Activities at Acrorad

February 2007
Outline

(1) About Acrorad

(2) High purity materials

(3) CdTe single crystal growth by THM

(4) Detector characteristics
   Ohmic detector and Schottky detector

(5) Detectors for high energy application
   $S^3$ type and Large area plane type

(6) Imaging detectors / devices
   Mini-gamma camera and X-ray imaging hybrid
Acrorad HQ, Plant is here
OKINAWA

Tokyo office
Okinawa is a popular “resort “ island,

but…. we have to work in this environment.

Photos by courtesy of Okinawa Convention & Visitors Bureau
Capital : 10M$
Number of employees : 43
Manufacturing facilities : 15,500ft² (1443m²)
History

~1987 : Developed the high purification process for Te and Cd (Nippon Mining Co.)
1988 : Started R&D of CdTe detector and CdTe growth by THM (1.2”)
1990 : CdTe detector are adopted for bone densitometers
1995 : Started 2” THM growth
1999 : Delivered over 30,000 detectors for ESA gamma telescope satellite project ISGRI/ INTEGRAL
2000 : MBO of the CdTe detector business. Acrorad founded
        Started 3” THM growth
2005 : Started R&D of 4” THM growth
2006 : Delivered 700,000 Schottky detectors for Medical Application in a year
We challenge the new radiation detector technology with the acrobatic mind (free imagination)
Production process

1. **Purification**
2. **Crystal Growth (THM)**
3. **Wafer Fabrication**
4. **Detector Fabrication**
5. **CdTe/ASIC module**
6. **Medical system**

**Raw material business**
- High purity Cd, Te and CdTe

**Detector business**
- Polished wafer
- Bare / Assembled chips

**Module business**
- X-ray imaging module

**Device business**
- mini gamma camera
Purification of raw materials
High purity metals in Acrorad

We purify the raw materials in house,

(1) to reduce the production cost, which is the key for CdTe to be used in many application fields

(2) to improve the CdTe detector qualities, as the purity is the most important for the radiation detector

(3) to secure the material supply
CdTe single crystal growth by THM

Requirements of the CdTe crystal for radiation detector

1. Large \( \frac{1}{\lambda} \) \( \cdot \) products & high resistivity
   - high purity \( \cdot \) Low temperature growth
   - Impurity gettering effects of the molten zone

2. Homogeneity \( \cdot \) Segregation of Cl

3. Productivity \( \cdot \) Large diameter
Crystal growth of CdTe:Cl by THM
Distribution of dopant concentration

(a) THM

(a) Bridgman method
Distribution of Cl in THM crystal
Evolution of CdTe THM growth in ACRORAD

- 1.26 inch
  1988~1998
- 2 inch
  1995~2002
- 3 inch
  2000~
CdTe Single crystal wafers
CdTe single crystal of 3inch diameter

(1) Uniform performance

(2) High reproducibility

(3) Average volume ratio of the largest grain in a ingot (single crystal yield in a ingot) ;

85% over

Mass production of CdTe detectors 700kpcs/year

Regular production of single crystal detector of 25x25mm2 size for X-ray imager
Detector characteristics

Shuri Castle  (G8 summit banquet was held in 2000)

Photos by courtesy of  Okinawa Convention & Visitors Bureau
Acrorad CdTe detectors

(1) Ohmic type

No polarization

(2) Schottky type

High bias voltage
Low dark current
I-V characteristics

(1) Ohmic type

Detector resistivity

\[ 1.8 \times 10^9 \ \Omega \text{cm} \quad @70V \]

dark current \ ~ 70nA

(2) Schottky type

Detector resistivity

\[ 3.7 \times 10^{11} \ \Omega \text{cm} \quad @700V \]

dark current \ ~ 3nA
Energy spectrum

Ohmic detector

4x4x1 mm

$^{241}$Am $7.4$ keV $12\%$

$^{57}$Co $8.8$ keV $7.2\%$

$^{137}$Cs $34.6$ keV $5.2\%$
Energy spectrum

Schottky detector
4x4x1 mm

$^{241}$Am 4.3 keV
7.2 %

$^{57}$Co 4.6 keV
3.8 %

$^{137}$Cs 16.9 keV
2.6 %
Energy spectrum comparison

<table>
<thead>
<tr>
<th></th>
<th>Ohmic</th>
<th>Schottky</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>keV</strong></td>
<td><strong>%</strong></td>
<td><strong>keV</strong></td>
</tr>
<tr>
<td>241Am</td>
<td>7.4</td>
<td>4.3</td>
</tr>
<tr>
<td>57Co</td>
<td>8.8</td>
<td>4.6</td>
</tr>
<tr>
<td>137Cs</td>
<td>34.6</td>
<td>16.9</td>
</tr>
</tbody>
</table>
Stable ohmic detector

Ohmic detector shows no polarization
Polarization of Schottky detector
Effect of bias voltage on polarization

After the bias applied, the spectrum is almost stable until polarization time $t_p$.
Effect of bias voltage and detector thickness on polarization
Effect of detector thickness on polarization time

The thinner detector is more stable
Recovery from the polarization

bias 500V 60min measurement
bias off/on (~1sec)
bias 500V 60min measurement
Recovery from the polarization(2)

4x4x1 bias 500V
Detector characteristics summary

(1) Ohmic detector
   low bias voltage  70~100V/mm
   moderate energy resolution
   stable with time (no polarization)

(2) Schottky detector
   high bias voltage  700V/mm
   superior energy resolution
   polarization
      thinner, higher bias voltage
      longer polarization time
   complete recovery by bias off/on
Detector for high energy applications

