MICRONOVA
Centre for Micro and Nanotechnology

GaAs Medipix 2 Hybrid Pixel Detector

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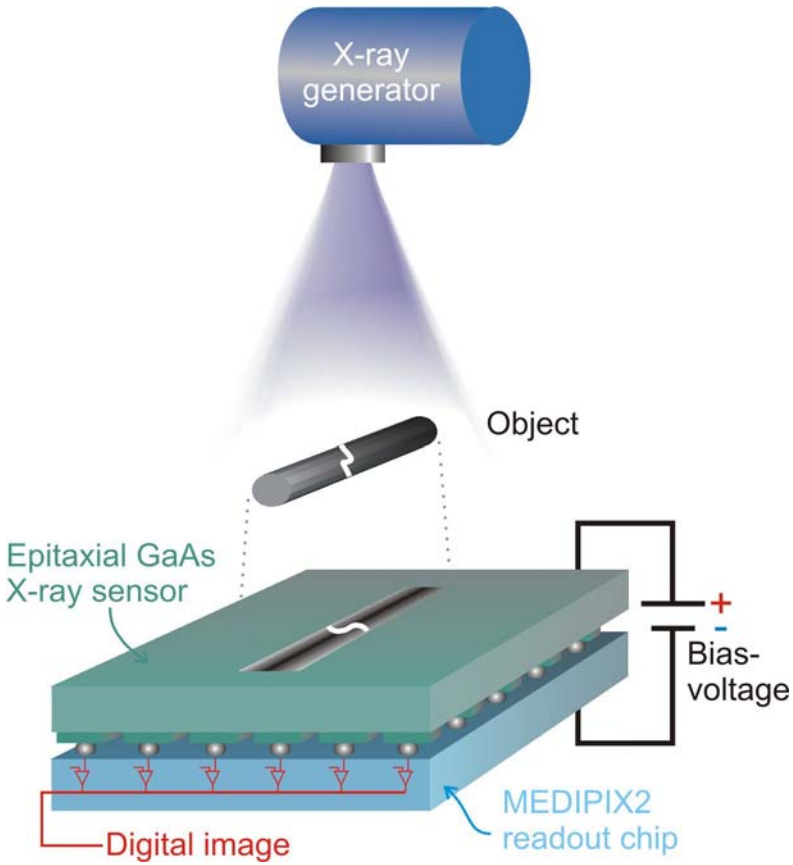
Detector System Schematic



- All epitaxial GaAs sensor
- Thickness 110 μm
- Medipix2 photon counting read out chip *
  - 256 x 256 (=65536) pixels
  - 55 x 55 μm^2 pixel size
  - Active area ~2cm^2
  - Positive or negative signal input

* X. Llopart, et. al., Nuclear Science, IEEE Transactions on, vol 49, Issue 5, Oct. 2002 pp. 2279 – 2283v

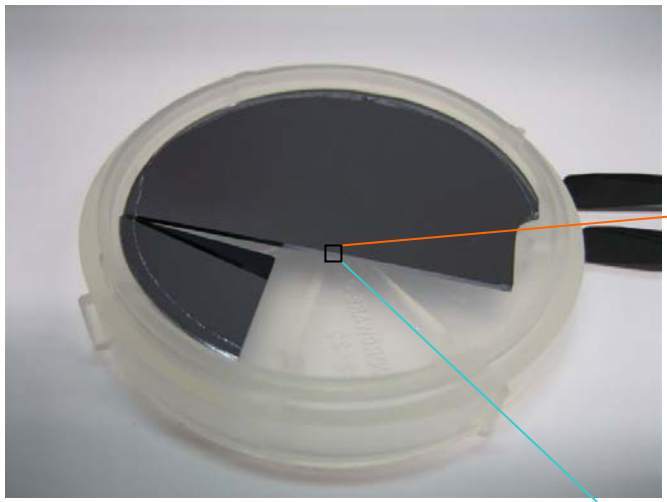
Why GaAs?

