CPAD White Paper Presentation:

Development of Ultrafast Timing Detectors Using Wide Band Gap Semiconductor Materials

Carl Haber on behalf of NCSU-LBNL-BNL Collaboration

Introduction

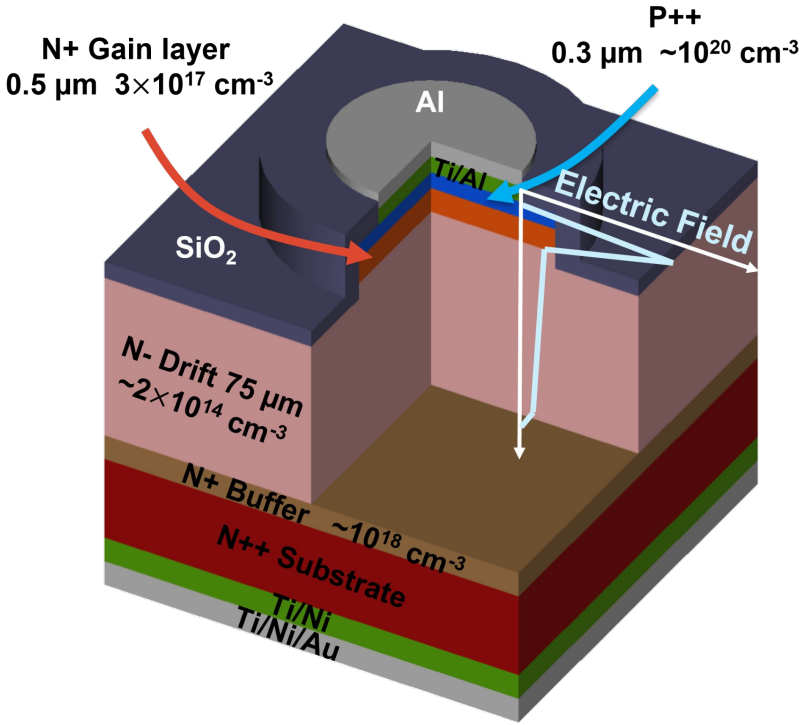
North Carolina State University is the lead institution (NCSU)

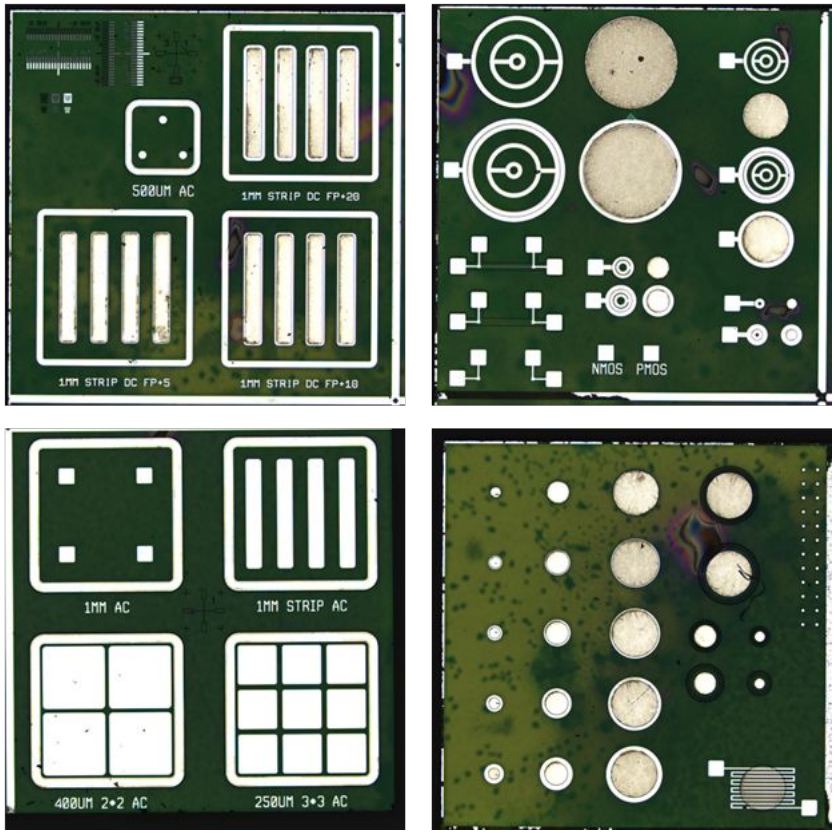
Our collaboration is already funded by DOE HEP, with a 2 year grant ending March 2025. We intend to submit a renewal proposal to this year's comparative review (DOE FOA 0003177). We have submitted a pre-proposal to DOE as per the FOA instructions

Our current work is on schedule relative to the plans included in the current proposal, as funded.

