs from bremsstrahlung of a dose of about 1 MGy per year.
- Our previous research on radiation-hardness of semi-insulating (SI) GaAs detectors:
  - against gamma rays: up to 1.14 MGy [3]
  - against neutrons: up to the fluency of 6.38 × 10^{13} cm^{-2} [4]
  - against elentrons: up to 104 kGy [5]
- Bulk SI GaAs detectors were irradiated by 5 MeV electrons to study their radiation hardness.
  - The influence of accumulative dose on the spectrometric properties (charge collection efficiency, energy resolution, detection efficiency) was evaluated.
  - The effect of dose rate (20, 40 and 80 kGy/h) during irradiation was also monitored.

SI GaAs Detectors

DETECTOR CROSS-SECTION VIEW



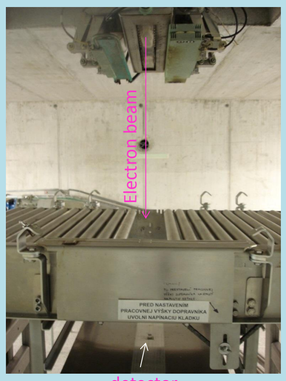
PHOTOGRAPH

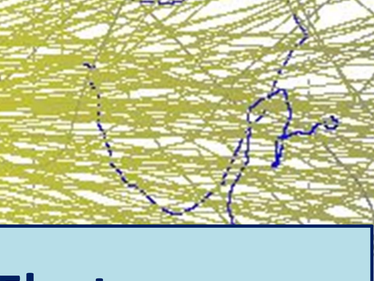
- VGF SI GaAs substrate made by CMK Ltd. Žarnovica, Slovakia
  Resistivity @ 300K: 2 × 10^7 Ωcm
  Hall mobility @ 300K: 7219 cm^2/Vs
- *Top Schottky circle contact:*
  ∅ 1 mm, Ti/Pt/Au (10/35/90 nm)
- *Back ohmic contact:*
  full-back-side, Ni/AuGe/Au (30/50/90 nm)
- *Prepared at:*
  Institute of Electrical Engineering SAS in Bratislava, Slovakia

Radiation Degradation by Electrons

At University Centre of Electron Accelerators in Trenčín, Slovakia by 5 MeV electrons:

- Detector distance from accelerator window: 95 cm
- Beam scanning width: 40 cm
- Beam scanning frequency: 0.25 Hz
- Beam diameter at sample: 8 cm
- Beam repetition rate: 10 Hz, 20 Hz, 40 Hz
- Average beam current: 8 μA, 16 μA, 32 μA
- Dose rate: 20 kGy/h, 40 kGy/h, 80 kGy/h
- Base: 1 cm thick aluminum board
- Irradiated in fifteen steps up to a cummulative surface dose of 200 kGy

