PROCEEDINGS OF SCIENCE

Multi-pixel Geiger mode imager for medical application

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Nowadays, there are two types of sensors to detect the low luminous flux, PMT (Photomultiplier Tube) and Geiger-APD (Geiger Avalanche Photodiode). The domain of Geiger-APD has reached an advanced development in the last years. The basic idea of this structure consists in polarizing an APD in Geiger-mode by applying a voltage beyond its breakdown voltage. In this case of polarization, the APD is working in a special mode and is able to detect the single photon. The theory of detection of single photon using this detector has been invented in the beginning of 90's and developed for detection of low light intensity. By using this kind of photodiode in the Geiger-mode, we designed a new type of detector and several applications have been explored. In astrophysics, we can use this detector for the detection of cosmic rays (through the detection of Cerenkov light generated by atmospheric showers). Another application is also possible and reveals an important method for detection of cancer cells.

The idea of this work is to use the spatial resolution and rapidity of the Geiger-APD in the field of very low light intensities; it would be possible to explore new areas. The equipment that we intend to achieve will be a series of Geiger-APD arrays (imagers) based on the principle detector unit.

But where is the importance of this detector in very low light intensities in life? For example, in all the phenomena of induced fluorescence, with risks of disruption of life due to lighting inducer itself. But also in spontaneous emissions which can occur at the cellular level. These emissions related to the exchange of oxygen, would be stronger in cancer cells because of their increased metabolism. This would be a new diagnostic tool for detecting these activated areas.

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1. Introduction

The work to be done includes the integration into Microsystems, with the aim, in the long run, to develop several applications in astrophysics, biology, optical detection, and most importantly, fast imaging systems. The manufacturing of imaging equipment through a new process must be defined by a detailed study on the imaging Geiger.

Different applications in astrophysics are possible such as the detection of Cerenkov flash [1]. But the most important application is a photonic solution for better health care.

These works is included in the study of cancerous cells by using a mechanical system to reconstruct an image of the scanned area to identify the photons emitted by this cell and then locate the disease. The mechanical system is related also to another electronic system that controls the detector array and realizes a mechanism to be followed to obtain a better resolution and optimized results.

In this work, we will present the main characteristics of the proposed technology with a design of the proposed imager is shown with important ideas to determine a cancer cell.

2. Design Structure

Our design is principally based on a mix of two technological structures. The first part is the photodiodes (APD) that permit the detection of single photons and the second part is the read-out circuit of the APD based on transistors manufactured in CMOS standard process. Actually, the entire ship is manufactured in CMOS 0.35µm Opto, designed by our team and achieved by AMS (Austria Micro-system) through the CMP (Circuit Multi-Projets) [2].

Many photodiode structures could be presented depending on the electrical characteristic i.e. the Breakdown Voltage BV, which is related principally to the doping of the epi-layer [3].

One of the advantageous structures for our work and particularly for the design constraints is presented below (fig. 1).

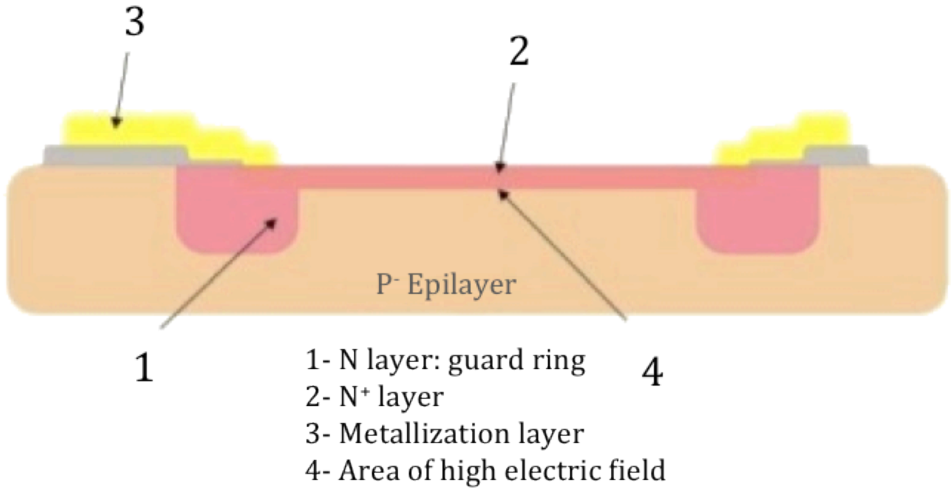

Figure 1: Geiger Photodiode structure based on N^+/P junction and guard ring N layer.

In the process CMOS 0,35µm Opto, P^- epi-layer (thickness ≈14µm) is predefined on P-type substrate. The guard ring has the role to protect the edges of the N^+ layer because of its low breakdown voltage comparing to that of the center.

The structure represented on fig. 2 has to be implemented with its read-out circuit in the same cell; each cell is called a pixel. To present the multi-pixel system, the imaging device can be defined on the following figure (fig. 2).

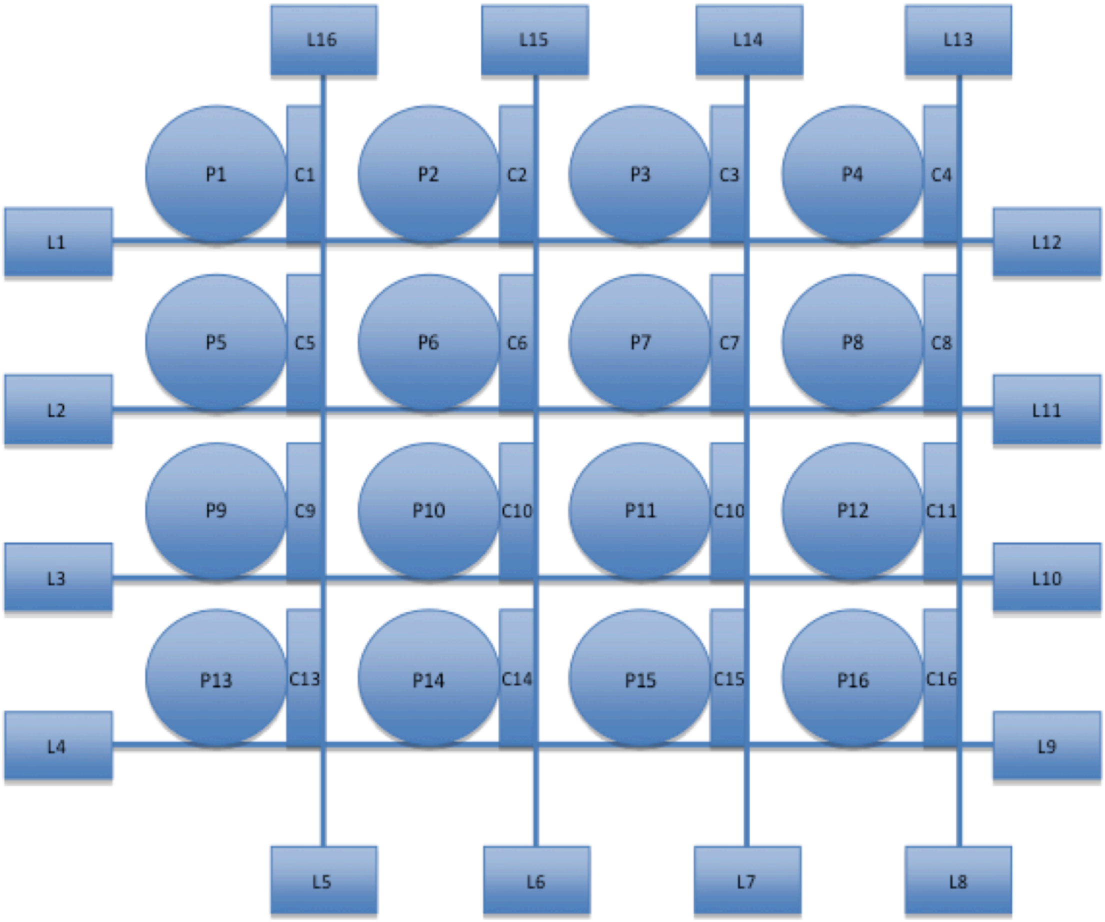

Figure 2: Illustration of an imaging system in CMOS 0.35µm Opto. An example of 4x4 photodiodes matrix, each photodiode has its read-out circuit.

In this structure, one can identify the round shapes (P) that represent the photodiodes, the rectangular shapes (C) that represent the counters and the quenching system (it could be a resistor or a transistor). Addressing of signals takes place through decoders row / column (L).

3. Use of imagers in medical applications:

The above system (fig. 2) presents an example of APD matrix to be used on cells suspected by a tumor. Actually, the principal aim of our study is to detect cells that are affected by a cancer.

Normally, cancer cells have the specific to emit more photons than normal cells [4] (in very low quantities of photons) due to their additional activity compared to

normal ones. Hence, the necessity to use Geiger APD as a detector able to detect low light flux, and count pulses by using a read-out circuit integrated on the same ship.
Many studies are already demonstrate that Geiger APD could be used to detect low light flux in human cells [5,6,7] and therefore, differentiate cancer cells from healthy ones. In fact, component such as SiPM [8], which is derived from the Geiger APD array concept. SiPM is a matrix of Geiger APD but all pixels are interconnected, it has only one-input and one-output signals. This kind of Geiger component has been used for development of small-animal PET prototype and presented in [9].

To illustrate the procedure of handling, the object in question is subjected to an examination. During this procedure, the object must be immobilized to prevent data loss; the lens receives the photons focused thereafter to the imager array. Following the illustration of this procedure (fig. 3).

