Overview of GaAs for pixel detectors

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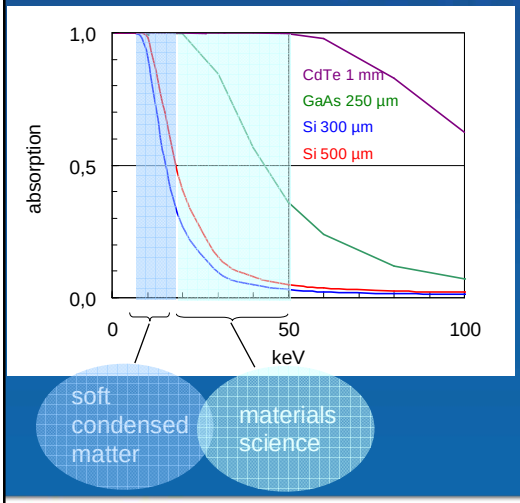
Outline

- 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 (Eg=1.42 eV)

Industrial availability of 4'' and 6'' wafers

Chemical and physical stability

Compatibility with microelectronics technologies

Some physical data

	Si	GaAs
density (g/cm3)	2.33	5.32
Z	14	31-33
Native type	n	n
Eg RT (eV)	1.12	1.42
EH pair creation energy RT (eV)	3.6	4.2
µ e- RT (cm2/V.s) µ h+ RT (cm2/V.s)	1500 1400	8000 (epi-GaAs) 400
τ e- RT (s) τ h- RT (s)	10^{-5} 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 ~2-4x10^3 cm^2/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 ~ 20 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 ΔE/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 (≥ 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 µm/minute

- 300 µm thick self-standing epi-GaAs diode (univ. Glasgow, 2005)
  2 versions tested : Schottky/Ohmic, ion implanted p+in+
  Carrier concentration ~ 10^{13} cm^{-3}
  I_{leak} = 2 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 (~1e16 cm^{-3})
  Hall mobility 7x10^3 cm^2/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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