Encapsulation and Segmentation of HPGe detectors at CANBERRA

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Outline

Segmentation

- Introduction
- Planar pixel and strip detectors
- Coaxial detectors

Encapsulation

- Coaxial detector
- Coaxial segmented detectors

Other associated technologies
HPGe segmentation early times …

- *First Ge detectors some 40 years ago …*
- *Segmentation was first implemented on Si detectors*

- *And first segmented planar Ge detectors in 1985*
  (Gutknecht, NIM A 288 (1990) 13)

- *Already nearly 25 years of expertise (1985)*
**HPGe segmentation: principle**

### Boron segmentation process

<table>
<thead>
<tr>
<th>STEPS</th>
<th>TOOLS</th>
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<tbody>
<tr>
<td>1. Lithium diffusion</td>
<td>Evaporator</td>
</tr>
<tr>
<td>2. Photoresist deposit</td>
<td>Spinner</td>
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<tr>
<td>3. Photoresist exposure</td>
<td>Mask aligner</td>
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<td>4. Implantation</td>
<td>Ion Implanter</td>
</tr>
<tr>
<td>5. Resist removal</td>
<td>U. S. Cleaner</td>
</tr>
<tr>
<td>6. Aluminium deposit</td>
<td>Sputtering</td>
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<tr>
<td>7. Photoresist exposure</td>
<td>Mask aligner</td>
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<tr>
<td>8. Development of metallization</td>
<td></td>
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<tr>
<td>9. Passivation.</td>
<td>Sputtering</td>
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HPGe segmented planar detectors (pad, strip, pixel)

- Segmentation offers many advantages:
  - Suppression of dead zones
  - Smallest pitch: down to 50µm
  - Good behavior at high count rates (up to 1 million pulses per second)
  - 2-sided photolithography capability, with a pitch down to 50µm
  - Possible thin contact (proprietary technology)
  - Excellent FWHM resolution: typically 150 eV at 5.9 keV
  - No measurable crosstalk

- Applications:
  - Synchrotron (EXAFS, medical beam lines)
  - Nuclear Physics
  - Non destructive control
  - Radiography
  - Compton cameras: imaging, tracking
HPGe segmented planar detectors
Example 1: 36 pixel for nuclear physics

Application: Scanning Positron Microscopy in Materials Science
- Fracture mechanics
- Precipitation hardening
- Radiation damage in multiphase systems
- Fibre-reinforced materials
- Coatings, wear, corrosion
- Degradation of current leads in microelectronic devices

Detector specifications
- Pixel pitch: 8mm
- Active surface: 48mm x 48mm
- Active thickness: 20mm
- FWHM < 1.3keV @661keV
HPGe segmented planar detectors
Example 2: 64 to 100 pixels for synchrotrons

Example of applications among others: Investigation (XANES, EXAFS) of the fine structure of: alloys, Amorphous layers (microelectronics), Pharmaceutical molecules, biological cells.
HPGe segmented planar detectors
Example 2: 64 to 100 pixels for synchrotrons

Graphic representation of the performances at 5.9keV for 12µs shaping time at 1kcps for the latest delivered 100 pixel detector (June 2009).

Mean value at 12µs/1Kcps: 129eV
HPGe segmented planar detectors

Example 2: 64 to 100 pixels for synchrotrons

Graphic representation of the performances at 5.9keV for 0.5µs shaping time at 100kcps for the latest delivered 100 pixel detector (June 2009).

Mean value at 0.5µs/100Kcps: 228eV
HPGe segmented planar detectors
Example 3: strip detector for synchrotrons

- Strip detector for detection of Compton Scattered X-rays.
  - Area: 40 x 40 x 6 mm$^3$
  - 128 strips pitch 350 µm
  - Integrated ASIC (32 ch. each)
  - FWHM: 2.5-3keV @ 122keV
HPGe segmented planar detector
Example 4: strip detector for medical applications

- Strip detector for Medical Beamlines (ESRF/France)
  - K-Edge Digital Subtraction Angiography (KEDSA): 
  - Improved image quality maintaining a low dose level (Iodine contrast agent)
HPGe segmented planar detectors
Example 5: double-sided strip detector

- DSSD detector
  - 56X-56Y DSSD
  - Strip pitch 1mm
  - Detector thickness 15mm
  - Transmission cryostat
  - Thin window technology
  - Rounded crystal corners
  - 45° tilted endcap
  - Easy dismountable Preamplifier boxes
Segmented planar detectors
Example 6: stack of X-Y strip HPGe or Si(Li)

Thin Window Strip detectors

GE X-Y 52 STRIPS TELESCOPE

2 segmented crystals with 13 strips on each side. Pitch 3mm

THIN WINDOW TECHNOLOGY

Fabricated by EURYSYS MESURES mail: dda_eurisys@compuserve.com

Recent performances obtained on 60x60x20 mm³ X-Y strip detector

- DC average: 0.92 keV @ 122 keV
- AC average: 1.08 keV @ 122 keV
Segmented planar detectors
Example 7: planar configuration for bolometry

- Large planar detectors for bolometry:
  - Edelweiss Experiment: Dark Matter search using a 320g Ge detector with inter-digitised electrodes
  - Dark matter search: heat and ionization at 10mK.
  - Ultra Low Background environment in the underground Lab of Modane
  - Energy and WIMPS interactions.
  - Exploration of new structures of contacts for better discrimination of surface effects.

