Performance of Integrated ΔE-E Silicon Detector Telescope with Light Charged Particles and Fission Fragments

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Introduction

Thin ΔE detectors with thickness of a few microns are used for study of nuclear reactions involving heavy charged particles such as fission fragments. Such detectors are difficult to fabricate using conventional silicon etching techniques and are also difficult to handle as they are very fragile. To overcome these problems, a novel detector in which the E and ΔE detectors are integrated on the same silicon chip has been developed [1]. The performance of the first prototype has been presented earlier [2]. In this paper, the performance of the second prototype with light charged particles (measured in ^{7}Li+^{12}C reaction) and fission fragments (measured in ^{19}F+^{209}Bi reaction) has been presented. The results presented in this paper demonstrate that the integrated detector has performance as good as that of a silicon detector telescope which incorporates commercially available physically separate E and ΔE detectors.

Fabrication Technology

The integrated E and ΔE detector has been fabricated using a double sided wafer processing technology. Such technology has been developed for the first time in India for realizing electrically active devices on both sides of the silicon wafer. The detector has been designed to have a thin ΔE detector in an epitaxially grown silicon on the top side of the wafer and the E detector on the back side of the base wafer. The complete process flow has been tuned to reduce leakage current, minimize dead layers and obtain high energy resolution for charged particles. Detectors with geometric area of 50mm^2 and 100mm^2 and ΔE thicknesses of 10 μm, 15 μm and 25 μm have been fabricated using the optimized process. The E detector thickness is 300 μm. The technology developed can be adopted to fabricate detectors with different ΔE thicknesses down to a few microns. Fig. 1 shows the packaged detector.

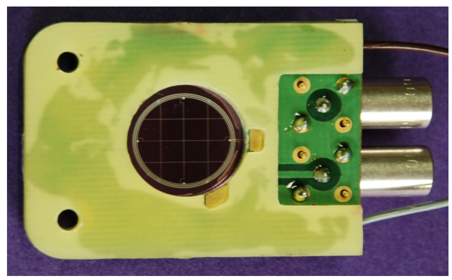

Fig.1 Packaged E-ΔE silicon detector telescope

Performance of the integrated detector

The E and ΔE detectors of the integrated detector have been tested to measure reverse leakage current and capacitance at various bias voltages. The leakage currents were observed to be about a few nanoamps. The detectors have been tested in vacuum using a dual alpha source of ^{238}Pu + ^{239}Pu to see the performance with charged particles. To study the performance of the integrated detector as a telescope, these detectors have been tested in FOTIA, BARC using 12 MeV ^{7}Li beam on ^{12}C target. The two dimensional spectrum obtained by plotting the ΔE and E signals is as shown in Fig.2. The thicknesses of ΔE and E detector are 10 μm and 300 μm respectively. As can be seen, the integrated detector clearly identifies the particles ^{7}Li^{+}, alpha and protons. Due to superior energy resolution of E detector, alpha groups corresponding to various states of ^{15}N created during the reaction can be clearly identified. The rightmost peak in the alpha spectrum corresponds to the alpha produced in the reaction $^1H(^7Li,\alpha)$ due to the presence of hydrogen impurity in the target. The result is similar to that obtained earlier using a telescope incorporating physically separate imported E and ΔE detectors.

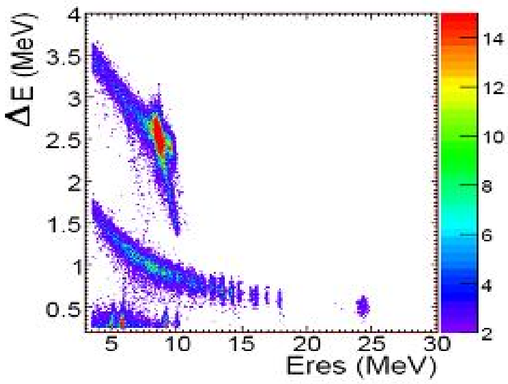

Fig.2 Two dimensional spectrum recorded by the integrated detector for the reaction of 12 MeV ^{7}Li beam on ^{12}C target

To investigate the performance of the integrated ΔE-E detectors for fission fragment measurements, two detectors of active area 100mm^2 and 50 mm^2 and ΔE thickness of 10μm were used in a typical charged particle measurement setup using ^{19}F beam from BARC-TIFR pelletron accelerator facility. A self-supporting Bi target of 800 μg/cm^2 thickness was used. The events occurred in the $^{19}F+^{209}Bi$ reaction at a bombarding energy of 44.8 MeV are recorded by the above detectors kept at 151^o and 131^o respectively. A typical 2D (ΔE-E) spectrum measured by the detector with 100mm^2 area is shown in Fig. 3. The corresponding 1D spectrum recorded by the ΔE detector is as shown in Fig.4. It can be observed that the events of fission are widely separated from those for elastic and direct reaction channels. Projectile like fragments of different Z (such as F, O, N, C) are also clearly separated from each other showing the quality of these detectors.

Conclusions

A novel detector with integrated E and ΔE detector on the same chip has been developed using double sided wafer processing technology. The detector can clearly identify charged

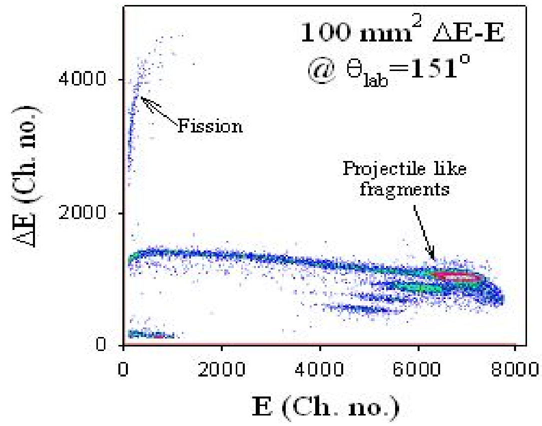

Fig.3 Two dimensional spectrum recorded by the integrated detector for fission fragment measurements in $^{19}F+^{209}Bi$ reaction

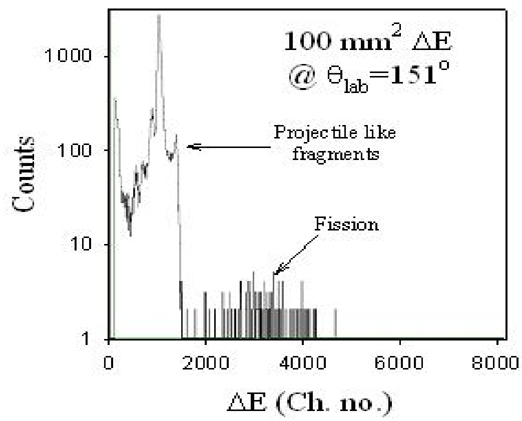

Fig.4 One dimensional spectrum recorded by the ΔE detector for the spectrum shown in Fig.3

particles such as protons, alpha and lithium and the results are equally comparable to those obtained with physically separate ΔE and E detectors. The integrated detector also shows clear separation of fission fragments. The tests carried out at FOTIA and Pelletron confirm the applicability of this detector as a telescope for physics experiments. Production of the integrated detector is presently being carried out to make it available to users for carrying out experiments.

References

[1] A Topkar et al,, Nucl. Instr. and Meth. A, 654, 330 (2011)

[2] Anita Topkar et al, DAE Symp. on Nucl. Physics 55, 702 (2010)