

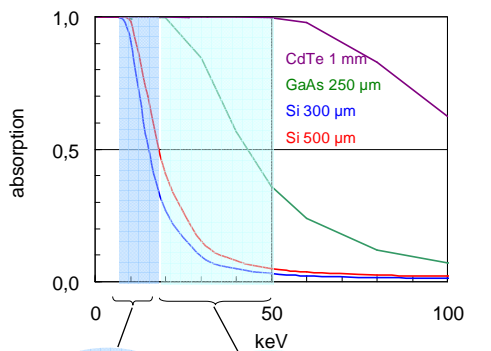
Overview of GaAs for pixel detectors

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Outline

- Advantages of GaAs
- GaAs providers, reported results
- Conclusions

Advantages of GaAs for SR pixel detectors



High X-ray absorption in the 20–50 keV range

Room-temperature operation ($E_g=1.42$ eV)

Industrial availability of 4'' and 6'' wafers

Chemical and physical stability

Compatibility with microelectronics technologies

soft condensed matter

materials science

Some physical data

	Si	GaAs
density (g/cm ³)	2.33	5.32
Z	14	31–33
Native type	n	n
E_g RT (eV)	1.12	1.42
EH pair creation energy RT (eV)	3.6	4.2
μ_{e^-} RT (cm ² /V.s)	1500	8000 (epi-GaAs)
μ_{h^+} RT (cm ² /V.s)	1400	400
τ_{e^-} RT (s)	10^{-5}	?
τ_{h^+} RT (s)	10^{-5}	10^{-6}

Main GaAs providers

FCM (Germany)	semi-insulating
METOREX (Finland)	epitaxial
GESEC (France)	epitaxial
CMK Ltd (Slovakia)	semi-insulating

Others (non-European) :

Hitachi cables (Japan, USA) semi-insulating + epiwafers

AXT (China, USA) : semi-insulating + epiwafers

...

FCM

LEC and VGF process, semiconducting (optoelectr.) or semi-insulating (microelectr.)
3" to 6" wafers

- 300 μm sensor on Medipix1 (170 μm pixel) and Medipix2 (55 μm pixel) (Univ. Freiburg, 2005)

Hall mobilities $\sim 2\text{--}4 \times 10^3 \text{ cm}^2/\text{Vs}$
X-ray images could be made (60 kV tube)
Non-uniform response
Incomplete CCE
Full depletion not reached at +270 V bias (dead layer)
BB defects at 55 μm pitch, few defects at 110 μm pitch
Energy threshold $\sim 20 \text{ keV}$?

METOREX

CVD epitaxial growth up to 400 μm thick

Reported tests and results :

· 5x5 and 32x32 matrixes (350 μm pixels) 325 μm thick epi on SI GaAs substrate tests at Hasylab (ESA/ESTEC, 2001)

energy threshold 1.3 keV (spectroscopic instrumentation)
estimated (?) CCE = 98%
breakdown voltage 80 V @ RT
slight $\Delta E/E$ improvement from RT to +5°C
but : layout not suitable for pixel chips (inactive SI layer on frontside)

· 100 μm thick self epi 55 μm pitch (Medipix2) (CERN/Medipix2 collab., 2007)

Good spectroscopic response (\geq Si) in the range 8–25 keV
(nearly) full depletion achieved
Low BB defects

GESEC

Epitaxial growth by “close vapor transport” process
4” wafers up to 400 μm thick
Fast growth rate (thus potentially cheap) up to 6 $\mu\text{m}/\text{minute}$

· 300 μm thick self-standing epi-GaAs diode (univ. Glasgow, 2005)
2 versions tested : Schottky/Ohmic, ion implanted p+in+
Carrier concentration $\sim 10^{13} \text{ cm}^{-3}$
 $I_{\text{leak}} = 2 \text{ nA/mm}^2$ @ 50 V bias
Max. CCE = 80 % at +80 V bias

Ongoing project with ESRF to evaluate pixel diodes with Medipix2
Impurity compensation by high energy e⁻ irradiation

CMK

2" SI wafers, VGF and LEC process

- GaAs diodes characterizations (IEE Bratislava, CZ)

Impurity level < 245 ppb atomic ($\sim 1e16 \text{ cm}^{-3}$)

Hall mobility $7 \times 10^3 \text{ cm}^2/\text{V.s}$ at RT

Comparison multilayer vs. alloyed contacts

Comparison LEC vs. VGF

No pixel layouts tested

Conclusions

55 μm pixel pitch achieved by 2 independent teams. For one, high BB yield

2 materials, epi and SI :

- X-ray images could be obtained with both

- epi :
+ 8-50 keV range
+ homogeneous
+ high CCE (low impurity and native defects content)
+ complete depletion achieved
- expensive ?

- SI :
+ large wafers (6") available (FCM - VGF only, Hitachi)
+ cheaper than epi
- ~20 keV minimum energy : improvable ?
- incomplete CCE (impurity content)
- inhomogeneous
- dead layer (incomplete depletion)

Prospects for further developments

- Compare METOREX and GESEC epi-GaAs pixel sensors
- Attempt 6" wafer self-standing epi (possible ? METOREX ?)
- Optimize SI GaAs growth to reduce impurities (CMK ? FCM ?)
- Optimize contacts technology
- Make diode structures for electron collection (better transport characteristics ?)

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