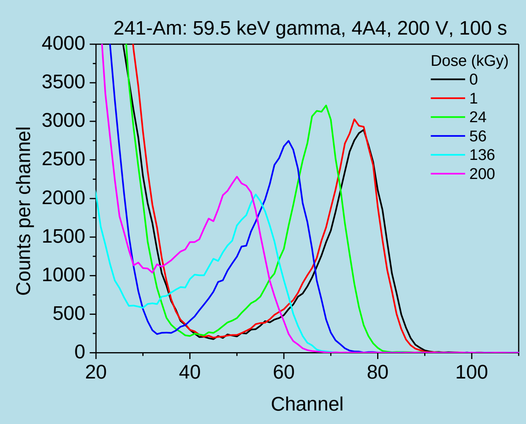


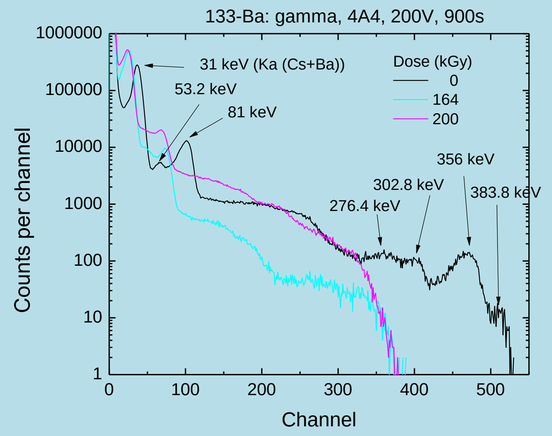


Conclusions

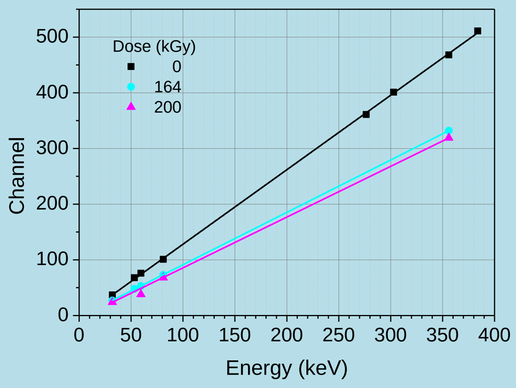
- Detector charge collection efficiency (CCE) was systematically decreasing with applied dose (from 74% to 49% at 200 V after 200 kGy).
- Gradual degradation of relative energy resolution (FWHM) with accumulative dose was observed in the range of doses of 24 up to 200 kGy.
- The global increase of detection efficiency (counts in photopeak) with applied dose can be observed with all samples.
- No significant influence of various dose rates used during irradiation on detection properties was observed.

Gamma Spectra Measurements

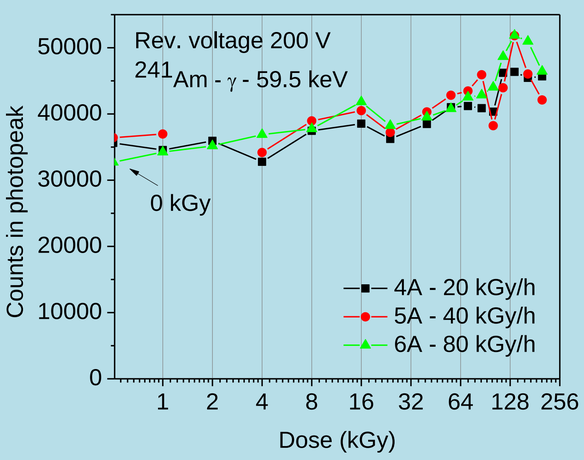


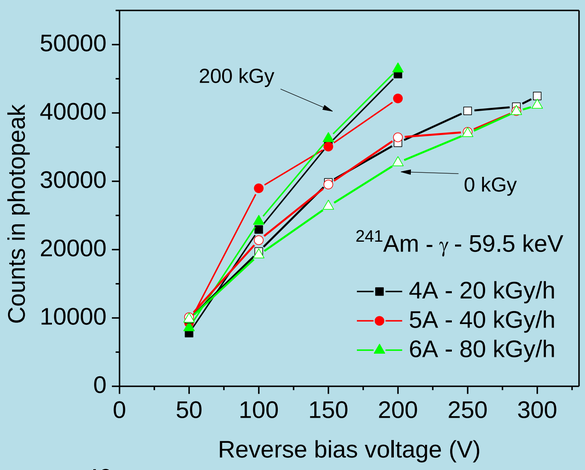


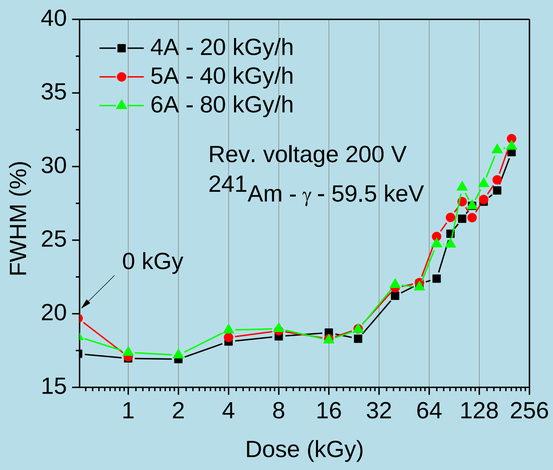
- To evaluate the detection properties of tested samples after their radiation degradation with 5 MeV electrons, the gamma spectra measurements were performed.
- We have used an ^{241}Am source with 59.5keV gamma-rays and ^{133}Ba with gamma-ray energies up to 384 keV.
- The following detection properties were studied:
  - Charge Collection Efficiency (CCE)
  - Relative energy resolution (FWHM)
  - Detection efficiency as number of counts in photopeak