- Better electrical properties (mobility, band gap) than Si
- Absorption efficiency of GaAs for X-rays is significantly better at 10-100 keV compared to silicon
- E.g. Si 700 μm and GaAs 300 μm @ 50 keV >> GaAs absorbs 10x more

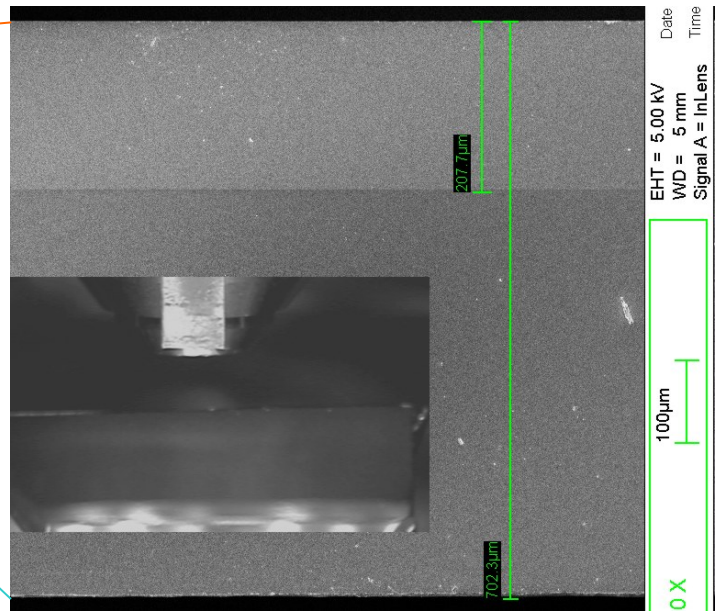
Epi-GaAs Material

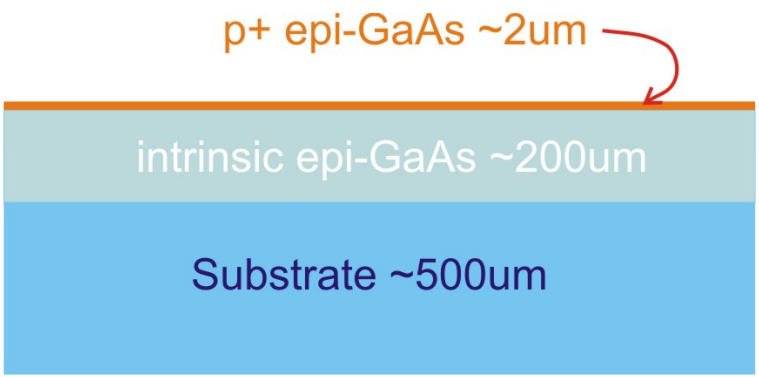
- Hydride vapor phase epitaxy
- High purity and low defect concentration
- Relatively high growth rate up to ~50um/h
  - Epi-layer thickness typically >200um
- Energy resolution 200-250 eV @ 5,9 keV with pad type detectors
- Depletion width max ~200 μm (@ -20°C)
- Good charge collection efficiency

