Si sensor study in Kyushu

CALICE Collaboration meeting @Hamburg
March 22nd, 2013

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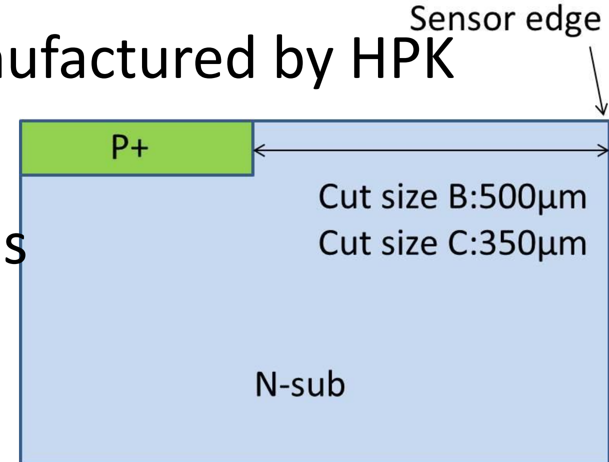
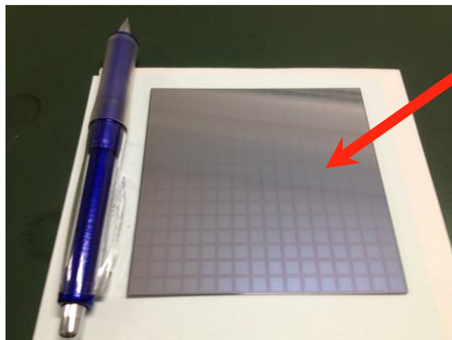
Activities at Kyushu

- I-V and C-V measurements
- Sensor edge, cross-talk measurement with an IR laser system (in preparation)
- Together with the French and Japanese colleagues, keep in contact with HPK for the Si sensors (design, quality, cost)

Si-sensors (HPK, 2012 batch)

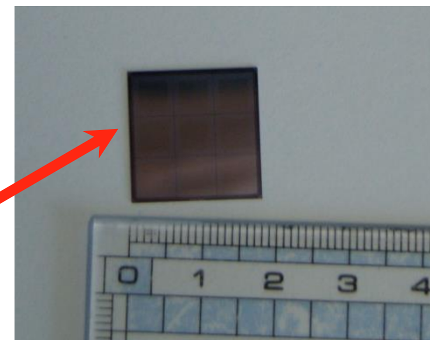
- We measured five types of Si-sensors manufactured by HPK
  - Main-chips (16 × 16 pixels)
    - type B (8.97 × 8.97 cm^2) : 12 samples
    - type C (8.94 × 8.94 cm^2) : 4 samples
  - Baby-chips (3 × 3 pixels)
    - guard rings same as the main-chip, Cut size C : 24 samples
    - split guard rings (4 rings), Cut size B : 8 samples
    - split guard rings (4 rings), Cut size C : 6 samples



