Multichannel Silicon Drift Detectors for High Speed, High Resolution X-ray Spectroscopy Applications

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Silicon Drift Detector – a success story

Silicon drift detector
- introduced by Gatti and Rehak in 1984
- revolutionized the spectroscopy world in the last ten years (the “smart phone” among the spectroscopic detectors)

SDDs manufactured by PNDetector / PNSensor
- first SDDs to serve the industry and the research
- monolithic integration of 1st amplifying FET
  - minimization of the input capacitance (down to 50 ff)
  - excellent energy resolution at high count rate
  - robust against pickup, microphony
- ultra-clean fabrication technology leading to low leakage current values $I_{\text{leak}} < 100 \text{ pA/cm}^2$ @ RT
- in 2013/2014 a new manufacturing line has been built and is being qualified
Single channel SDDs

Standard round geometry (SDD):
- Anode and FET in the center of the device
- Radial drift fields
- Sizes: 5, 10, 20, 30, 60, 100 mm²

Droplet type geometry (SD3):
- Displaced anode and FET
- Reduced input capacitance
- Improved peak to background
- Sizes: 5, 10, 20, 30 mm²
Single channel SDDs

Spectroscopic performance at the theoretical limit

**Excellent performance at high photon count rates**

\[ ICR_{\text{max}} = \frac{1}{2 \cdot 2.7 \cdot t_{\text{sh}}} \]

- \( F \text{whm}_{\text{opt}} \leq 126 \text{ eV} \)
- \( F \text{whm}_{\text{opt}} \leq 122 \text{ eV} \)

A. Niculae, Paris, 16th of March 2015
Single channel SDDs

Excellent light element performance due to low noise and optimum EW

- energy resolution at C-K down to 37 eV
- energy threshold < 50 eV
Multi-channel SDD detectors

Focus on customized detector solutions – multi-channel SDDs are part of it.

Why multi-channel SDDs?

Applications requiring multi-channel SDD detectors:
1. Good spectroscopic performance at ultra-high count rates (e.g. > 1 Mcps)
   „a sorrow shared is a sorrow halved“
2. Special geometry for optimum collection of the incoming photons
3. Spatial resolution for the incoming x-rays and γ-rays

Advantages of monolithically integrated SDD arrays
- Minimum dead area between the cells
- Flexible design of the cells
- Compact packaging of the whole detector
Multi-channel SDD detectors

Applications requiring multi-channel SDD detectors:

1. Good spectroscopic performance at ultra-high count rates (e.g. > 1 Mcps)
   
   „a sorrow shared is a sorrow halved“

2. Optimum geometry for high collection efficiency of the incoming photons

3. Spatial resolution for the incoming x-rays and γ-rays
Multi-channel SDDs for ultra-high count rates

Rococo1 - 4-channel SD3 detector

- active area 4 x 10 mm²
- SD3 topology - excellent energy resolution
- light element detection down to Be or lower
Multi-channel SDDs for ultra-high count rates

Compact 7-channel SDD detector

- active area of 7 x 10 mm²
- maximal count rate capability of $7 \cdot 10^6$ cps
- allow compact packaging on socket with Peltier cooler

Fe55 spectra of all 7 channels (no collimator)

FWHM @ Mn-Ka: 135 - 137 eV
Multi-channel SDD detectors

Applications requiring multi-channel SDD detectors:

1. Good spectroscopic performance at ultra-high count rates (e.g. > 1 Mcps)
   "a sorrow shared is a sorrow halved"

2. Optimum geometry for high collection efficiency of the incoming photons

3. Spatial resolution for the incoming x-rays and γ-rays
Multi-channel SDDs for high collection angle

Rococo2 – 4-channel SD3 detector with central hole

- ideal as pole-shoe EDX detector in SEM / TEM

Comparative SEM elemental maps

- same acquisition time
- up to 100x more photons collected with the Rococo2 detector

Solid angle coverage
Multi-channel SDDs for high collection angle

Rococo2 – 4-channel SD3 detector with central hole

- ultra-fast XRF analysis (“in-line” QC) in combination with poly-capillary optics
- high throughput measurements

- active area 60 mm²
- input count rate > 2·10⁶ cps
Multi-channel SDDs for high collection angle

Rococo2 – 4-channel SD3 detector with central hole

- concept for a flat configuration for Nano-Beam XRF
- detector package can be less than 1 cm thin
Multi-channel SDDs with large collection area

Large area SDDs for synchrotron experiments:

- 3x100 mm$^2$ SDDs (1 sensor packaged)
- 6x100 mm$^2$ SDDs (2 sensor in a package)
Multi-channel SDDs with large collection area

Large area SDDs for synchrotron experiments:

- 3x100 mm² SDDs (1 sensor packaged)
- 6x100 mm² SDDs (2 sensor in a package)

Several systems installed at various beam lines (ANKA, DLS, ESRF)
Multi-channel SDD detectors

Applications requiring multi-channel SDD detectors:

1. Good spectroscopic performance at ultra-high count rates (e.g. $> 1 \text{ Mcps}$)
   
   „a sorrow shared is a sorrow halved“

2. Optimum geometry for high collection efficiency of the incoming photons

3. Spatial resolution for the incoming x-rays and $\gamma$-rays
SDD arrays for x-ray / $\gamma$-ray imaging and spectroscopy

- 19-cell array
- 6-cell linear array
- 61-cell array
- 77-cell array

the SDD arrays can be combined with scintillators for $\gamma$-ray imaging
Thank you for your attention!