Epi-GaAs Material

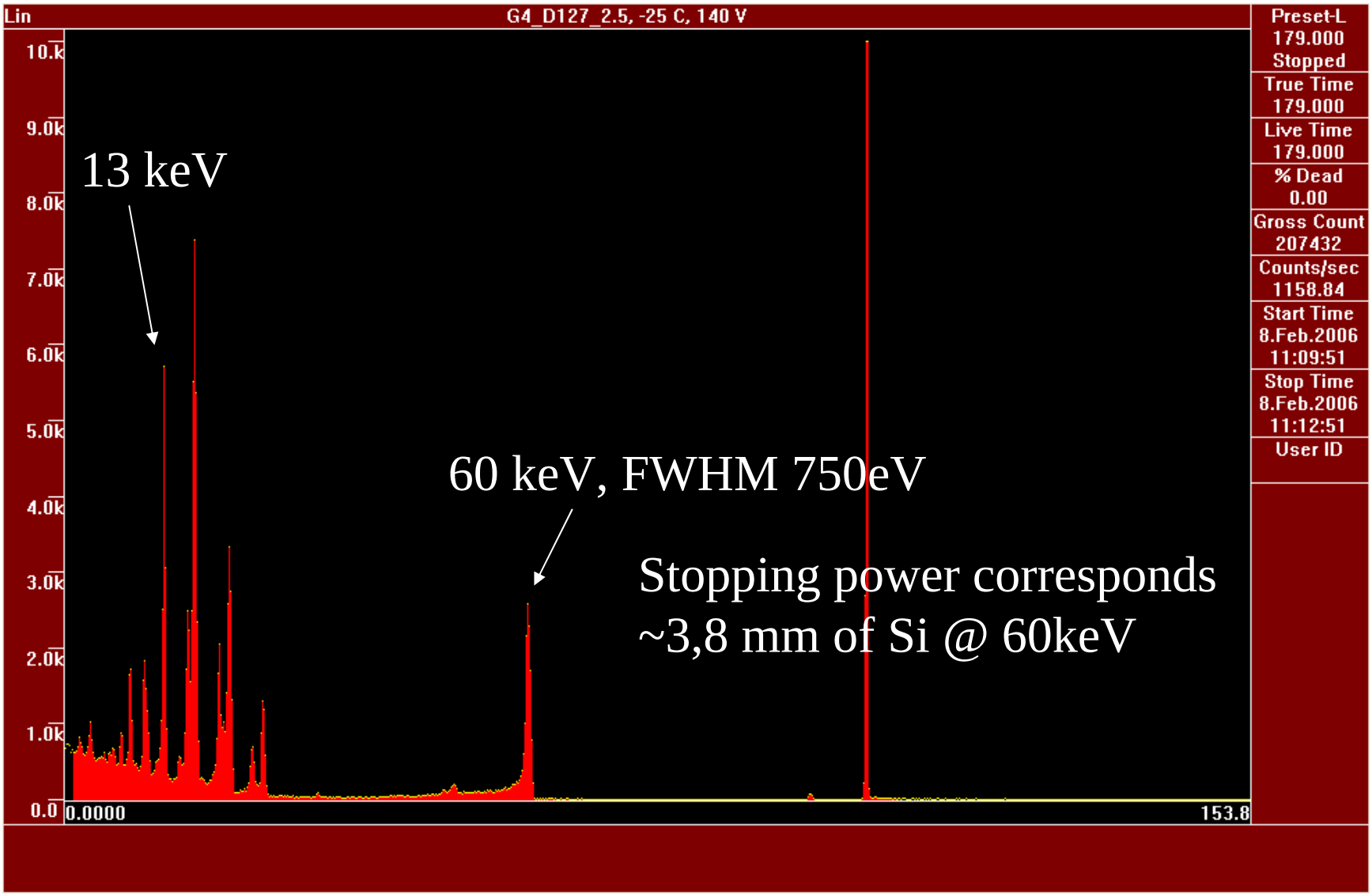


HVPE GaAs on 50mm substrate





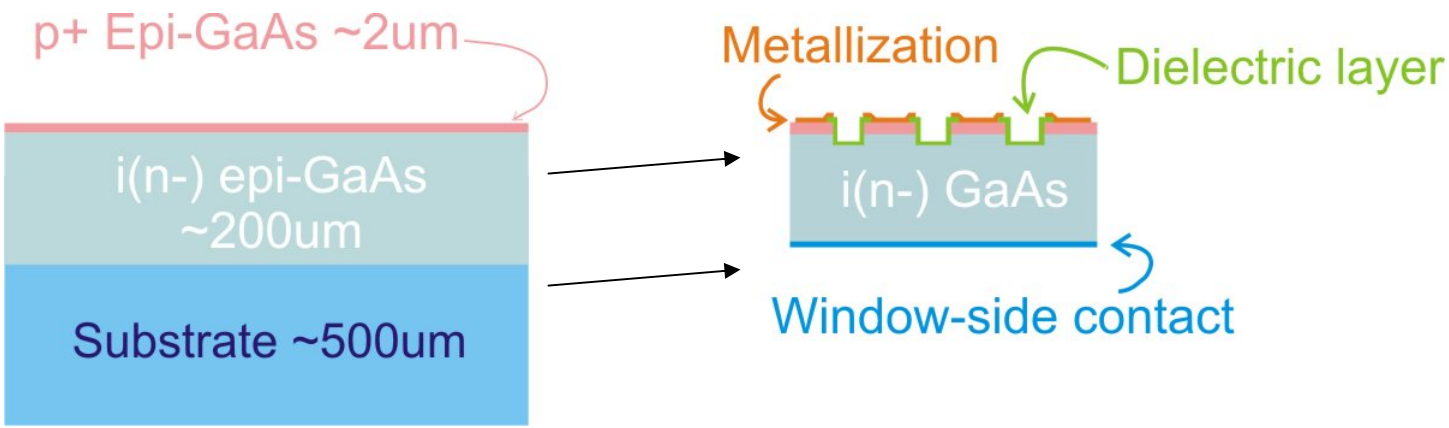
Am-241 Spectrum (pad detector)