Photos by courtesy of Okinawa Convention & Visitors Bureau
Schottky detector for the higher energy (1)

Good resolution and relatively stable but **low sensitivity**

Large stopping power but **severe polarization**
**Edge on type**

In

Pt

+  -

radiation

Large stopping power with good resolution, stability but small area (volume)

**Schottky Stack Structure ($S^3$ type)**

In

Pt

In

Pt

+  -

Large stopping power with good resolution, stability, large area

**Acrorad**
Schottky Stack Structure (S³ type)

Be able to change the absorption depth without increasing the carrier travel distance

Absorption width 15mm, 20mm, 50mm, 100mm possible
Schottky Stack Structure Detector (S$^3$ type)

10x10x1mm Schottky detector x 10pcs

Electrode
Measurement system
CdTe detector for high energy application (S\(^3\)-type)

< Specification >
Schottky Stack Structure Detector (S\(^3\) type)
Volume :1,000mm\(^3\)
Absorption thickness :10mm
Bias :700V
FWHM :less than 4% (700V 25 µ\(^\circ\) )

(Measuring condition)
Source 137Cs
Temperature 25 µ\(^\circ\)
Bias voltage 700 V
Shaping time 0.5 µsec
$S^3$ detector spectrum
S\textsuperscript{3} detector I-V characteristics
Sensitivity ($^{137}$Cs)

about 20 cps/ $\mu$ Sv/h

(rough measurement)

Discrimination level 30keV

Lower energy is cut by the brass case
Temperature dependence of $S^3$ type detector

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>FWHM (keV)</th>
<th>Resolution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>20.5</td>
<td>3.1</td>
</tr>
<tr>
<td>25</td>
<td>21.2</td>
<td>3.2</td>
</tr>
<tr>
<td>37</td>
<td>21.2</td>
<td>3.2</td>
</tr>
<tr>
<td>50</td>
<td>21.2</td>
<td>3.2</td>
</tr>
</tbody>
</table>

![Graph showing temperature dependence of $S^3$ type detector]
Stability of S^3 type detector
(1) $S^3$ type enables the good energy resolution in higher energy with practical stability

(2) $S^3$ type has the potential to increase the volume (thickness) of the detector without increasing the carrier travel length
Schottky detector for the higher energy (2)

Larger area of detector is simply effective
Sensitivity plane type vs cubic type (1000mm$^3$)
Large area Plane type detector

Detector volume

900mm$^3$

Alumina substrate

15x15x1t
Measurement system

- Brass 0.5 mm CdTe detector
- Pt electrode
- In electrode
- Pre-amplifier
- ORTEC 142
- MCA EG&G 7800 main amplifier ORTEC 571 (0.5 µ)
- GND
- HV power supply 6637 CP (700 V)
- Gamma-ray Measurement system
### Comparison  $S^3$ type vs Large area plane type

<table>
<thead>
<tr>
<th></th>
<th>241Am</th>
<th></th>
<th>57Co</th>
<th></th>
<th>137Cs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PC(ch)</td>
<td>FWHM (keV)</td>
<td>COUNT</td>
<td>PC(ch)</td>
<td>FWHM (keV)</td>
<td>COUNT</td>
</tr>
<tr>
<td><strong>Plane type</strong></td>
<td>255</td>
<td>13.3</td>
<td>156,340</td>
<td>257</td>
<td>12</td>
<td>85,256</td>
</tr>
<tr>
<td><strong>Plane type element</strong></td>
<td>255</td>
<td>6.1</td>
<td>38,638</td>
<td>257</td>
<td>6.6</td>
<td>21,110</td>
</tr>
<tr>
<td><strong>$S^3$ type</strong></td>
<td>253</td>
<td>12.9</td>
<td>24,469</td>
<td>256</td>
<td>12.1</td>
<td>24,834</td>
</tr>
<tr>
<td><strong>Count ratio (*)</strong></td>
<td></td>
<td>6.4</td>
<td></td>
<td></td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td><strong>Plane type/$S^3$ type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Large area plane type : better sensitivity (especially at low energy )
almost same energy resolution
Large area plane type Summary

(1) A 30 x 30 x 1mm CdTe detector (900mm³) was fabricated.

(2) The detector showed almost same energy resolution and higher sensitivity compared to 10x10x10mm detector.
Imaging Detectors /devices

Photos by courtesy of Okinawa Convention & Visitors Bureau
Single detector to imaging module

X-ray detectors

Gamma camera

25mm

0.1mm

45mm
Mini gamma camera
MGC500 (FDA approved)
Comparison of gamma image
(99mTc is filled in a plastic tube)
Collection time 2 sec
MGC conventional scinti-camera
Development of CdTe X-ray imager

Pixel pitch: 100 µm pixel pitch
Number of pixel: 120k
FOV: 25mm x 50 mm
CdTe X-ray imaging hybrid

100 μm pitch array

¥1 coin (aluminum)

High contrast
High spatial resolution
Resolution

CsI (indirect conversion)
Pixel pitch 100 μm

CdTe (direct conversion)
Pixel pitch 100 μm

Test chart image (60 kV  50 μA)

* with image correction

* without image correction
Imaging detector/device summary

(1) Mini Gamma Camera was developed
   the high sensitivity and high spatial resolution were demonstrated

(2) CdTe/readout ASIC hybrid for the X-ray imaging is being developed
   Better resolution than CsI FPD was demonstrated
   Large and homogeneous CdTe single crystal wafer is suitable for the x-ray imaging device
Thank you for attention!

CdTe detectors
ACRORAD

Photos by courtesy of Okinawa Convention & Visitors Bureau