# Fabrication and characterization of silicon detectors on indigenously grown high resistivity wafer

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## Introduction

Silicon is the widely used semiconductor material for developing high-resolution radiation detectors, integrated circuits, advanced devices for quantum computing and other state-of-the-art technological applications. High resolution Si-detectors are used in nuclear physics experiments, high energy physics experiments, radiation safety and monitoring systems. These detectors require high resistivity detector grade Si wafers. However, these wafers are not available easily as only a very few manufacturers grow detector grade silicon material. Heavy Water Division, BARC has taken an initiative to grow high resistivity, detector grade silicon crystal under the program **Sand to Silicon** to fulfil DAE's requirement and also cater to strategic requirement of the country.

## Development of silicon detector

In order to validate and qualify the wafers as detector grade material, silicon detectors in various sizes and geometry were developed by Electronics Division, BARC. These detectors are fabricated at Bharat Electronics Limited (BEL), Bengaluru [1].


**Fig 1**: Diced 6x6 silicon pad (individual element of 1 $cm^2$)

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The combinations of small and large detectors were arranged across the wafer for full utilization of wafer surface area. Encouraging results were obtained during electrical characterization of the processed wafer. A few good detectors are packaged at BEL, Bengaluru. Fig. 1 shows the diced 6x6 large area (~ 40 $cm^2$) silicon pad sensor while Fig. 2 shows packaged detectors in different size and shape.

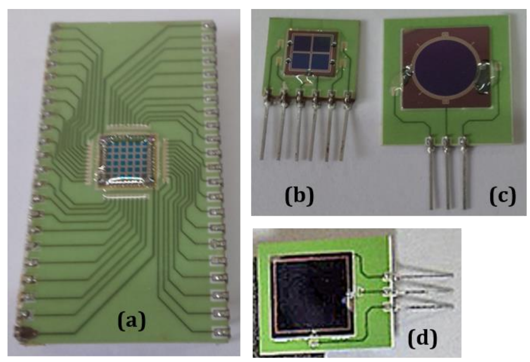


**Fig 2**: Packaged silicon photodiodes in various shapes and sizes. (a) 6x6 silicon pad of 1 $mm^2$ individual element, (b) 2x2 array of silicon pad, (c) Circular pad (1 $cm^2$) (d) Square pad (1 $cm^2$)

## Characterization of the packaged detectors

The packaged small detectors were tested with laboratory radiation sources to validate the quality of the indigenously grown high resistivity wafer. As a benchmark similar detector fabricated on a commercially available wafer [2] was also used and compared vis-à-vis.

## Experimental setup

The characterization of the packaged silicon photodiode detectors of area 1 $cm^2$ in circular and square geometry was carried out using laboratory alpha sources at NPD, BARC.

The experimental setup consisted of a vacuum test chamber, radiation source, Si detector, HV bias supply, commercial pre-amplifier & shaper module (MSI-8) and 16K MCA (developed by ED, BARC) [3] as shown in Fig 3. The detectors were biased at 60 – 70 V and the signal was processed using 1 μs shaping time. The spectrum is obtained using ANUSPECT gamma spectrum analysis software [4].

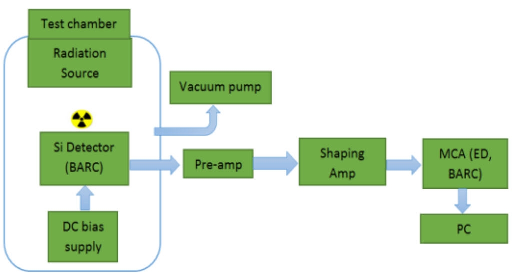


**Fig 3**: Schematic of Experimental Setup

## Result

The detector characterization was carried out using two laboratory alpha sources, Am-241 and Th-229. The oscilloscope results of the shaped detector pulse are shown in Fig 4.

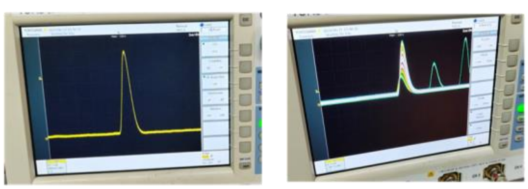

**Fig 4:** Response of the silicon detectors (Shaped output from MSI-8 module) grown on the indigenous wafer in the oscilloscope with sources (a) Am-241 and (b) Th-229

The energy spectrum of the Am-241 source using 1 cm$^2$ square photodiode developed on indigenous wafer is shown in Fig 5. The energy resolution of the in-house developed detector is obtained as ~ 2.4 % which is near to the resolution achieved with the detector (same design) developed with a commercial wafer (~ 1.8 %). The difference in resolution is mostly due to the little higher leakage current of the detector developed with indigenous wafer. The leakage current can further be improved with better wafer finishing and controlling the minority carrier life time. The test procedure is repeated for the circular photodiodes and similar results are obtained.

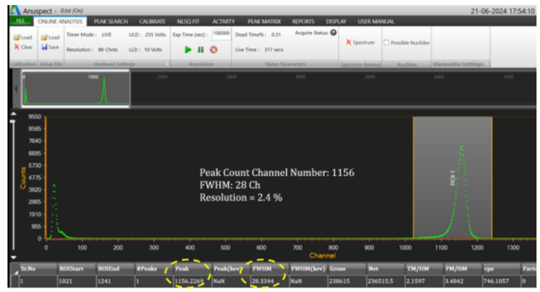


**Fig 5:** Energy spectrum of Am-241 source with 1 cm$^2$ square photodiode (fig 2d) developed using in-house grown wafer. Resolution achieved is ~ 130 KeV

## Conclusion

The test results of the packaged small detectors (photodiodes) with laboratory alpha source are encouraging. The results indicate that the indigenous technology of growing Si wafer is very close to achieving the required detector grade quality. The response of these small detectors with gamma sources will be observed by coupling with a suitable inorganic scintillator in future.

The packaging of the large area silicon pad sensor (Fig. 1) is in progress in the foundry with a suitably designed PCB by ED, BARC to facilitate low energy nuclear physics experiments.

## Acknowledgement

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## References

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