Thin Detector Processing

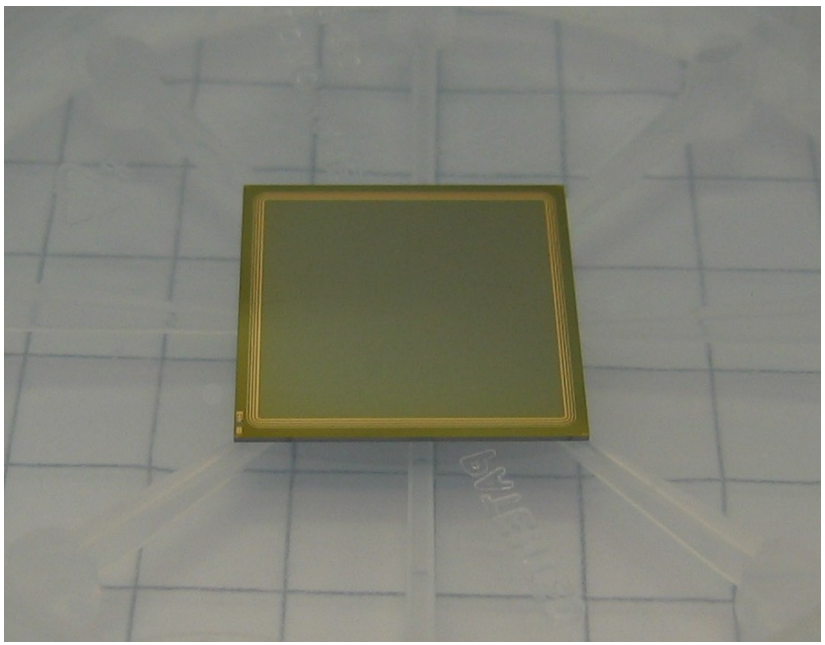
Different processing schemes under study but in general

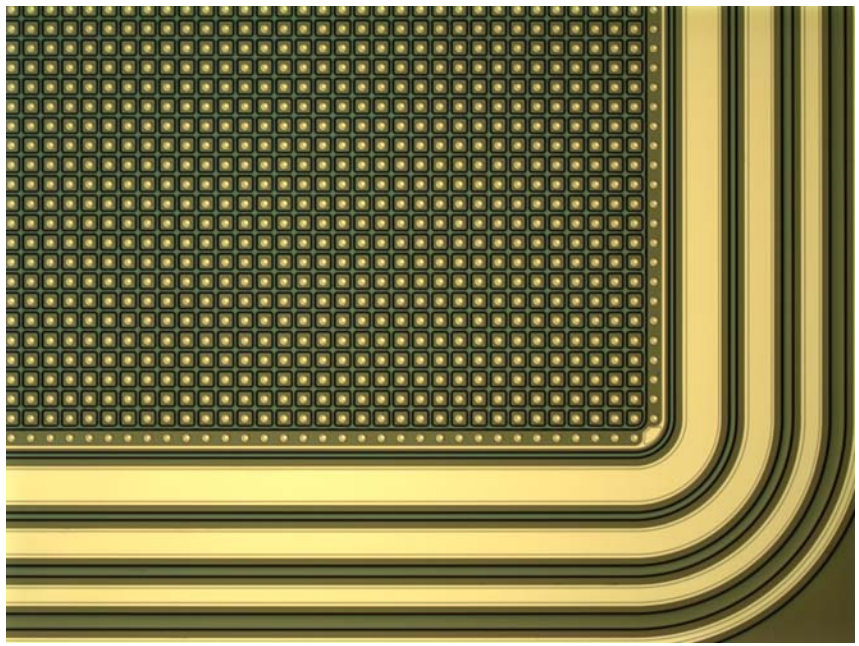
1. Cleaning
2. Mesa etching (ICP-RIE)
3. Passivation
4. Metallization
5. Thinning (target <200 μm)
6. X-ray window metallization