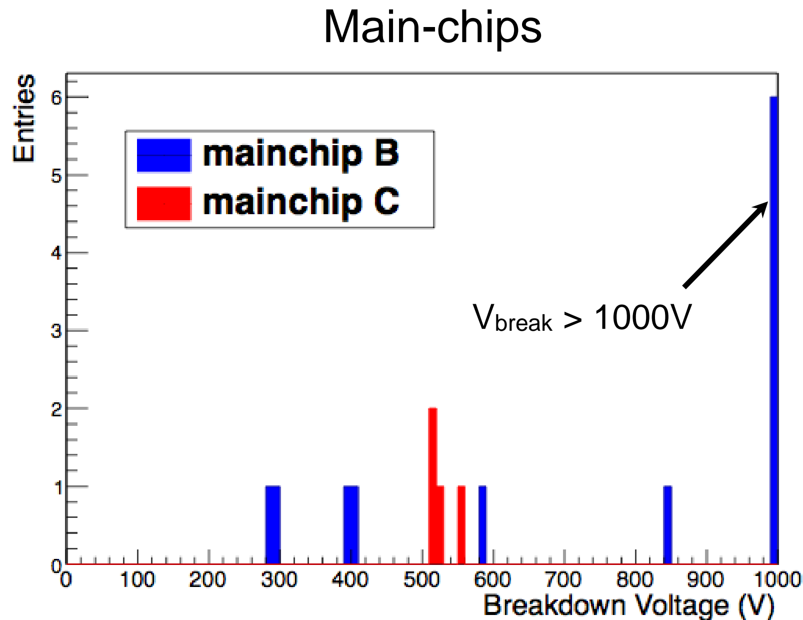


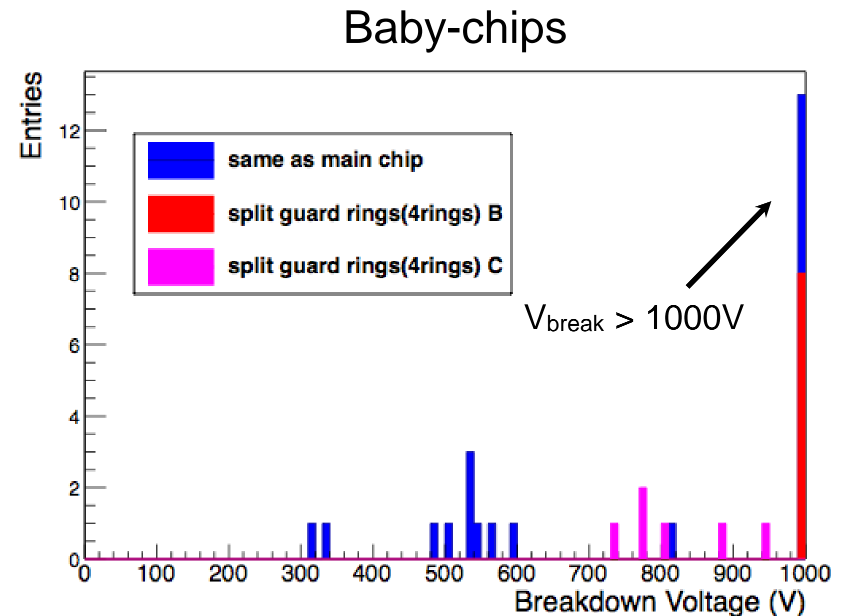
Main-chip

Baby-chip



Breakdown Voltage



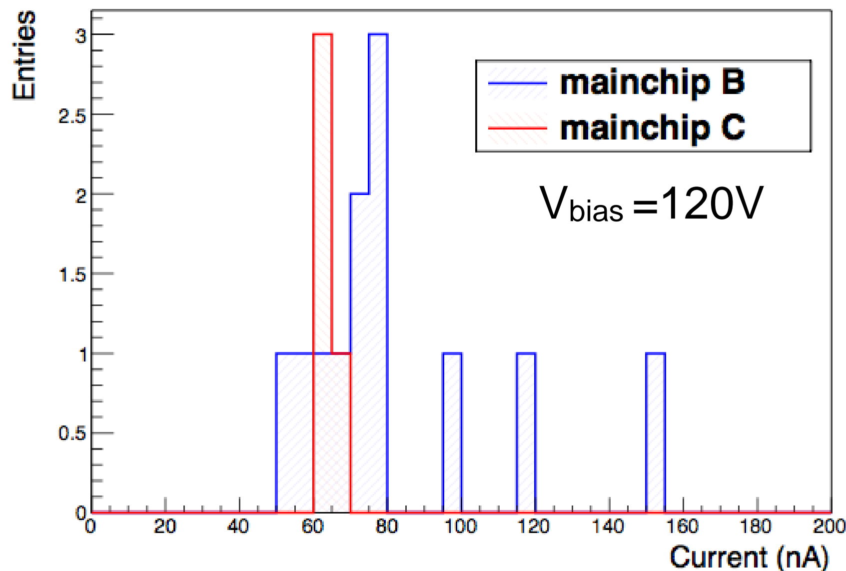


- Samples in the last bin did not break down until 1000V.
- Breakdown voltage is more than 2.5 times higher than the operating voltage (~120V).

