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Low Gain Avalanche Detectors (LGAD) for particle physics and synchrotron applications

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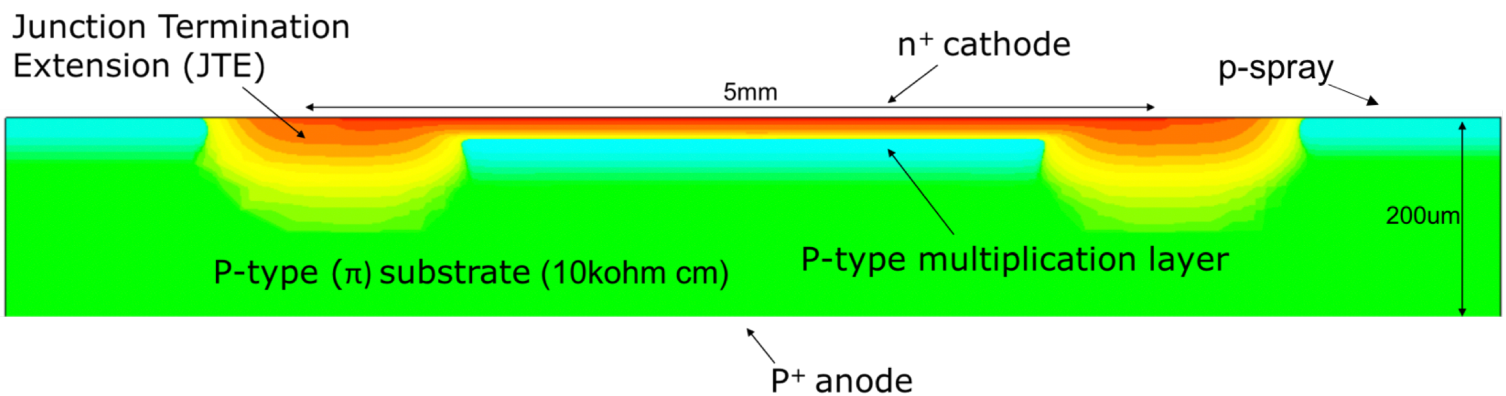
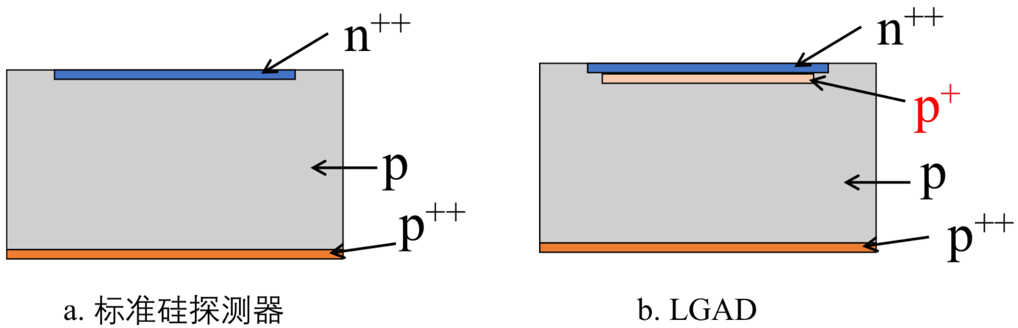
Introduction

- Low-Gain Avalanche Detectors (LGAD)——a new avalanche silicon detector concept
- The detector's characteristics are simulated via a full process simulation to obtain the required doping profiles which demonstrate the desired operational characteristics of high breakdown voltage (500 V) and a gain of 10 at 200 V reverse bias for X-ray detection.
- The first low gain avalanche detectors fabricated by Micron Semiconductor Ltd are presented. The doping profiles of the multiplication junctions were measured with SIMS and reproduced by simulating the full fabrication process which enabled further development of the manufacturing process.
- The detectors are 300 μm thick p-type silicon with a resistivity of 8.5 kΩcm, which fully depletes at 116 V. The current characteristics are presented and demonstrate breakdown voltages in excess of 500 V and a current density of 40 to 100 nAcm−2 before breakdown measured at 20◦C.

LGAD Concept



Schematic cross-section of the LGAD pad design. A p-type layer is diffused below the N+ electrode to form the n+/p/p– junction where the multiplication takes place.