Description of R&D

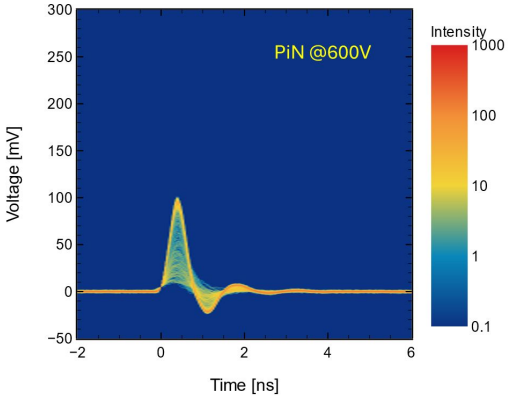
- Goal is to develop LGADs using wide band gap (WBG) materials - SiC, GaN
- Application is to 4D tracking and PID
- These materials can operate at high temperature, can be faster than Si, may be more radiation resistant - could lead to mass/cost reduction due to cooling
- North Carolina State University is a leading institution in the area of wide band gap materials and has fabrication facilities
- Significant growth in industrial base, including high quality substrates and epi, driven by power conversion, electric vehicles, and lighting markets
- We have designed and fabricated 2 generations of prototype devices. Gen 2, now under test shows charge gain using alpha particles
- We have irradiations scheduled for this summer
- We have fabricated segmented devices which will be studied in the near future
- Junction termination structures is an important topic of upcoming study
- We work with industry to supply, and develop, the required epitaxy

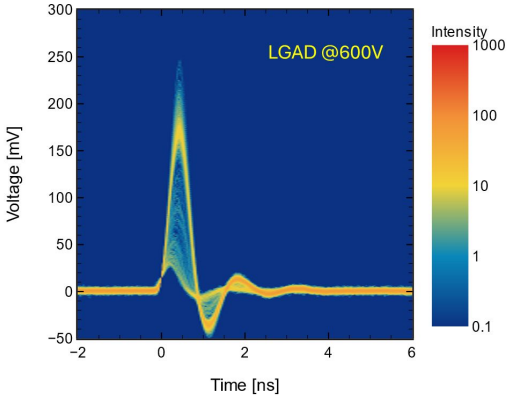


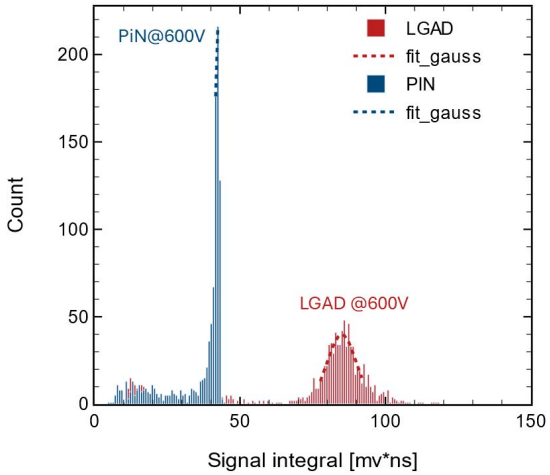


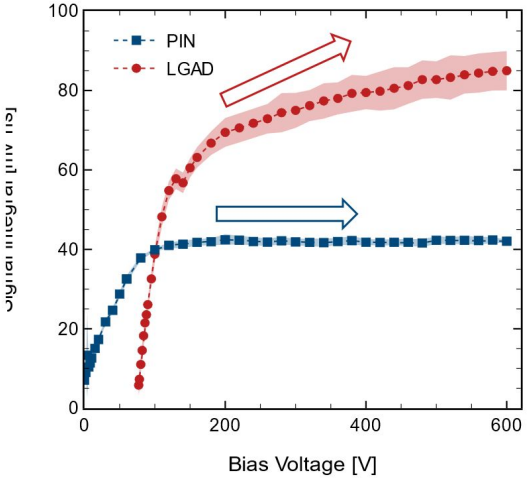
Unlike Si-LGAD, structure is p++,n+,n-drift since $\propto_h > \propto_e$ and fast signal is due to electrons

preliminary









Team and Responsibilities

The present collaboration works as follows and proposes to continue in this way.

NCSU: Responsible for the processing of the semiconductor wafers, device measurements, process and functional simulations, device physics, participation in irradiations: John Muth, Spyridon Pavlidis (faculty), Phil Barletta, Greg Allion (staff), Ben Sekeley, Yashas Satapathy (PhD students)

LBNL: Responsible for device design and simulation, device parametric and source testing, irradiations, and test beams, front end electronics development: Carl Haber, Steve Holland (staff), Tao Yang (postdoc)

BNL: Responsible for ion implantation, device testing, lead and coordinate irradiations, test beams: Stefania Stucci (staff)

Overlap with RD’s

RDC3: Solid State Tracking: unclear as whether LGADs live in RDC3 or RDC11
RDC4: Electronics and ASICs: concerning the development of appropriate front ends in silicon or in SiC
RDC9: Calorimetry
RDC11: Fast timing: unclear as to whether LGADs in in RDC3 or RDC11

We have also presented to DRD3, suggest that RDC11 is a natural home for us since DRD3 has a big overlap with RDC3

Timeline

Timelines for the project are as follows (calendar years):
(2024) Demonstrate first SiC-LGAD devices, initiate radiation damage program
2025 Further study of 2nd generation devices, segmented arrays, JTE structures, test beam and irradiation program. Work with industry on wafer source development. Submission of 3rd generation wafer designs. Possible procurement of GaN wafer, prototyping
2026 Further refinement of device design, continued evaluation program
2027-28 Prototype designs optimized for PID at large radius, and fine segmentation for 4D inner tracking