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HELPFUL RESOURCE:

The role of Semiconductor Detectors in the future of nuclear medicine



IN MEMORY OF...



A. Bertrand (Randy) Brill, M.D. Ph.D. 12/19/1928 – 2/13/2023

Conducted imaging research with Si(Li), Ge(Li), and HPGe detectors beginning in the late 60s







ADVANTAGES OF SEMICONDUCTOR DETECTORS

- Direct conversion avoid scintillator problems (# of steps, photodetector quantum eff., etc.)
- Compact
- Energy resolution (Fano factors ~0.05 0.2)
- Photolithography used to create pattern of electrodes on device



OPTIONS FOR CAMERAS

		Attenuation		Mobility-	lifetime	
	Density	@ 140 keV	Energy per	Electron	Hole	
	(g/cm ³)	(cm ⁻¹)	e-h pair (eV)	(cm ² /V)	(cm²/V)	•1
Si	2.33	0.02	3.61	0.42	0.22	
Ge	5.32	0.72	2.98	0.72	0.84	
CdTe	5.85	3.22	4.43	3×10 ⁻³	5×10-4	
CdZnTe	5.82	3.07	~5	3×10-3	5×10-5	
HgI ₂	6.40	8.03	4.20	<10-2	5×10-5	_



CHALLENGES WITH SEMICONDUCTOR DETECTORS

- Large number of channels
- Interconnects
- Hole trapping (CdTe/CZT)
- Charge sharing (& charge loss)





PIXELS VS STRIPS





Common Cathode

- N² channel count
- Single-sided processing
- Complicated interconnects and signal routing
- Tile to cover larger area



- **Strip Cathode**
- 2N channel count
- Double-sided processing
- Connect near edges
- Transmission configuration



CLINICAL CZT CAMERAS

Direct Anger camera replacement:



Modular scanning columns:







HIGH-PURITY GERMANIUM (HPGe) DETECTORS

- Germanium detectors are long-time gold standard for gamma-ray spectroscopy
- Early attempts at medical imaging in early 70's
- Contacts/segmentation challenging

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• Chief drawback: requires cryogenic temps (LN₂)



McCready et al., 1971 Semiconductor Detectors in the Future of Nuclear Medicine



SELECTIVE RECENT HISTORY OF HPGe

- Luke & Amman LBNL (~2000) amorphous contacts
- Burks, Hull, Mihailescu, Vetter LLNL (~2004) signal interpolation
- Peterson Vanderbilt (2009) DOE grant: "Small-animal SPECT/CT System Based on Position-sensitive Semiconductor Detectors"
- Hull PHDS (2011) NIH SBIR grant: "Germanium Gamma Cameras"

→ HPGe mechanically-cooled double-sided strip detectors





EVOLUTION OF HPGe DSSDS













ENERGY RESOLUTION





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IMAGING THERAPEUTIC RADIONUCLIDES



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CURRENT DEVELOPMENTS & FUTURE CONSIDERATIONS

- Larger detectors
- Higher temperature operation
- Waveform processing
- Optimizing strip (pixel?) pitch







HPGe BRAIN SPECT CONCEPT





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