Development of Integrated ΔE-E Silicon Detector Telescope

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Introduction

Particle identification method using the E–ΔE detector telescope method is very popular in nuclear physics experiments. For heavy ions, the ΔE detector of the telescope has to be thin and uniform which is difficult to attain using the standard production methods of silicon etching. Conventional ΔE detectors are very fragile, and this puts serious limitation to their applications. Also, it is difficult to attain the uniformity of thickness when the ΔE detector thickness is few microns. Such ΔE-E detectors are also not very suitable for multi detector array system. These difficulties could be overcome by a novel integrated ΔE-E detector telescope in which both the detectors are fabricated on the same wafer. The aim of the present work was to indigenously develop the fabrication technology of such novel ΔE-E silicon detector telescope. In this paper we discuss the device structure and technology development of this integrated detector. The detector has been tested in FOTIA, BARC using a Lithium beam. The results of these tests showing the performance of the detector are presented.

Device Structure and Fabrication Technology

The ΔE-E silicon detector consists of a ΔE detector fabricated over a E detector. A double sided processing technology has been used for the first time in India to realize the ΔE and E detectors on the same wafer, i.e., ΔE on the front side and E detector on the back side of the wafer. Both the detectors are PIN type of detectors. The detectors have area of 50mm^2 and 100 mm^2 and have circular and square geometry. The thickness of the ΔE detector is 10μm, 15μm or 25μm. The top ΔE detector and bottom E-detector share a common N-type buried layer as anode formed by ion implantation. The E detector is formed within a high resistivity (3-5kΩ-cm) silicon substrate (thickness=300μm). The bulk of the ΔE detector is then formed by an epitaxially grown layer of silicon (10μm -25μm thickness) over the high resistivity substrate after obtaining buried N type layer. The contact to the buried layer is provided on the top side and is obtained by using a N$^+$ plug. The P$^+$ layer for the top PIN (ΔE detector) and back side PIN (E detector) are obtained using boron ion implantation. The process is optimized to achieve low leakage currents and minimize the dead layer.

A custom package has been developed to mount the detector in transmission mount and to enable wire bonding on the front side and back side detector. The packaged detector is as shown in Fig.1.

Experimental

The ΔE and E detectors have been tested to obtain leakage current (I-V) and capacitance characteristics (C-V) at different bias voltages. The energy resolution of the detectors has been studied by measuring the pulse height spectrum using a ^{238}Pu and ^{239}Pu dual alpha source. A test setup having a preamplifier, shaping amplifier, HV and a MCA has been used for these measurements. The measurements were carried in a vacuum chamber and the source to detector distance was optimized to get best energy resolution. For obtaining the pulse height spectrum of the E detector, the source was kept on the P$^+$ side of the E detector.

The detector has been tested in FOTIA, BARC using a lithium ion beam at 13MeV. A two dimensional spectrum has been obtained for a gold and carbon target to study the performance of the detector as a particle telescope. The results of these tests are presented in the subsequent section of this paper.

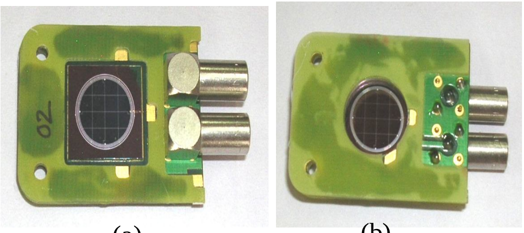
Results

The energy resolution of the E detector has been observed to be better than 30keV while the ΔE detector showed the energy resolution of about 120keV. This is expected as the capacitance of the ΔE detector is quite large due to a thinner active region. The typical pulse height spectrum for the ΔE and E detector is as shown in Fig. 2 and 3 respectively.

The performance of the ΔE-E detector as a particle telescope has been studied by using a Li beam in FOTIA, BARC. The beam energy was 13MeV. The two dimensional spectrum was obtained for a gold target and carbon target. As shown in Fig. 4, the integrated detector clearly separates the protons, alphas and lithium particles.

Conclusions

A novel silicon detector telescope with integrated ΔE and E detector on the same wafer has been developed indigenously. The initial studies carried out for evaluating the performance of the detector are very encouraging. The tests carried out in FOTIA using a lithium ion beam show that the detector clearly separates particles such as protons, alphas and lithium. More studies for evaluating the performance of the detector are underway.



(a) (b)

Fig. 1 Packaged a) front side ΔE and b) back side E detector

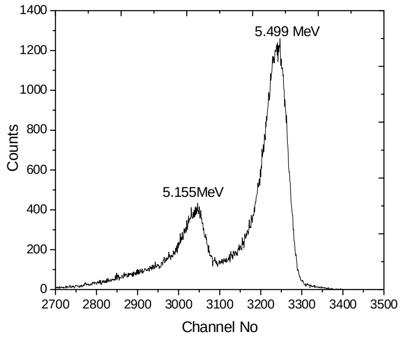


Fig.2 Pulse height spectrum for the ΔE detector

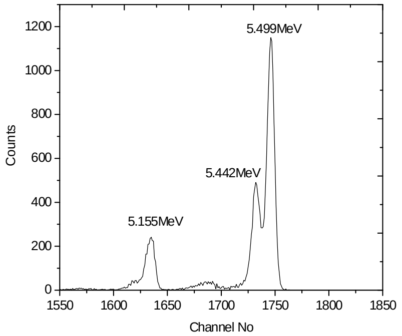


Fig.3 Pulse height spectrum for the E detector

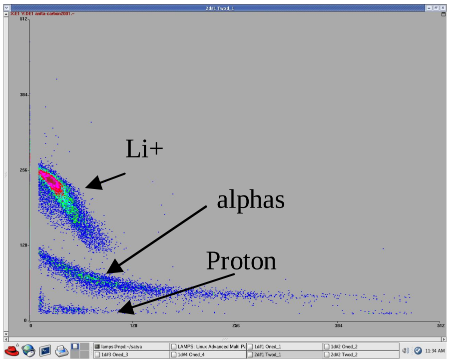


Fig.4 Two dimensional spectrum obtained by plotting ΔE channel No on Y axis and E channel No on X axis

References

[1] Anita Topkar, Pourus Mehta and P K Mukhopadhyay, DAE Symp. on Nucl. Physics. 2008.