Micrographs of the sensor

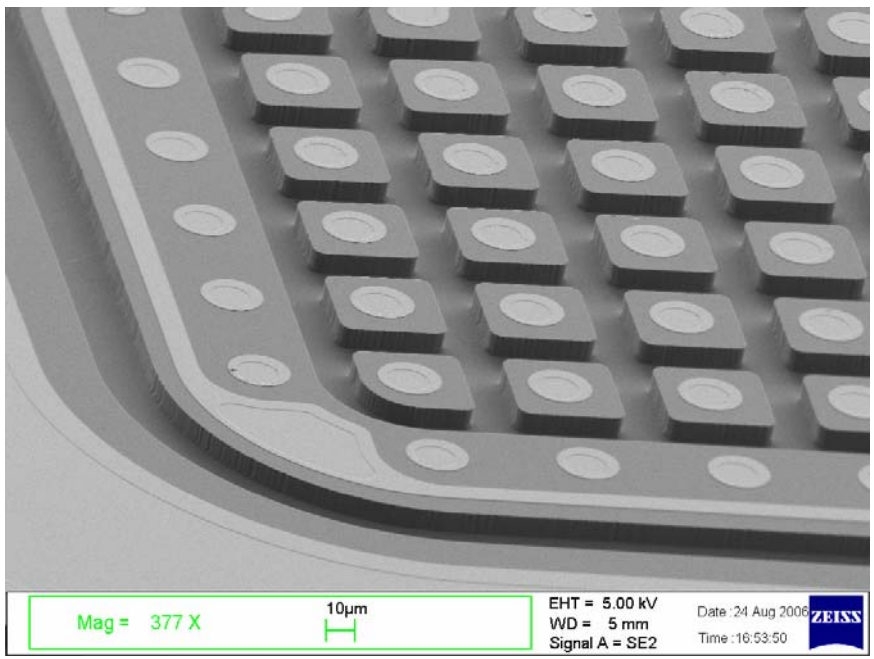
- Process for manufacture of thin (~100μm) all epitaxial sensors developed
- Good quality sensors obtained

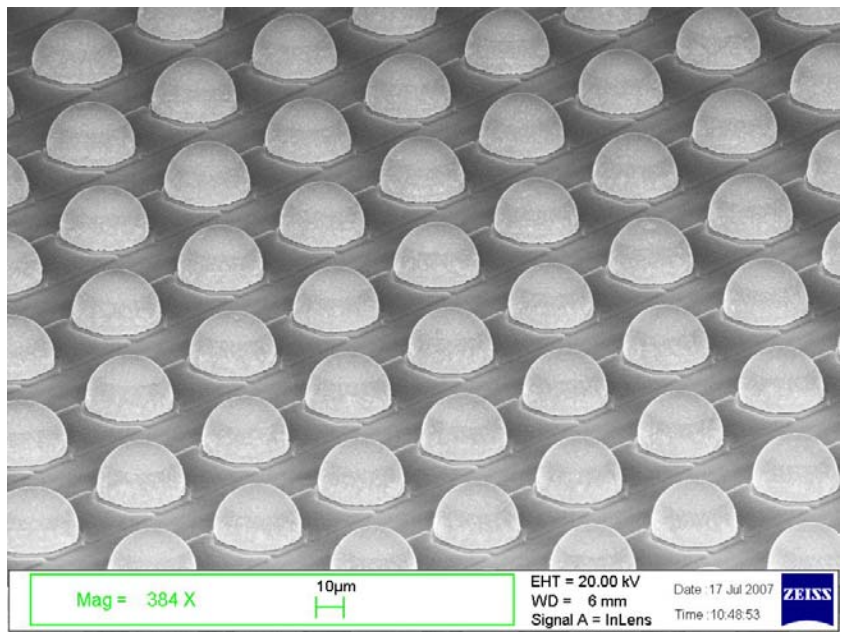




Bump bonding

- Bump bonding was done with Karl Süss FC150 Flip Chip Bonding Tool at VTT
- Bumps only on the read out chip
- Pb-Sn eutectic solder was used for bonding

