Forward Region Instrumentation

Wolfgang Lohmann

DESY

On behalf of the FCAL collaboration
Recent Developments:

- Sensor Prototyping
- ASIC Development and Test
  - System test
  - PITZ test
- Applications of FCAL R&D at FLASH and CMS
BeamCal Sensors, GaAs

- n-type (Te or Sn - shallow donor) GaAs grown by Liquid Encapsulated Czochralski (LEC) method in Siberian Institute of Physics and Technology (Tomsk, Russia)
- low-ohmic material, filling the electron trapping centers EL2+
- Cr (deep acceptor) diffusion
- high-ohmic

Thicknnesses 150 - 200 µm

Metallization:
V (30 nm) + Au (1 µm) from both sides

Irradiation in a 10 MeV electron Beam, Doses up to 1.1 MGy

<table>
<thead>
<tr>
<th>Initial n-GaAs</th>
<th>Fabrication method</th>
</tr>
</thead>
<tbody>
<tr>
<td>№1, ( n \approx (1 - 1.5) \times 10^{17} \text{ cm}^{-3} ), Te</td>
<td>Diffusion of Cr under temperature ( T_2 )</td>
</tr>
<tr>
<td>№2, ( n \approx (5 - 6) \times 10^{16} \text{ cm}^{-3} ), Te</td>
<td>Diffusion of Cr under temperature ( T_m )</td>
</tr>
<tr>
<td>№3, ( n \approx (1 - 3) \times 10^{16} \text{ cm}^{-3} ), Sn</td>
<td>Diffusion of Cr under temperature ( T_1 )</td>
</tr>
<tr>
<td>№4, ( n \approx (2 - 5) \times 10^{16} \text{ cm}^{-3} ), Te</td>
<td>p-v-n- structure*</td>
</tr>
</tbody>
</table>

Notice \( T_1 < T_m < T_2 \).

* - presence in the detector n-type low-resistance domain, all other detectors №1, 2, 3 had structure m-i-m: metal-insulator (high-resistance GaAs) – metal.
BeamCal Sensors, GaAs

Irradiation with an 10 MeV electron beam (DALINAC, TU Darmstadt)
10 - 400 kGy/h

Up to 500 kGy a mip signal is clearly seen

Sensors with a lower concentration of shallow donor and Cr as deep acceptor show better rad. tolerance
BeamCal Sensors, Diamond

sCVD diamond (E6), 5x5x0.3 mm³

Irradiated in 2007 up to 5 MGy
2008: up to 10 MGy

New set-up, for switching polarity during the measurement
BeamCal Sensors, Sapphire

Band gap: 9.9 eV  
(diamond: 5.5 eV, Si: 1.12 eV)

Single crystal, 1x1 cm$^2$, cut 0001

Wafer: 30 cm diameter)

Metallization:
50/50/200 nm Al/Ti/Au

Ratio of the detector and Faraday cup currents

Charge collection efficiency: few %

~ 30 % of the initial charge collection efficiency after 12 MGy
Sensor prototypes (LumiCal)

“Cracow-Design”

- High resistivity n-type Si
- 1.7 mm p⁺-strips with an Al-metallization
- Backplane: n⁺ implant and an Al-metallization
- 3 Guard rings

x-Size = 10.8 cm
y-Size = 4...12 cm (6 Inch Wafers)

I(V) and C(V) measurements on Probe-stations in Tel Aviv, Cracow and DESY
Sensor prototypes (LumiCal)

Capacitance vs. Voltage

Serial No3 _ L1

Capacitance [F]  Voltage [V]

Ch1  Ch10  Ch15  Ch20  Ch25  Ch30  Ch35  Ch40  Ch45  Ch50  Ch55  Ch60  Ch63  Ch64

Current [A]  Voltage [V]

Serial No. 5 - R1 channel 30

Current [A]  Voltage [V]

without neighbors  with neighbors

30.09.2009 Albuquerque
Design of a 32 channel prototype currently ongoing, First prototypes (smaller number of channels) will be ready in December

- Dual gain charge amplifier
- Switched capacitor filter
- ADC ASIC 10 bit successive approximation ADC (3.25 MS/s)
- Additional 8 bit low latency output (beam diagnostics)
ASIC development, LumiCal

8 channel preamplifier ASIC, lab tests, matches the requirements

Power consumption per channel: 8.9 mW

Ready for tests with sensors!

- PCB design for an assembly of ASIC and sensor
- Test in the lab and testbeam
- Redesign after these tests

30.09.2009
Albuquerque
ASIC development, LumiCal

One channel ADC ASIC
(differential pipeline architecture)

- New 10 bit ADC fully functional
- Stable operation up to 25 MHz
- Good static performance (DNL, INL, ENOB)
- Dynamic measurements just started
- Clock and power switching tests
- Preparation of a multichannel version
System Test in a beam

Readout/Fanout of sensors

- fine pitch PCB, (100...200µm for a few channel FE chips)

- additional flexible PCM to be designed (matters of crosstalk & capacitive load)

- wire bonding or bump bonding to pads (wire bonding needs ~ 3mm gap between absorber tiles; conductive gluing also discussed)

- wire bonding to FE chip

- Silicon and GaAs sensor samples

Template of a readout board, to be instrumented with FE ASICS
System Test in a beam

Readout/Fanout of sensors

- fine pitch PCB, (100…200µm for current few channel FE chips
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- wire bonding to FE chip
- Silicon and GaAs sensor samples
- Beam test planned 2010

30.09.2009

Template of a readout board, to be instrumented with FE ASICS
Test in PITZ

Electron beam, 14 MeV, bunches

Diamond sensor was installed in the vacuum of the beam pipe

Moving the sensor through an electron beam,

Bunch charge: 1 pC to 1 nC
Beam spot: few mm²
Beam profile

EMI negligible!

xRMS = 3.36 mm
yRMS = 3.29 mm

30.09.2009

Albuquerque
FCAL designed, constructed and installed a Beam-Condition Monitor at FLASH (4 diamond and 4 sapphire sensors) BHM.

Operation in the “9 mA” run of FLASH was successful.

About one week of data taking
In September 2009

Analysis ongoing

Preliminary results sweeping the beam
Application at CMS: BCM1F

- Fully assembled Module
- sCVD sensor

- Optical Receiver
- Fan In Fan Out
- Discriminator
- TDC

Diagram shows the integration of various components:
- Trigger
- ADC
- Control and Readout PC
- Front End Module (sensor+preamp & laser driver)
- Optical Fiber

Date: 30.09.2009

Location: Albuquerque

~ 100 mm
Application at CMS: BCM1F

First signals September 10, 2008

Difference of the arrival time in the two sensor planes

~ 12 ns time of flight for 3.6 m

Data taken September, 2008

Signal Spectrum

pedestal

signal

Time resolution ~ 1.3 ns
Conclusions

• Investigation of the radiation hardness of GaAs, diamond and Sapphire up to 10 MGy. However, no baseline material for BeamCal sensors so far.

• Prototyping of Si sensors for Lumical successful.

• FE ASICS ready for test with sensors.

• System test in preparation.

• ADC ASICS - prototypes under test.

• First test of a diamond sensor in a bunched electron beam.

• Successful application of diamond sensors in CMS and FLASH.

30.09.2009
BeamCal Sensors, Diamond

Study of the irradiated sensor in the lab using a $^{90}\text{Sr}$ $\beta$ source

After 10 MGy

First 500 min data taking: