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30 June 2018

PhD Grants from the China Scholarship Council:
Co-operation Program with the UT and INSA (France)
Proposal:

Development of 3D Silicon Coincidence Avalanche Detector (3D-SiCAD) for charged particle detection

Keywords:

Charged particle detection, single photon avalanche diode - SPAD, coincidence

Context

The need of charged particle detector allowing both time and spatial information is important for various applications such as medical physics applications (hadron therapy and proton computed Tomography), high energy physics experiments (vertex tracking), electron transmission microscopy (direct electron detection) etc. with an increasing demand for more aggressive performances in terms of low material budget, low noise, and very high spatial and time resolutions with an acceptable radiation hardness.

In these domains, Geiger-mode avalanche diodes (also referred to as Single-Photon Avalanche Diodes, SPADs) have encountered lots of interest in the past years due to their high sensitivity and their timing performances (in the picoseconds range) as well as the possibility of their implementation in CMOS technology. Nevertheless, their relatively high Dark Count Rate (DCR) is a major issue for charged particle detection, especially when it is much higher than the incoming particle rate. To tackle this issue, we have developed a first prototype of 3D Silicon Coincidence Avalanche Detector (3D-SiCAD), figures 1-2 [1-2]. This novel device implements two vertically aligned SPADs featuring on-chip electronics for the detection of coincident avalanche events launched by a unique charged particle crossing both SPADs. Such a coincidence detection mode allows an efficient discrimination of events related to an incoming charged particle (producing a quasi-simultaneous activation of both SPADs) from dark counts occurring independently on each SPAD.

Project proposal

The goal of the project is to pursue the 3D-SiCAD development with different challenges keeping in mind a low cost and versatile approach:

- 3D assembly of two tiers at die level (wafer level may be excluded due to technological costs),
- targeting large detection area (few cm² to tens of cm²) abutting detectors in plane,
- Choice of the CMOS technology(ies) for bottom and top layers.

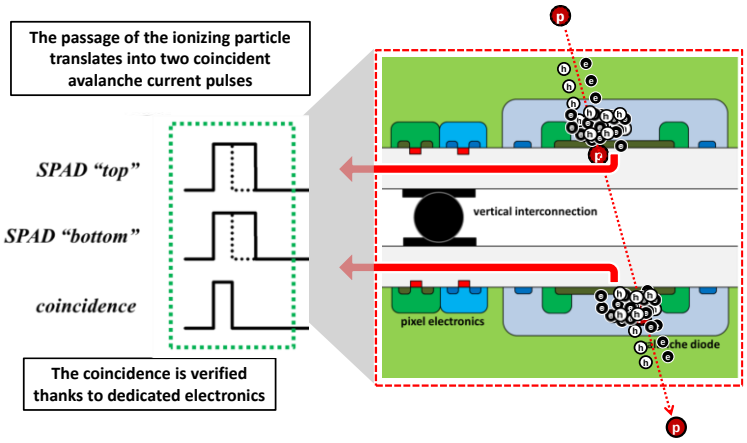

Figure 1: Illustration of the coincidence concept (two avalanche events are detected simultaneously with the passage of a charged particle)

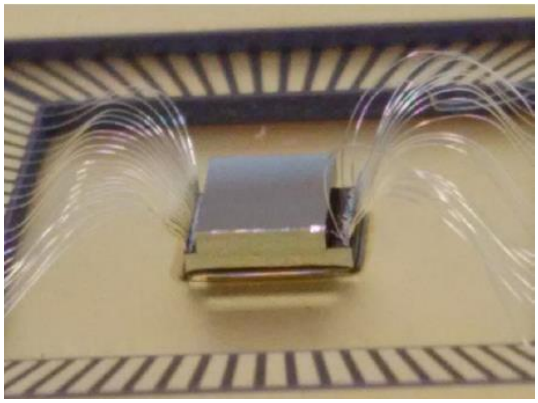

Figure 2: 1st prototype of 3DSiCAD (two CMOS integrated circuits integrating SPADs and associated electronics are stacked vertically)

The PhD student will have to propose a global detector architecture taking into account technological constraints, to design the circuit(s) (CMOS technology), to propose the 3D assembly technology (in house or sub-contractor), to develop the testing board and the experimental setup, to measure the detector performances.

Supervising and collaborations

The PhD student will be supervised by Pr. Francis CALMON and Patrick PITTET in collaboration with experts of CMOS technology, medical physicians and experimenters. The work will be done at Institut des Nanotechnologies de Lyon - France (CNRS joined laboratory) with a link to the Labex PRIMES[1] (for experimental facilities).

Candidate skills

The applicant must hold a Master's in Electrical Engineering / Electronics-Microelectronics Engineering. He/she is expected to have the following technical skills:

- Good knowledge in semiconductor physics and technology,
- Good knowledge of microelectronics and electronics: analog and digital circuit design,
- Some experience with the VLSI design techniques and the use TCAD, EDA design tools is desirable.

It is expected that the candidate will have excellent communication skills and a strong motivation for this multi-domain project.

References

[1] M. M. Vignetti, F. Calmon, R. Cellier, P. Pittet, L. Quiquerez, G. Pares, A. Savoy-Navarro "*Development of a 3D Silicon Coincidence Avalanche Detector for Charged Particle Tracking in Medical Applications*" IEEE NSS-MIC Nuclear Science Symposium - Medical Imaging Conference, 29 oct. – 6 nov. 2016, Strasbourg (https://doi.org/10.1109/NSSMIC.2016.8069553).

[2] M. M. Vignetti, F. Calmon, P. Pittet, G. Pares, R. Cellier, L. Quiquerez, T. Chaves de Albuquerque, E. Bechetoille, E Testa, J.-P. Lopez, D. Dauvergne, A. Savoy-Navarro "*3D Silicon Coincidence Avalanche Detector (3D-SiCAD) for charged particle detection*" Elsevier Nuclear Inst. and Methods in Physics Research A, Vol. 881, pp. 53–59, 2018 (https://doi.org/10.1016/j.nima.2017.10.089).

[1] http://primes.universite-lyon.fr/