

Silicon-Gas Pixel Detector

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Abstract. The proposed Silicon-Gas Pixel Detector (SGPD) combines the advantages of Silicon and Gas-pixel detectors (GPD). 7 micron space resolution and down to 0.2 degree both angles measurements are inside 10 mm thick and very low material detector. Silicon pixels implemented directly into electronic chip structure allow to know exact time when particle crossed the detector and to use SGPD as a completely self-triggered device. Binary readout, advanced data collection and analysis on hardware level allow to obtain all the information in less than 1 microsecond and to use SGPD for the fast trigger generation.

1. Introduction

Gas Pixel Detectors (GPD) are very attractive for application in existing and future accelerator experiments and beyond. They can be produced radiation hard and have low power consumption using relatively cheap technology. Figure 1 presents GPD schematic view during accelerator test when 10 μm space accuracy has been obtained [1].

Using a time projection method one obtains 3D particle track reconstruction with precise coordinate and angular accuracy. With fast readout and data processing on hardware level all the information can be transmitted in less than 1 μs and used for the fast trigger generation [2].

With time projection method GPD assumes permanent data collection and processing with 25 ns cycles corresponding LHC beam crossing cycle. With 10 mm thick gas volume and maximum drift time of the elections generated by charged particles in gas about 200 ns, we can obtain 8 points with X and Y coordinates along the particle track and Z coordinate, which corresponds to the cycle number when the coordinates were measured. It allows particle trajectory reconstruction and angle determination in both XZ and YZ planes with down to 0.2° accuracy and particle entry point measurements with $\pm 37 \mu\text{m}$ accuracy.

The only real disadvantage of the device is the absence of exact time knowledge when the particle crossed the detector. It becomes more important if a few particles arrived during 200 ns drift time needed to collect the data.

The simple way to obtain time coordinate is to add a layer of silicon pad or strip detector to existed GPD structure. But it means additional layer of silicon, a lot of interconnections and substantial increase of production cost. Therefore we decided to use a charged particle detection in epitaxial layer created during regular chip production technology.



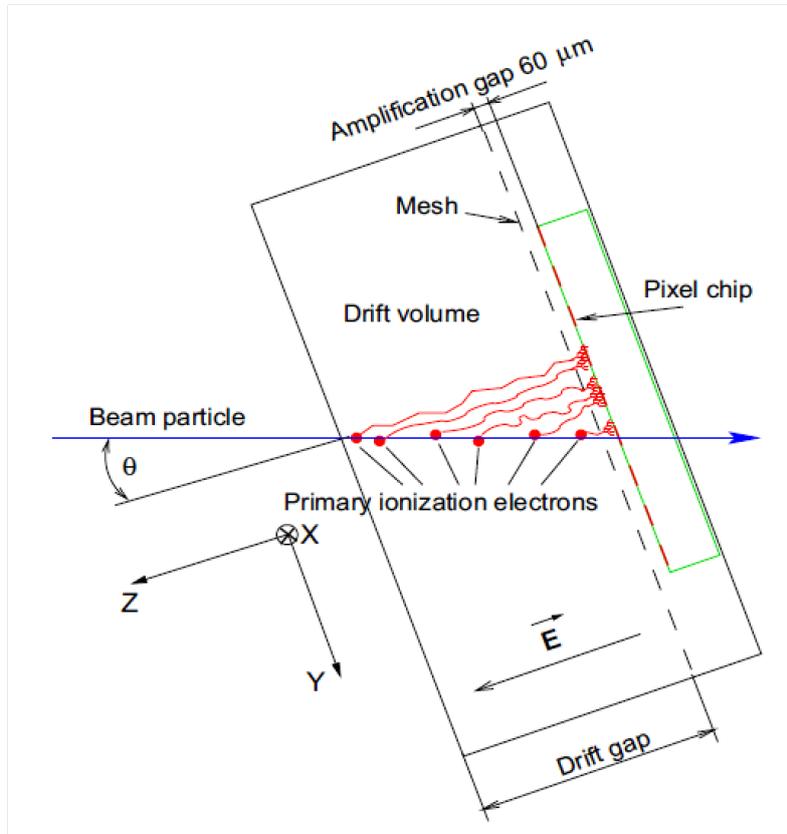


Figure 1. The schematic view of the GPD exposed to the test beam.