Germanium detector for EDELWEISS
Segmented planar detectors
Example 8: Si(Li) detector

- True Well design with LTS detectors segmented Si(Li)
- Detector Array for micro PIXE applications

Results of micro PIXE: Potassium distribution in a mosquito leg

Three element true well design with LEGe detectors
Segmented coaxial detectors

**Highlights:**
- Monolithic longitudinal / transverse / front segmentation
- No dead zone
- No crosstalk effects
- High granularity
- Tracking capability
- Doppler effect correction

**Applications:**
- Nuclear physics:
  - doppler correction (MSU)
  - tracking (AGATA/GRETA)
- Imaging: 3 D (segmentation + pulse shape analysis)
- Compton and beta decay suppression
Segmented Coaxial Detectors
Example 1: 32 segments

- SeGA detectors at MSU (USA):
  - Total of 18 detectors.
  - Typical “golf player” cryostat.
  - Versatile configuration as a $4\pi$ gamma box
Several segmentation patterns are possible to best fit our customer’s expectations.
Segmented coaxial detectors
Clover configuration

- Clover detectors
  - High photopeak efficiency in “add-back” mode
  - Good energy resolution
  - Good timing response
  - Reduced vulnerability to neutron damage
  - Reduction of Doppler broadening improved when using segmented crystals
  - Good sensitivity to Gamma ray polarization

199 clover detectors delivered in many countries

Exogam clover detector
Outline

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Encapsulation

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- Coaxial segmented detectors

Other associated technologies

Summary
Encapsulated HPGe detectors

**Highlights:**
- Reliability
- Easy mounting/exchange
- Compact assembly
- Wide range of shapes
- On-site annealing without pumping

**Applications:**
- Nuclear Physics:
  - Euroball Cluster - Miniball Rising
  - Greta / Agata
- Space:
  - Integral (ESA)
  - Mars (NASA)
- Airborne.
- Industrial: rough motion applications

More than 290 capsules delivered in many countries
Encapsulated HPGe detectors
Example 1: EUROBALL

- Euroball cluster detector: first 7 capsule array detector.
  - Unsegmented 300cc N type detectors
  - Total efficiency at 1.33MeV: 7x 55% x 1.4 = 539%
  - More than 150 units delivered and still in operation
Encapsulated HPGe detectors
Example 2: INTEGRAL/SPI

Space applications: INTEGRAL/SPI spectrometer

- An array of 19 encapsulated Ge detectors
- 16 still in operation
- Relative efficiency 40% each
- Crystal to crystal gap: 3.5mm

Figure 3: SPI spectrum of the locally induced gamma-ray lines by solar flare protons. This spectrum illustrates the excellent spectral capabilities of SPI. Courtesy: J. Knödlseder and the SPI team.
Encapsulated HPGe detectors
Example 3: Mars Odyssey/GRS

MARS Odyssey

- Titanium canister
- First traces of water on Mars
Encapsulated HPGe detectors
Example 3: Kaguya GRS

- SELENE Moon Project: “KAGUYA”
  - SELenological and ENgineering Explorer using a CANBERRA Aluminium canister for gamma fluorescence on Moon.
Encapsulated + segmented HPGe detectors
Example 4: AGATA

AGATA canister:
- 3 shapes
- Ge crystal dimensions:
  - Diameter 80mm
  - Length 90mm
  - Outer contact segmented in 36.
Encapsulated + segmented HPGe detectors
Example 5: GRETA

- GRETA Quad detector:
  - 2 shapes, 4 detectors per cryostat
  - Crystal configuration:
    - Diameter 80mm
    - Length 90mm
    - Outer contact segmented in 36.
  - Phase 1: GRETINA 7 quadruple detectors (demonstrator)
Other technologies developed by CANBERRA
Point contact detectors

- CANBERRA detectors for ultimate noise edges:
  - Modified-Electrode P type Point Contact Ge Detectors (PCGe) in ULB cryostat.
  - With high performances low energy threshold central contact.
  - Best performances at low & high energies close to theoretical values.
  - External AC coupled preamp for veto and spectrum cleaning.
  - Several low capacitance Ge detectors with a 130eV FWHM with test pulser, already in use.
  - Active sizes from 500g up to 1000g
  - Applications: new innovative tool in astroparticle & neutrino physics by direct interaction measurement within the Germanium detector. Double-beta decay, neutrino magnetic moment and WIMP searches.

Detector performances: FWHM Vs energy

<table>
<thead>
<tr>
<th>TEST (pulser)</th>
<th>60 keV</th>
<th>122 keV</th>
<th>1.33MeV</th>
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<tr>
<td>130 eV</td>
<td>360 eV</td>
<td>500 eV</td>
<td>1.68 keV</td>
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Thank you for your attention