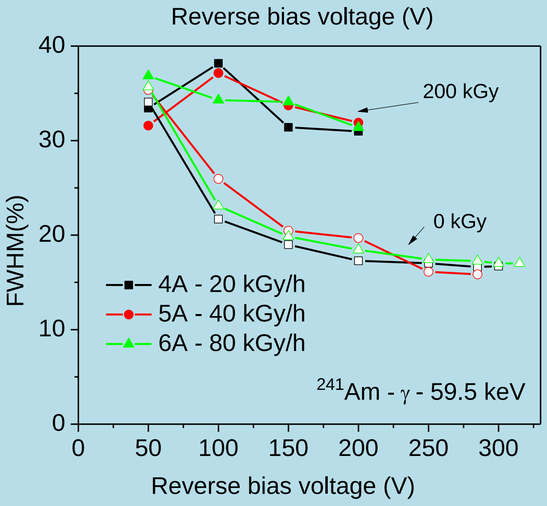


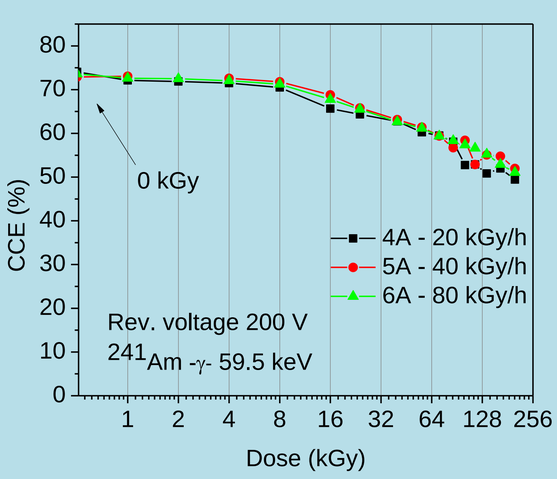
Results

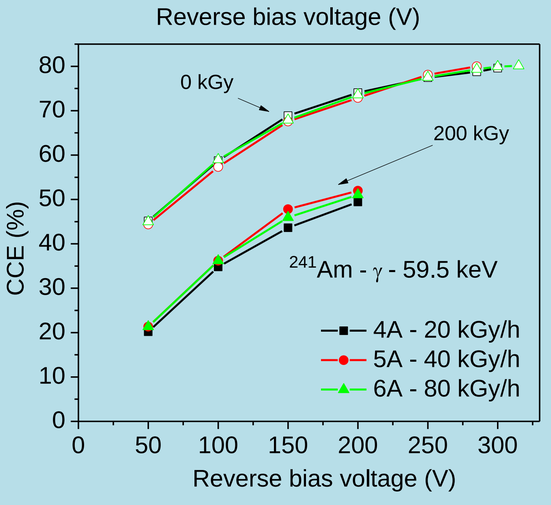




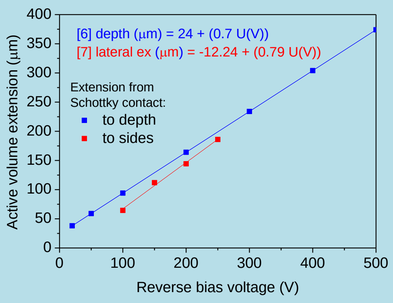


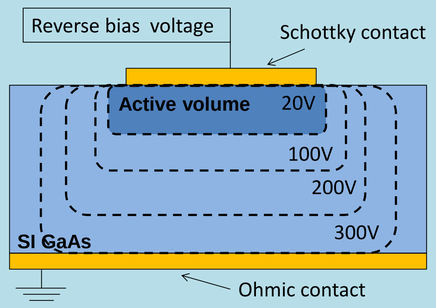






- The spreading of collecting field in SI GaAs with reverse applied voltage was observed to be linear both to depth and to the sides [6-7]:





References:

[1] Ts. P. Dachev et al.: *J. Atmos. Sol.-Terr. Phys.* **99,** 150 (2013). [2]International Linear Collider, *ILC reference design report. Volume 4 — Detectors*, http://www.linearcollider.org/about/Publications/Reference-Design-Report [3] T. Ly Anh, et al., *Nuclear Physics B (Proceedings Supplements)*, **150**, 402-406 (2006). [4] M. Ladziansky, et al., *Nuclear Instruments and Methods in Physics Research,* **A607**, 135-137 (2009). [5] A. Šagátová et al.: *JINST* **11,** C12078 (2016). [6] A. Castaldini et al.: *Nucl. Instr. and Meth.* **A410,** 79 (1998). [7] A. Šagátová et al.: In: *Applied Physics of Condensed Matter*, J. Vajda and I. Jamnický (ed.), 12.-14.6.2017, Štrbské Pleso, Slovakia, 119 (2017), ISBN 978-80-227-4699-1