2. Silicon Pixels Implementation

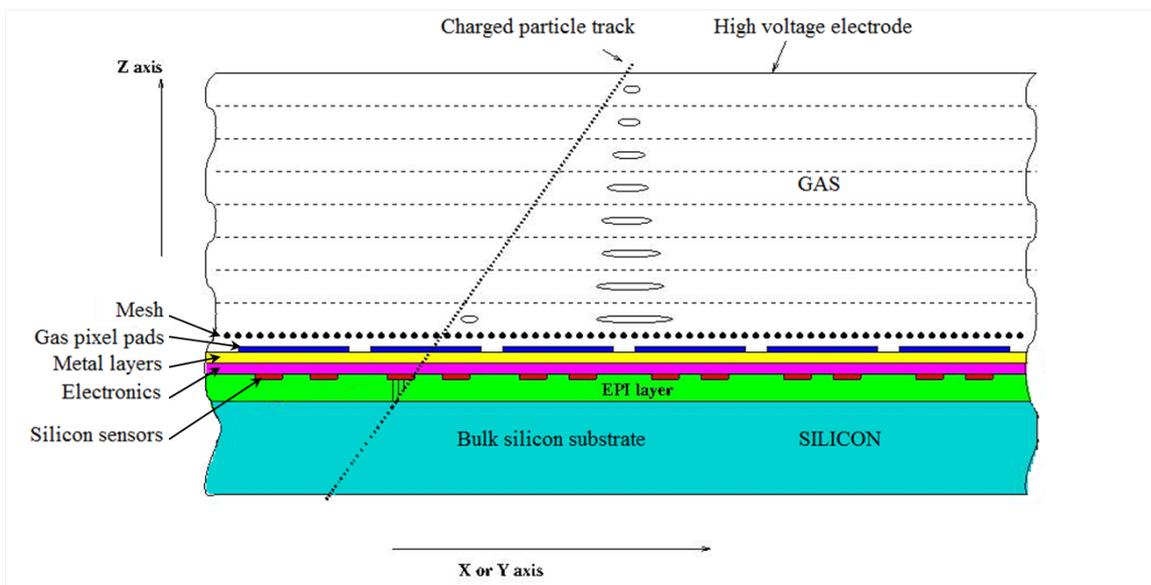


Figure 2. The schematic view of SGPD structure.

In GPD $100 \times 200 \mu\text{m}$ pixels are the metal pads on the $2 \times 2 \text{ cm}^2$ electronic chip surface. Each pixel electronics is positioned near the pixel. Data acquisition and processing electronics is at two chip edges for X and Y coordinates determination correspondingly.

Adding about $25 \times 25 \text{ m}$ silicon sensors below chip electronics within epitaxial layer we can collect electrons generated by the charged particle in the epitaxial layer in very short time about 1 ns and we can obtain exact information about the particle arrival immediately.