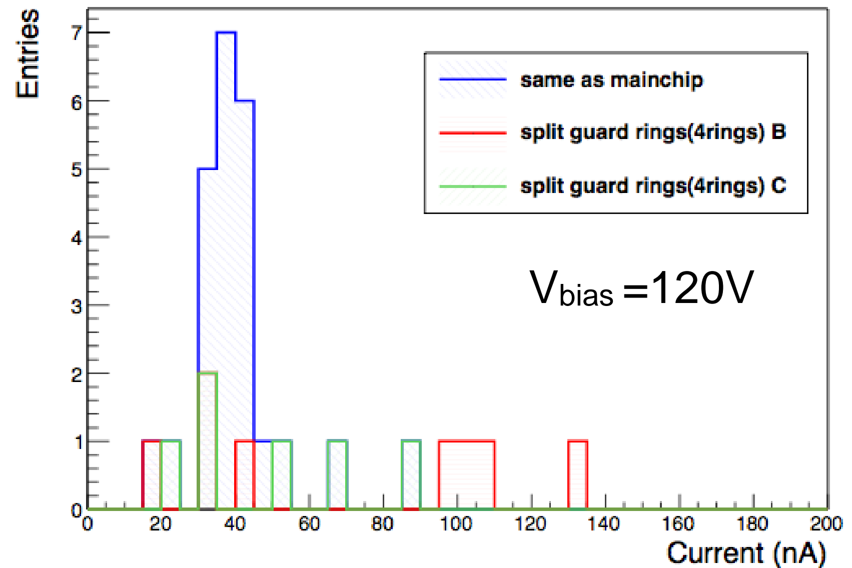
Dark current at 120V

- We measured the total dark current of a Si sensor at the operation voltage

Main-chips
Dark Current at 120V

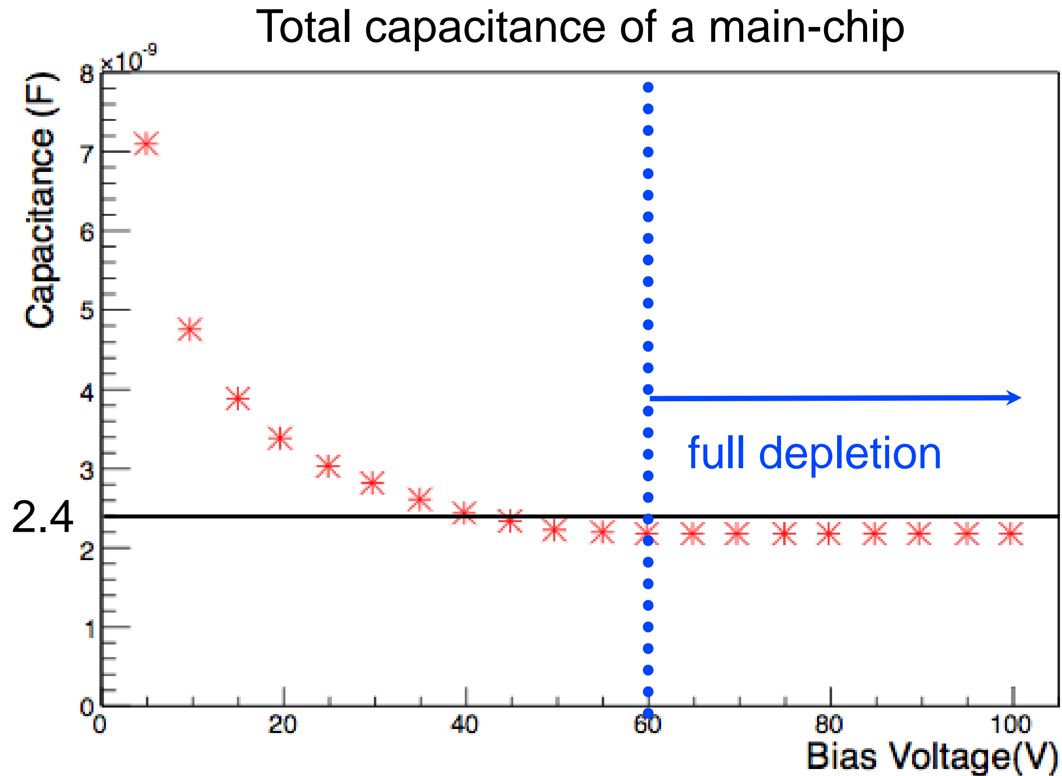


Baby-chips
Dark Current at 120V



Dark current of the chips is less than 200 nA at the operating voltage.
HPK Si sensors are superior (too good?) in quality.

C-V measurement



- All main-chips are fully depleted around 60V.
- Capacitance of the main-chips is ~2.4 nF, consistent with the expectation

Meeting @ HPK, Dec 2012

We (Japan-France team for ECAL) visited Hamamatsu photonics company (HPK) on December 19, 2012, and discussed design of the next batch and possible cost reduction.

