Status of Silicon Tracking Detector R&D

- CCD vertex detector R&D: Y. Sugimoto (KEK)
  - collaboration of KEK, Niigata, Tohoku, Toyama

- DSSD R&D: H. Park (KNU)
  - collaboration of YJ Kim, DH Shim (KNU), J. Lee (SNU),
    HJ Kim, YJ Kwon, SP Kim (YSU)
    BG Cheon, YI Choi, YK Choi (SKKU)
• R&D activities for CCD
  - thin wafer
  - radiation tolerance
  - charge spread

• R&D activities for DSSD
  - sensor and mask designs
R&D for thin wafer

- **Structure of CCD**
  - p+ substrate: ~300 μm
  - Epitaxial p layer: ~20 μm
  - n layer: few μm
  ➞ We need only ~20 μm for charged particle detection
  ➞ Mechanical strength?
    - backing
    - stretching
    - partial thinning
      large area thinning brings non-flatness
  aim average thickness < 100 μm
Study of radiation tolerance

- Non-Ionizing Energy Loss Hypothesis
  - bulk damage is thought to be proportional to NIEL
  - NIEL of electrons has strong energy dependence
  - $e^+/e^-$ pair background hitting the inner-most layer of VTX at LC peaks at ~20MeV
    - High energy electron beam irradiation test
  - NIEL of neutrons is $\sim\times10$ than that of H.E. electrons, but expected b.g. rate is 1/100~1/1000
    - Not so serious
Electron Damage Study

- Hot Pixels
  - Observed only in beam-irradiated CCDs
  - Presumably due to cluster defects which cannot be created by low energy electrons

Measured at +10 °C, Cycle time: 2 sec

Sr-90
- 1x$10^{11}$/cm$^2$
- 2x$10^{11}$/cm$^2$

150MeV Beam
- Before Irradiation
- 1x$10^{11}$/cm$^2$
Electron Damage Study

- **Charge Transfer Inefficiency**
  - derived from position dependence of Fe-55 X-ray (5.9keV) peak
  - CTI induced by 150MeV beam is x2~3 larger than Sr-90 induced CTI
  - CTI suppression by fat-zero charge injection was observed
Study of Charge Spread

- Diffusion of electrons in epitaxial layer
  - Key of excellent spatial resolution for CCD (and CMOS)
  - Takes time to diffuse: How long do we have to wait for the charge collection?
    ➔ Measurement with IR LASER pulse
Possible design of the CCD vertex detector

- Baseline design
  - R=24, 36, 48, 60 mm
  - |cosθ| < 0.9
  - σ = 4 µm
  - Wafer thickness = 300 µm
  - B = 3T
    \[ \sigma_b = 7 \oplus \frac{20}{\beta \sin^{3/2} \theta} \] µm
- R&D milestone
  - R=15, 24, 36, 48, 60 mm
  - |cosθ| < 0.9
  - σ = 4 µm
  - Wafer thickness = 100 µm
  - B = 4T
    \[ \sigma_b = 5 \oplus \frac{10}{\beta \sin^{3/2} \theta} \] µm
Intermediate Tracker

- CDC, 50 wires
- IT, 5 layers
- VTX, 4 layers
- Beam pipe

Support Tube

- 5 layers at r=9 to 37 cm
- Angular coverage: $|\cos \theta| < 0.9$
- Spatial resolution: $\sigma = 40 \mu m$
- Thickness of a layer: 0.6% radiation length
DSSD design (3D)

- Metal 1 and metal 2 contact (VIA)
- Metal 1 and metal 2 contact (VIA)
- n+ ohmic side
- p+ junction side
- 1st metal
- 2nd metal readout line
- Metal 1 and metal 2 contact (VIA)
n+ ohmic side design

strip length 25600um

p-stop

guardring

DC-pad

P-stop

guardring
p+ junction side design

strip length 51072um

DC-pad

guardring

guardring
Guardring

Sensor has three guardring

Guardring width 15um

n+ side and p+ side same guardring
Mask design (n+ side 512 channel)

N - Side MASK
Total 5
Mask design (p+ side 512 channel)

P – Side MASK
Total 6
Mask design (5inch Wafer)
Align mark and test pattern
Summary and Plan (CCD)

- Study of partially thinned wafer (sample wafers ordered)
- Study of radiation damage with 150MeV beam
  - hot pixel generation
  - factor 2-3 larger CTI than \(^{90}\text{Sr}\) irradiated
  - CTI suppression by fat-zero charge injection
- Study of charge spread

- Extend present R&D
  - optimize the design of partially thinned wafer
  - CTI study as function of clock width, speed and amplitude
  - study the feasibility of multi-thread CCD and try to make prototype CCD+ readout ASIC
Korean group is accumulating knowledge of silicon detector
- sensor and mask designs were done
- mask production (a total of 11) was done
- fab is in processes (6 wafers/batch)

Hope to show preliminary test (I-V/C-V) results in April LC workshop

Silicon \(\mu\)-strip R&D proposal submitted
- have very positive response