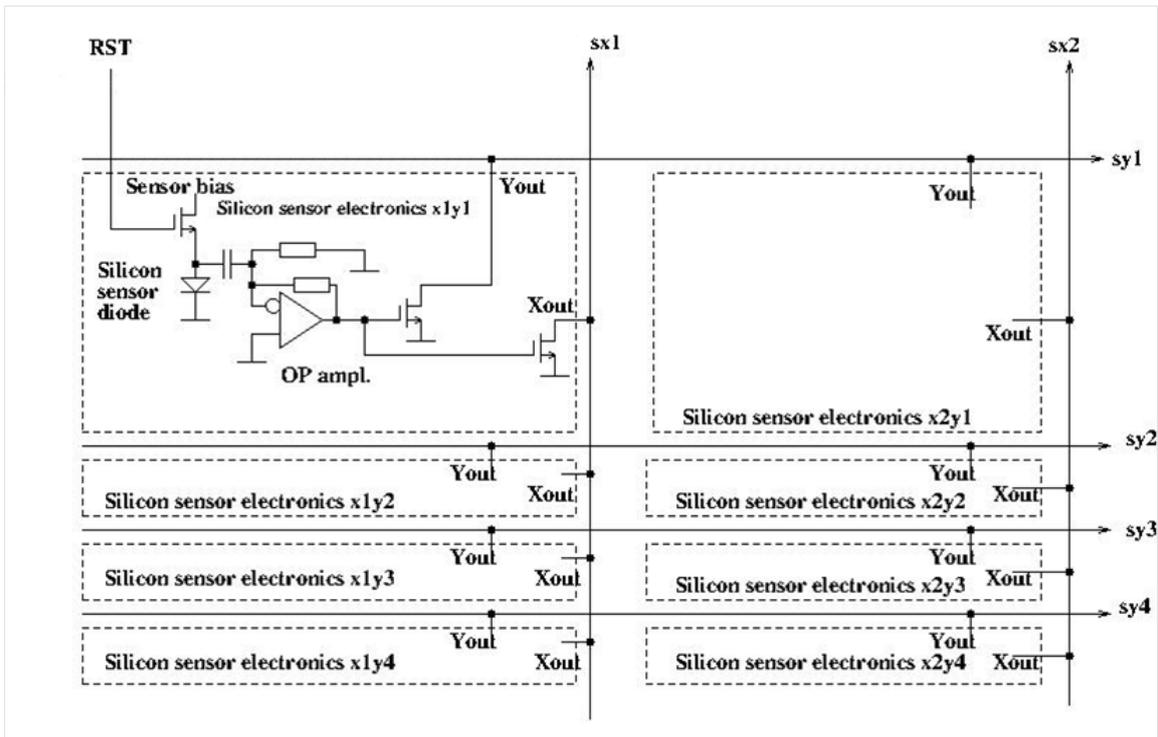


Figure 3. Silicon sensor electronics.

With binary silicon pixel readout we can determine XY coordinate of the particle arrival with $7 \mu\text{m}$ accuracy. If power consumption/dissipation is a critical point, the silicon pixel size can be increased to $50 \times 50 \mu\text{m}$. In this case XY accuracy is still $15 \mu\text{m}$ but power dissipation is four times less.

3. SGPD properties

Each chip has an internal generator which starts readout process when particle crosses detector volume and generates as many cycles as needed to collect and analyze the data from the chip pixels and transmit the information about particle coordinates and both angles. If SGPD works in accelerator environment internal generator clocks must be synchronized with beam crossings. For example LHC cycle is 25 ns (40 MHz frequency). In this case the internal generator frequency can be also 40 or 80 , 120 , 160 MHz . Higher frequency is useful if we need to increase the speed of data processing in chip electronics.

Suggested chip electronics analyses the data and measure both X and Y coordinates as well as both angles on hardware level. The latency of output information is about 40 clock periods. With 40 MHz frequency, it is $1 \mu\text{s}$. If smaller latency is required we can increase frequency to 80 MHz and decrease latency to about $0.5 \mu\text{s}$. If we use $0.25 \mu\text{m}$ technology for electronics production, 80 MHz looks like reasonable clock speed. Higher frequency can be a challenge.