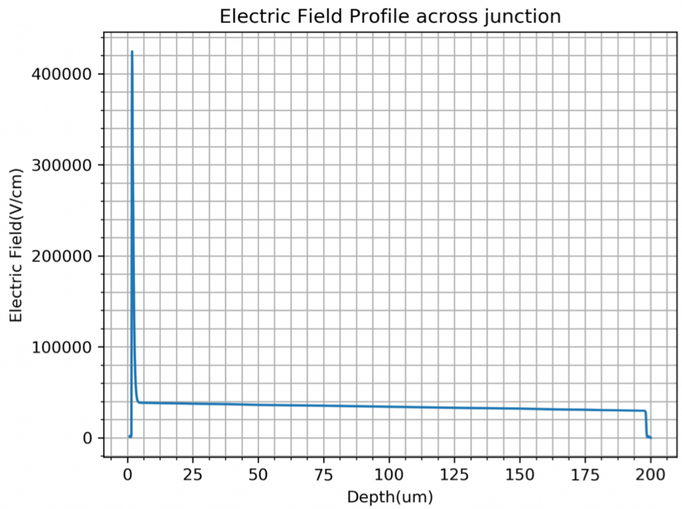
$$G = \alpha_n n v_n + \alpha_p p v_p$$

$$\alpha = E \exp[-E_i/E]$$

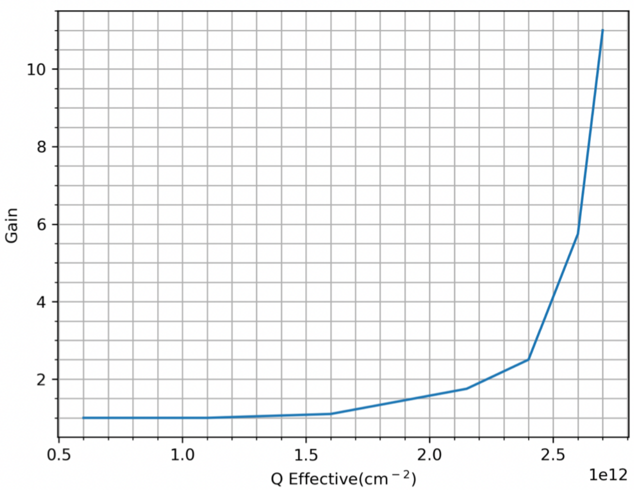
LGAD Simulation

Software: Synopsis Sentaurus TCAD (Version G – 2012.06)

- **the gain as a function of doping**
- **the high voltage breakdown characteristics**

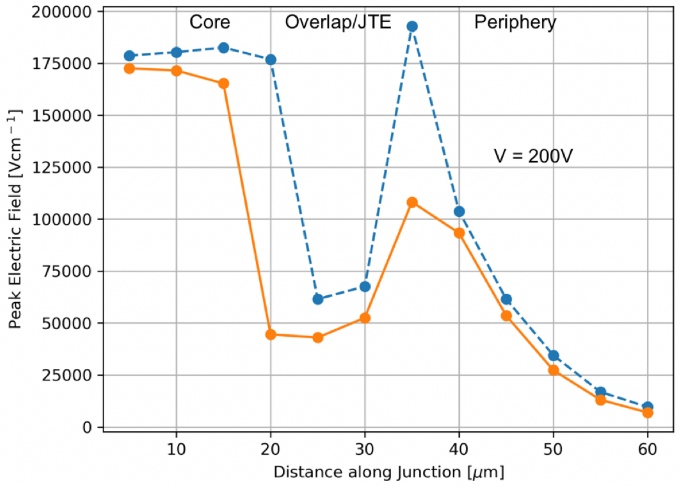


Typical electric field profile through device showing high electric field at junction between n+/p region. The device is 200 µm thick with a reverse bias of 700 V.



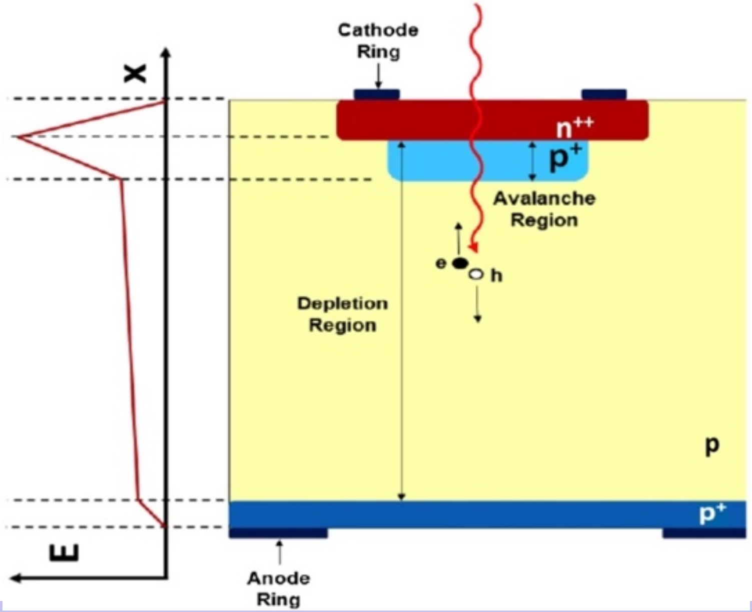
Simulated Gain against Q effective for a bias voltage of 400 V.