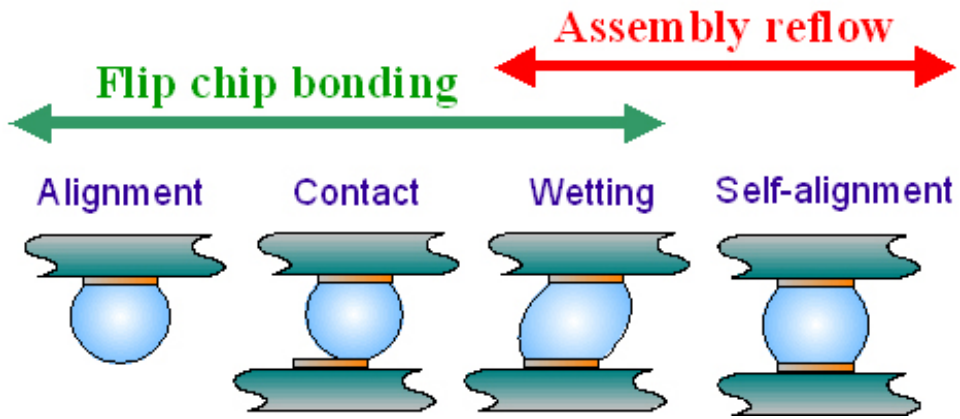




Bump Bonding

Process flow

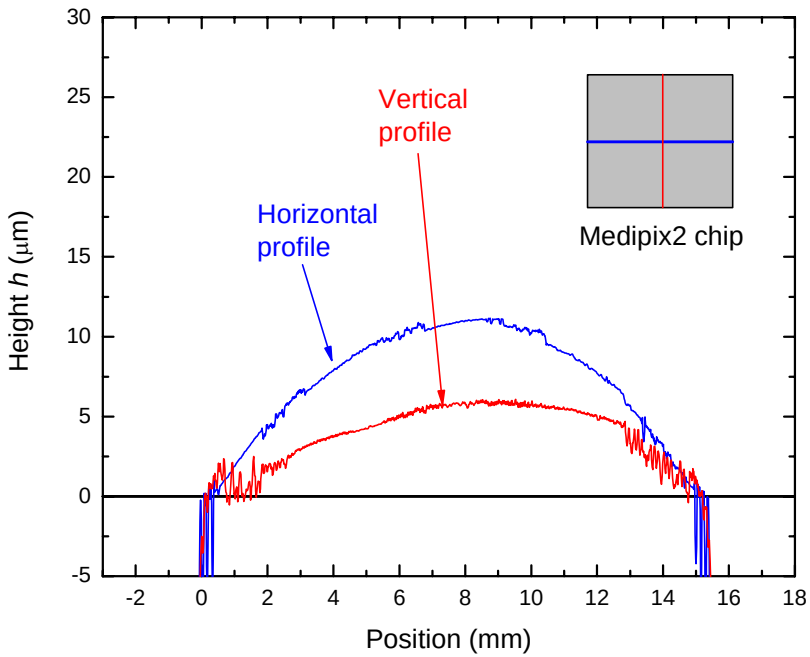
- Preliminary alignment
- Detector and readout chips are adjusted exactly parallel
  - Sensor was not planar
- Lateral alignment (x,y, q)
- Thermo compression of softened bumps
- Cooling
- Assembly reflow

