Fabrication of active-edge detectors without support wafer using a unique "perforated edge" approach

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• The edge termination of radiation detectors is important
• Gradually dropping the potential and help increasing breakdown voltage
• Prevents current injection from the dicing region
• Some standard solutions include:
  — Combination of grounded and floating guard-rings\textsuperscript{1}
  — Current terminating structures\textsuperscript{2}
• Dead region around the sensors amounts to about 1-1.5mm
• Seamless tiling of multiple detectors to cover large areas is difficult

Active-Edge
Origin and development

ADVANTAGES

• Reduction in the extension of the dead edge area
• Efficient tiling of sensors for seamless area coverage
• Complete isolation from the dicing lanes

DISADVANTAGES

• Complicated fabrication process
• More expensive approach
• Necessary to use a support wafer during processing

[S. I. Parker, et. al., IEEE TNS, VOL. 53, NO. 3, JUNE 2006]
[C.J. Kenney, et al., NIMA 565 (2006), 272-277]
Active-edge at SINTEF MiNaLab
With support wafer

- Initial approach with support wafers
- Excellent electrical results
- Similar to planar IV
- Leakage current as low as \(~0.3\ nA/cm^2\)

Without in-house bump-bonding and wafer grinding facilities, extremely difficult to address the issues with support wafer removal!
Achieving the active-edge without a support wafer

The idea was proposed and investigated through numerical simulations.

Simulation results indicated that this approach could deliver an active-edge termination without etching a full trench.

Necessary to demonstrate fabrication feasibility and mechanical integrity of the wafer.

Perform the tuning of the trench aspect ratio to achieve the desired depth.
Development at SINTEF MiNaLab
Numerical simulations (1)

- Through numerical simulation investigate the dopant depths required to achieve isolation from the dicing edge
- At the edge, the lifetimes are reduced to 1ns to simulate a highly damaged cut region
- The I-V curve is simulated for different dopant depths
• For a shallow dopant depth there is no “active-edge” formation and the depletion region can reach the dicing region
• With deeper doping profiles, it is possible to achieve a full active-edge
• The dopant depth depends on the distance between the trenches
• The distance between trenches depends on the requirements for the mechanical strength of the wafer
Layout design

- Diodes with different trench configuration ($5 \times 5\text{mm}^2$)
- Strip detectors with $75\mu\text{m}$ pitch
- Medipix sensors
- Test structures for process monitoring
- Dicing marks at different distances from the trench
Fabrication (1)

1. Silicon wafer
2. Trench etching
3. Trench doping
4. Polysilicon filling
5. Planar processing
6. Dicing
Fabrication (2)

- Picture of a full wafer
- Corner of a Medipix sensor
- SEM picture
Electrical characterisation (1)

Dicing tests

- Test carried out on diodes
- The diodes are etched at different distances from the trench and the I-V is measured again
- No increase in current is observed even when dicing inside the segmented trench
- To see current increase we must dice 10\(\mu\)m inside the active area
Electrical characterisation (2)

- The short edge termination gives an increase in capacitance as expected
- The increase amounts to about 10%
- Good agreement with numerical simulations
Final considerations and future development

- This technology was developed on N-type substrates but can be transferred to P-type as well.
- It is only considered production level for 300µm thick substrates.
- For thicker substrates the aspect ratio of the trenches needs to be adjusted and the quality of the photo lithography following the trench etching needs to be assessed.
- It might be necessary to move away from resist spinning if the trenches become too wide.
- These aspects will be evaluated and developed in the near future.
Conclusions

- We have successfully developed a fabrication procedure to produce active-edge devices without using a support wafer.
- The electrical characterisation returned excellent results and the devices work as expected and in agreement with numerical simulations.
- Further development is necessary for thicker substrates (>300 $\mu$m).
- This technology can also be applied to our N-on-P process.
Technology for a better society