Simulation



Simulated maximum electric field in the device for a bias of 200 V as a function of distance along the surface in the edge region of the n+ junction for a device with and without a JTE. The caption is; simulated without JTE: dashed line, simulated with JTE: solid line.

Xin Shi:
On Fig. 5, are there any reason for the electrical peak near 35um?



Simulation

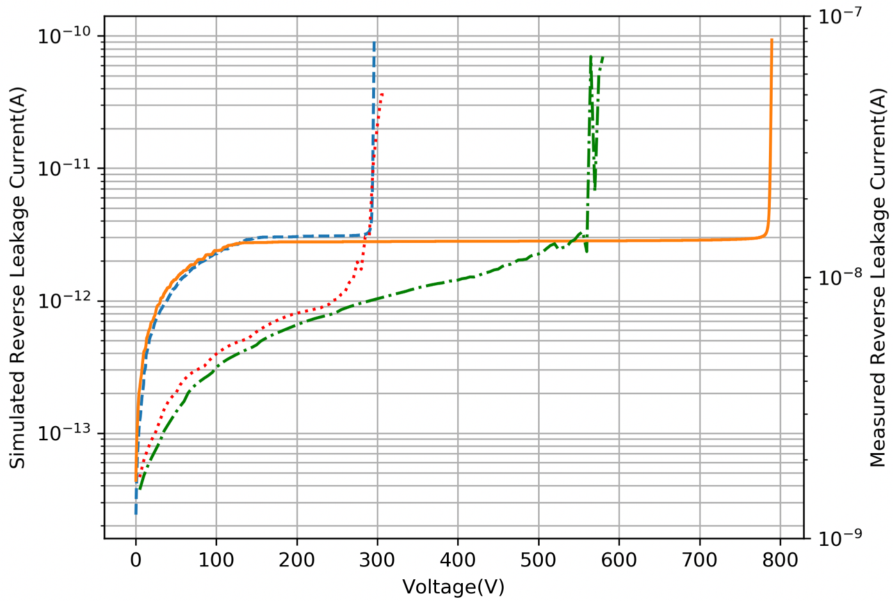
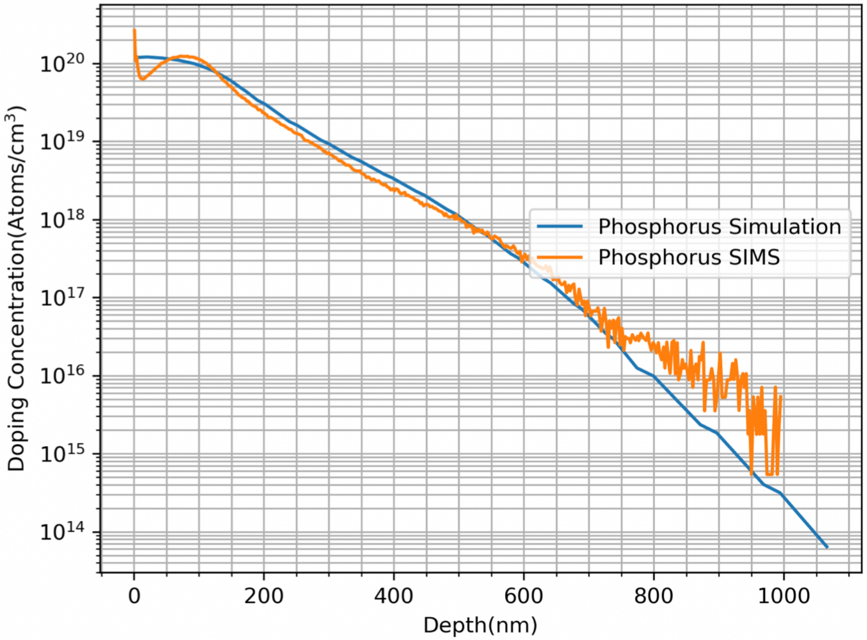