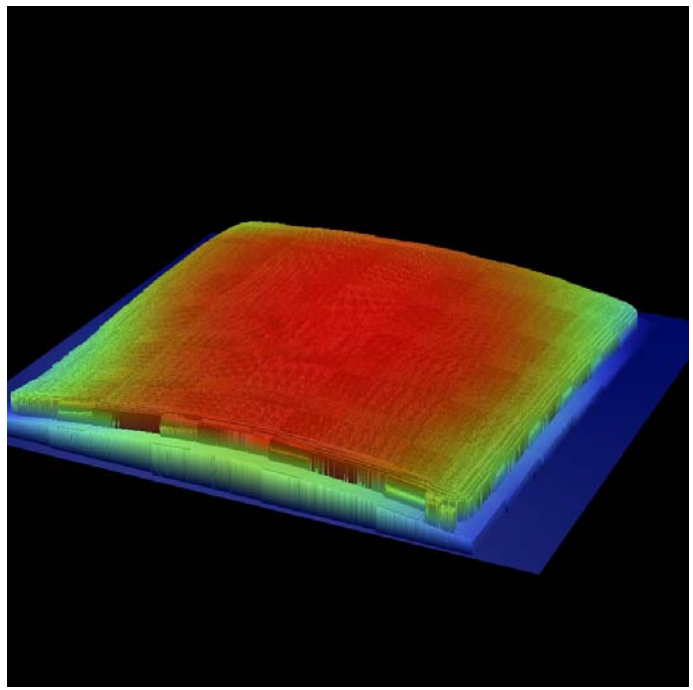


* S. Savolainen-Pulli, et. al., Experiences in flip chip production of radiation detectors, Nuclear Instruments and Methods in Physics Research A 565 (2006) 314–319

Profile of the Pixelated Side

- The bow is due to inhomogeneous growth rate
- Not a problem for small component size

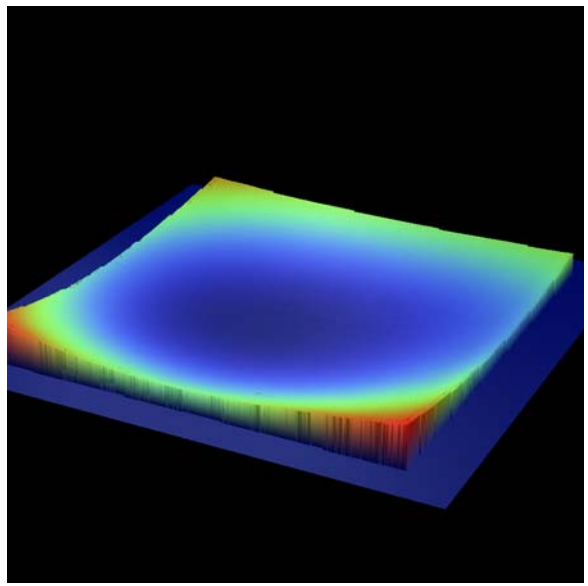




Profile of the X-ray Window Side

- The sensor element was fixed with thermo wax to a glass substrate
- Stress exists in the epi-layer
- The sample may have been strained during lapping