4. SGPD chip layout

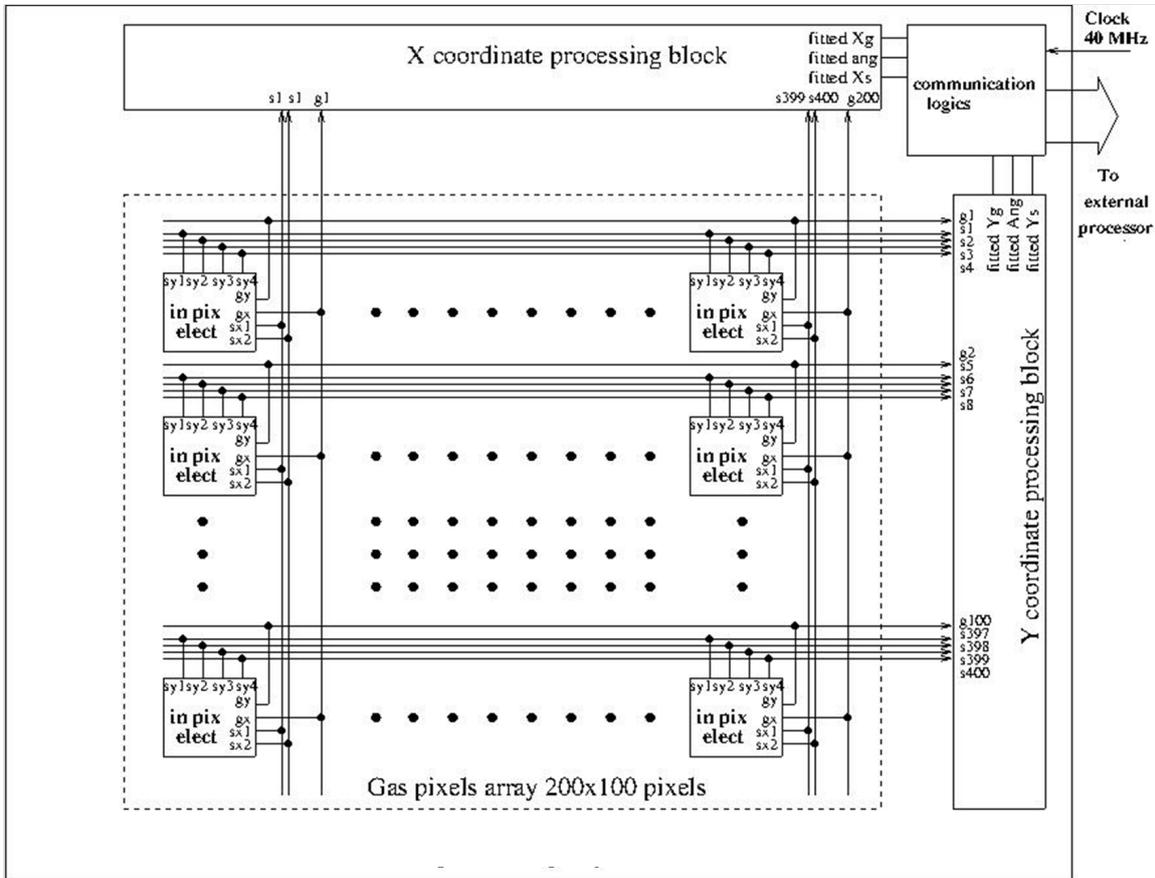


Figure 4. SGPD chip layout.

As shown on the figure 4, chip electronics consists of blocks under each gas pixel pad, peripheral processing blocks (X-coordinate processing and Y-coordinate processing blocks) and some communication logic to transfer data to host computer.

We assume the size of gas pixel pads to be $100 \times 200 \mu\text{m}^2$, while for silicon sensors suggested area covered by 1 sensor is $50 \times 50 \mu\text{m}^2$. So, in each in pixel electronics block we will have 1 block of gas pixel registration and 8 blocks of silicon sensor registration. As described in [2], all signals from the pixels in 1 row are combined on 1 wire, making the row of pixels similar to strip in micro strip detector, and the same is done for each column. So, each pixel generate 2 outputs one for x-strip another for y-strip.

Same procedure will be employed for silicon sensor outputs, with some difference, though for gas pixels we add signals from pixels, each pixel contributing fixed amount of current, so by the signal amplitude we can say how many pixels in the given strip had generated signal, we are not doing this for silicon sensors every strip has the logical OR of all signals generated.

5. Conclusion

GPD with a silicon pixel layer integrated into its electronic chip is a new type of detectors (SGPD) with significantly extended functionalities. SGPD has low material and relatively cheap structure combined with good coordinate and angular accuracy of particle track reconstruction within 10 mm thick device. SGPD has fast on-line data processing and ability to provide charged

particle trajectory measurements within $0.5 \mu\text{s}$ and therefore can be used to generate first level trigger. SGPD can work as completely self-triggered device. It expands SGPD application in many areas beyond high energy physics.

Acknowledgments

This work was partially supported by Russian Foundation for Basic Research (grant No. 14-22-0353). Special thanks to Prof. Martin Breidenbach and Prof. Su Dong for useful discussions.

References

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