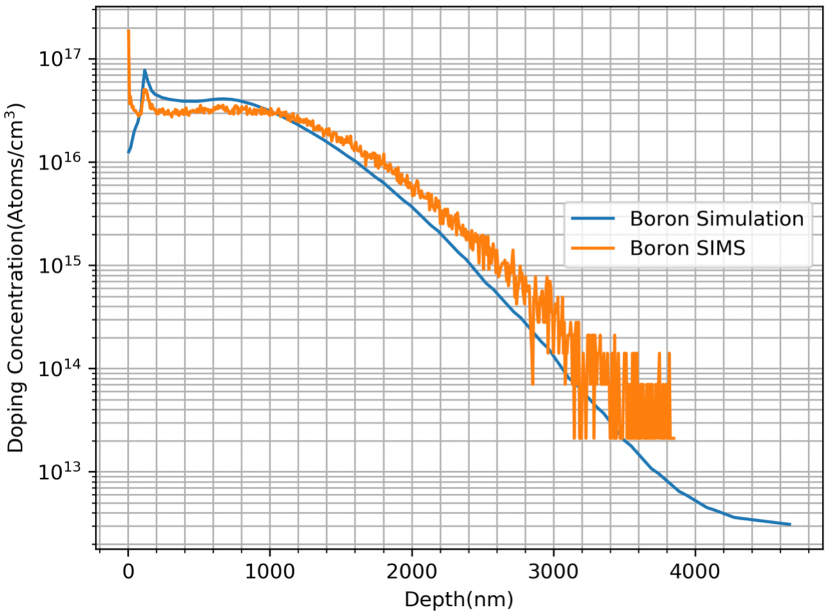
Figure 6. IV curves for simulated and measured LGAD devices with and without a JTE. The caption is; simulated without JTE: dashed line, simulated with JTE: solid line, measured without JTE: dotted line, and measured with JTE: dot-dashed line.

Question by Kai: From Figure 6, we indeed could get the conclusion that the breakdown voltage increased obviously with the JTE.

But for me, the difference between simulation and measurement for cases with JTE (orange, and green lines) is about 200V, seems not that small, why they say: The fabricated results show **reasonable** agreement with simulation for the breakdown voltage. what kind of difference could be called unreasonable?

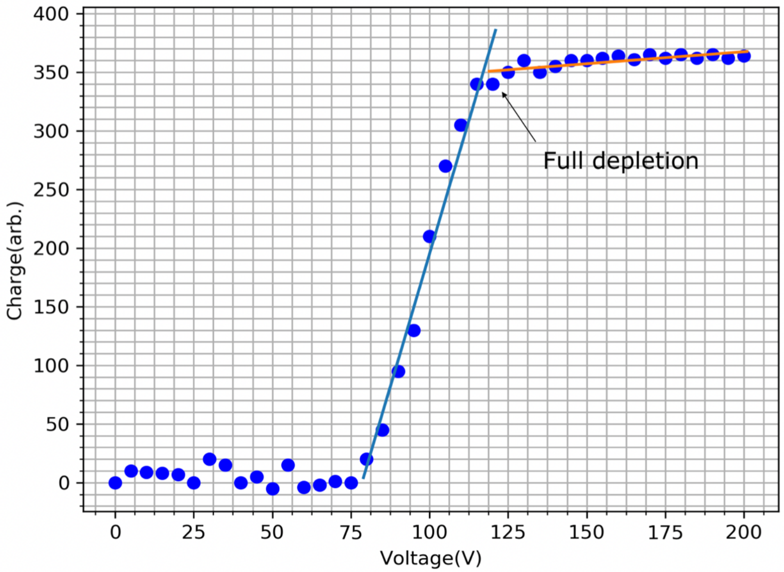
Device Characterisation



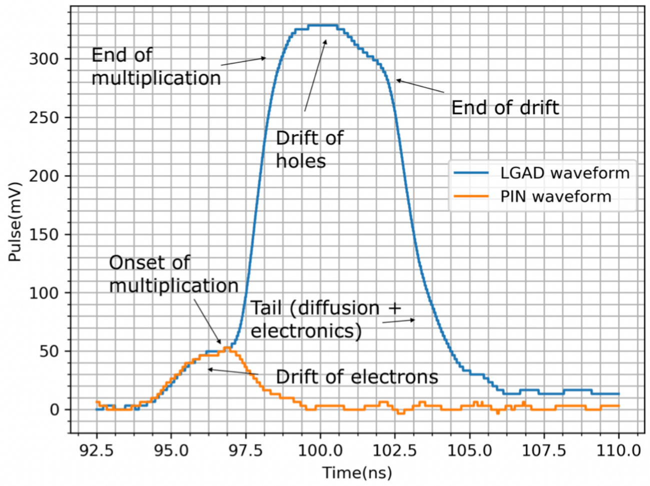


Comparison of dopant profiles from simulation and SIMS measurements.

LGAD Characterisation



A TCT method for finding full the depletion voltage. Where the two fits intersect all charge deposited is collected and hence full depletion.



Comparison of waveforms produced by red laser backside TCT for both LGAD and PIN diodes in blue and orange respectively at 300 V.

Conclusion

Question

Amit Pathak: What is the meaning of Qeffective? Is these any relation between Qeffective and Gain?
A:

Shan: Can you explain "gain" in this paper?
What does its level mean?

A: the ratio of output to input signal

Question

Yuhang Tan: In page1.How to detect low energy X-rays with hybrid pixel?

A:

Suyu Xiao: What's the noise floor? Is it just a threshold?

Question

Ryuta Kiuchi: Could you explain the relationship between the Gain and the doping density or the electric field ?
From this point of view, how we can very roughly understand the Fig4.and Fig.10 ?