Bowing is order of 5 μm at the window side



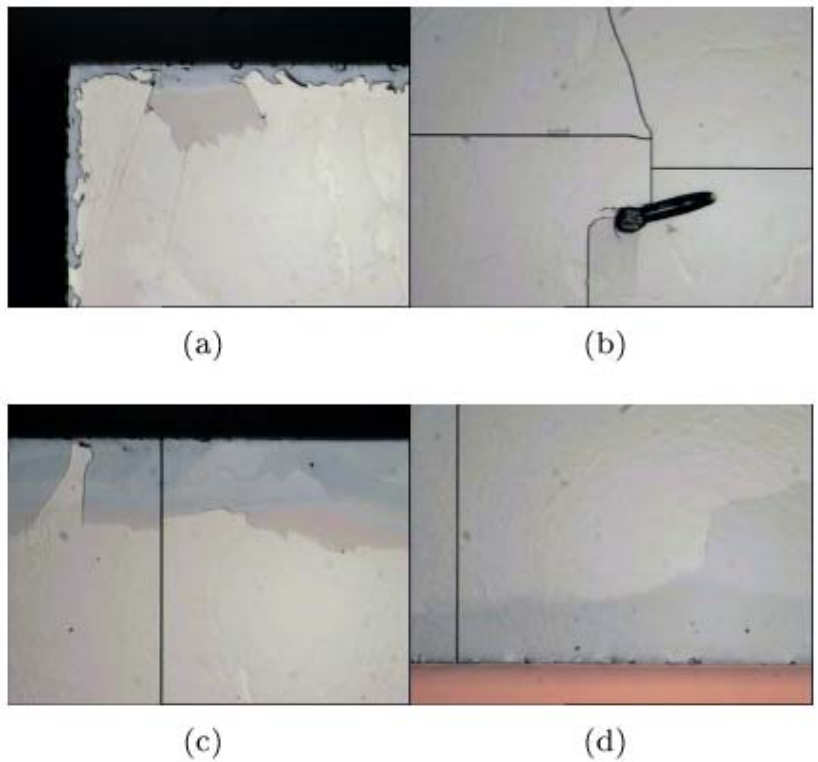
Thermal expansion

- Coefficients of thermal expansion
  - $\alpha_{GaAs} = 5{,}73*10^{-6}\ cm^{-1}$
  - $\alpha_{Si} = 2{,}60*10^{-6}\ cm^{-1}$
- Dimesions of the detector element and readout chip $1{,}4*1{,}4\ cm^2$
- Temperature during thermo compression 170°C
- $\Delta L = 6{,}6\ \mu m$
- Some compensation could be applied to the pixel spacing in the sensor chip

Reflow temperature for Pb-Sn solder 210°C (for In based solder 180°C)

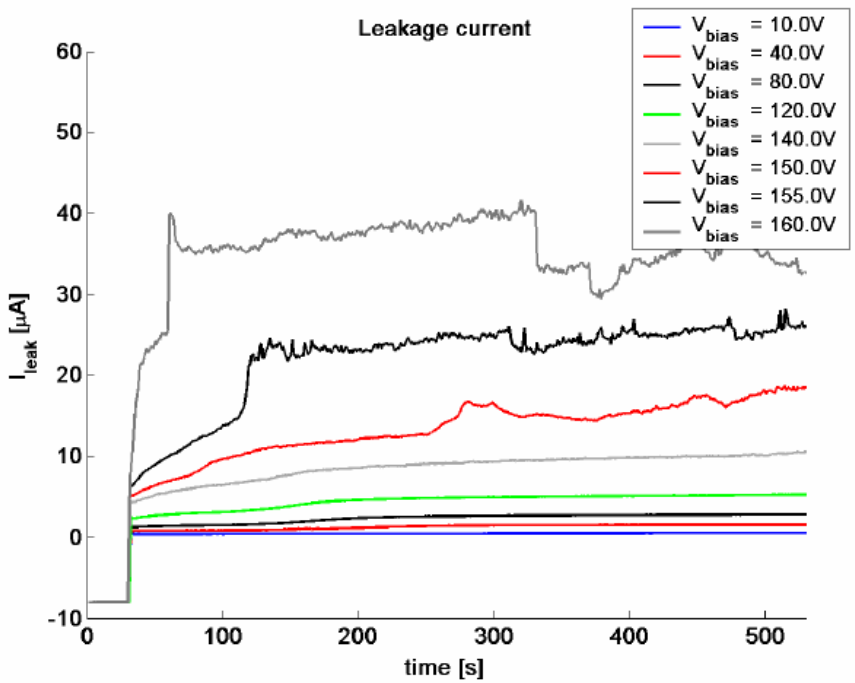
Ready Detector

- Flip chip hybridization was successful
- But the sensor was broken in 5 pieces
  - –The detector was laid in a package for transportation GaAs sensor facing to adhesive
  - –The detector was cracked in 5 pieces during removal



IV Results of MEDIPIX 2 Detector

- Detector was operational despite of the cracking
- Characterization of the component done at CERN



Conclusions

- Flip chip assembly of Medipix2 readout chip with epitaxial GaAs sensor has been successfully demonstrated
- 2 new detectors have been produced
- Thermal expansion causes problems
- Planarization of the chip would be highly desirable
- Cooling of the detector would enhance the depletion width
- Will the chip take the thermal stress if cooled?