Participants
France – LAL, LLR
Japan – Kyushu, Shinshu, Tokyo

Comments and suggestions from HPK

- Operation voltage

If operated at < 200 V : no GR (or separate GR) is needed.
Otherwise (> 200 V), GR is needed.

- Cut Type B (C)

- distance between pixels and sensor edge is 500 (350) µm.
- breakdown voltage of type B should be higher than type C.

- If there are bad pixels in a wafer,

-- dark current is increased
-- breakdown voltage is shifted to lower side.

Some possibility to reduce the cost

- Yield & Loss

Yield up (loss down) → Cost down

9x9 cm^2 → 9.8x9.8 cm^2

- Material

Reduce resistivity of Si wafer → Cost down

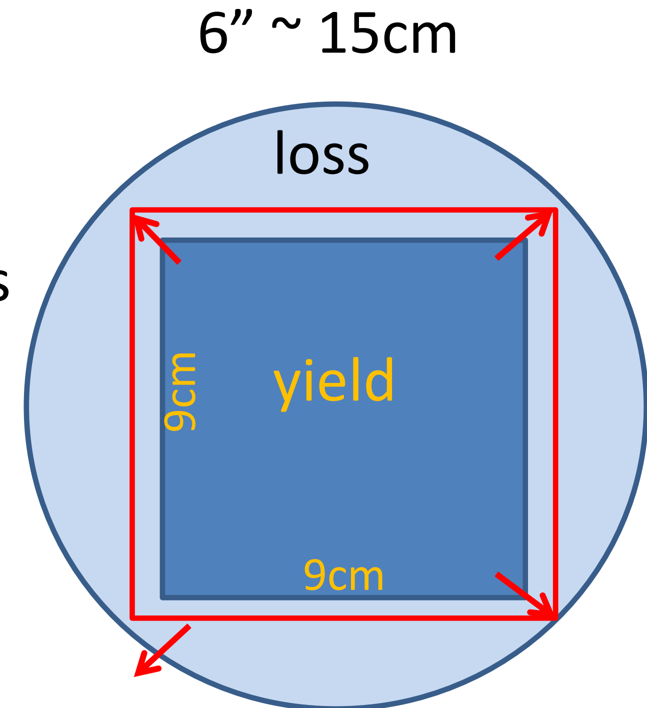
Because suppliers can produce such Si wafers more easily.

- Productivity

6” wafer can be grinded to be thin

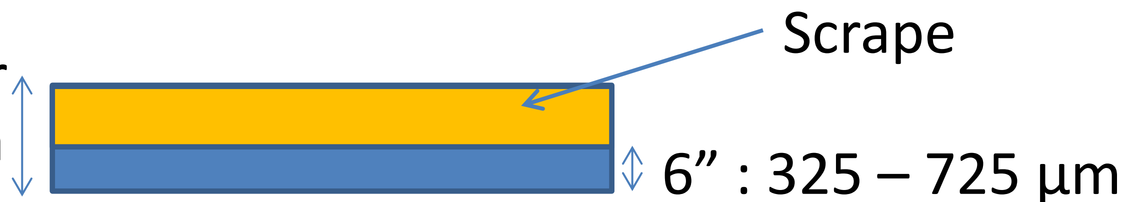
→ 8” wafer is difficult to grind

→ cost down but thickness up



-- 100k pieces/year

8” : 725 +- 20 μm



6” : 325 – 725 μm

Design of the next batch (2013)

- 16x16 pixels
- 9.8x9.8 cm^2 (current design 8.97x8.97 cm^2)
- 6.06x6.06 mm^2/pixel (current design 5x5 mm^2)
- thickness 325 μm
- No GR
- Completely dead channel less than 1 % (yield up)
- Bad pixels (= Dark current higher than 25 nA) less than 10% (yield up)

Summary

- We measured Si sensors manufactured by HPK in 2012.
- Breakdown voltage was higher than ~ 2.5 x operating voltage.
- Dark current of all measured chips was less than 200 nA at operating voltage.

- To reduce the cost of Si sensors
  - Larger area sensor from a wafer
  - Loosen the selection criteria for dead pixel and dark current at company

Next step

- Laser measurement system.
- Single pixel measurement.
- New design Si sensor