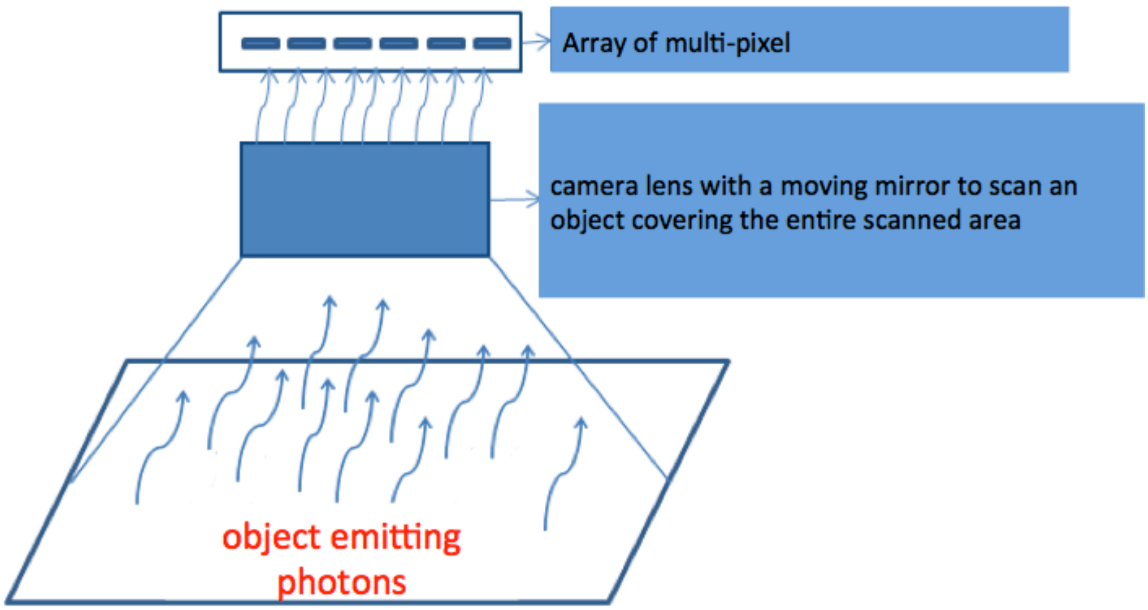

Figure 3: Illustration of detection system; photons are emitted by the scanned object and are collected by the lens which converge them to the detector (figure not to scale).

4. Improvement of the imaging system:

For a future improvement of the imaging system, a new structure also based on CMOS standard technology could be proposed. This structure is based on the 3D IC technology wish is a very recent concept for imaging system. Many advantages could be providing:

1- A reduced loss in the fill factor, due to the separating of the 2 principal parts (detectors and read-out circuits).
2- A better QE (Quantum Efficiency).
3- Possibility to design counter circuits with more transistors (no constraint surface).
4- Fewer electrical constraints between diodes and counters (separated and related by via contacts).

Proposed structure is shown on figure below (fig. 4).

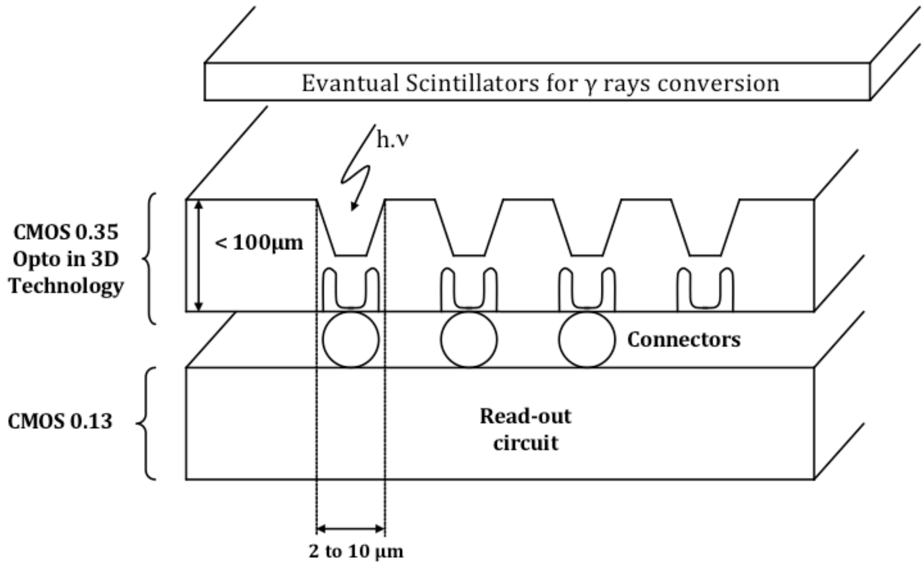

Figure 4: Proposed structure in 3D technology. Top layer includes photodiode structures; bottom layer includes read-out circuits for signal treatments.

In conclusion, the new structure is promoted to give important results in the domain of detection of low light intensity and new structures are included in this process for a new era of imagery in Geiger-mode for detection of cancer cells.

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