THIN $\frac{dE}{dx}$ DETECTORS OF UNIFORM THICKNESS MADE ON EPITAXIAL SILICON

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ABSTRACT

Anodic dissolution of the low resistivity N^+ silicon substrate has been used to prepare $\frac{dE}{dx}$ nuclear particle detectors on the remaining epitaxially grown high resistivity N film. Robust fully depleted counters with sensitive layers thinner than 5 µ, with good uniformity can be made by this technique. Their characteristics are discussed.

At present time $\frac{dE}{dx}$ silicon nuclear particle detectors are prepared by lapping and chemical etching of the samples. However, two important problems arise from this technique : a good thickness uniformity over larger areas is difficult to achieve and a very great care is needed when handling the devices. It has been demonstrated recently [1-3] that thin uniform silicon films (down to several thousand Å) can be obtained by electrochemical etching of N^+/N epitaxial structure in a hydrofluoric acid solution. As a low resistivity material is more rapidly electropolished than a less doped one, it becomes rather easy, with an epitaxial structure, to etch out about 200 µ of a low resistivity substrate and stop the anodic dissolution of silicon when the thin epitaxial layer is reached.

The purpose of this paper will be to demonstrate the usefulness of such a technique for the fabrication of thin silicon surface barrier detectors.

1. DEVICE FABRICATION

Low resistivity (5.10^{-3} to 5.10^{-2} Ω.cm) N^+ silicon substrates, 200 µ thick, with high resistivity (4 – 20 Ω.cm) N epitaxial layers 4, 6 to 12 µ thick were used as starting material. Epitaxial silicon layers down to about 1 µ thickness are commercially available. The substrate is anodically dissolved over an area of 4 to 20 mm^2 as previously described by MEEK [1, 2] in a 5 % HF solution under a bias voltage of 10 volts. On the remaining epitaxial layer, a gold surface barrier is realized, without any further chemical treatment, and aluminium is deposited on the electropolished face as the back contact. The different steps are summarized on fig. 1. Such a structure strongly reduces handling difficulties of the devices.

2. DIODES CHARACTERISTICS

The forward and reverse I-V characteristics of two detectors are shown on fig. 2. Detector 1 (13.6 Ω.cm, 4.4 μ thick) may be operated at 20 volts, whereas detector 2 (4 Ω.cm, 11.4 μ thick) is able to widstand 60 V. As shown by capacitance measurements (fig. 3) the bias voltages are sufficiently high to fully deplete the detectors.

3. DETECTION MEASUREMENTS

The detector thicknesses were first measured by studying the response of a classical surface barrier to 5.3 MeV α-particles of ^{210}Po. When the particles pass through the dE/dx device before impinging the normal silicon detector, the α-peak is shifted down to a lower energy. Then the measurement of the pulse height defect easily allows the determination of the samples thicknesses. The energy lost by these α-particles was 0.58 and 1.57 MeV respectively, which corresponds to an equivalent silicon layer of 4.30 μ and 11.40 μ respectively for detectors 1 and 2.

The 5.3 MeV α-particles spectra obtained with both counters are reported on fig. 4. The large F.W.H.M. (144 keV and 192 keV) arises from energy straggling in the sensitive volume and from electronic noise resulting mainly from the large capacitances. The absorbed energy is respectively 0.61 MeV and 1.4 MeV ; this leads to sensitive layer thicknesses of 4.40 μ and 10.20 μ respectively. The value for detector 1 is in good agreement with that found above. Although detector 2 is fully depleted the energy deposited by the α-particles seems to be a little lower than expected. This probably results from incomplete charge collection in the sensitive layer, due to the low electric field at the back side of the detector and the low resistivity of the material. The layer thickness as determined for counter 1 with α-particles is in good agreement with that given by ellipsometry on the starting material layer.

4. THICKNESS UNIFORMITY

The change in thickness of a 4.8 μ epitaxial layer was determined as follows. The surface was scanned using a 0.5 mm in diameter spot given by the 6, 328 Å ray of a He-Ne laser. As the intensity of the transmitted light strongly depends upon the silicon thickness, the measurement of the relative variation of the photoelectric current with a normal silicon surface barrier (having a very uniform entrance window) just behind the thin layer allows the determination of any change in the epitaxial layer thickness. These variations are reported on fig. 5, which shows that the uniformity is about ± 0, 3 μ at least over 10 mm^2.

CONCLUSION

The interest and the feasability of electrochemical etching of silicon for the preparation of dE/dx counters has been shown. This technique allows to obtain very thin detectors but also very uniform in thickness, without excess handling difficulties. The optimalization of the experimental conditions constitutes our next goal.

REFERENCES

[1] R.L. MEEK. J. Electrochem. Soc. 118 (1971) 437.

[2] R.L. MEEK. J. Electrochem. Soc. 118 (1971) 1240.

[3] R.L. MEEK, W.M. GIBSON, R.H. BRAUN. Nucl. Instr. Meth. 94 (1971) 435.

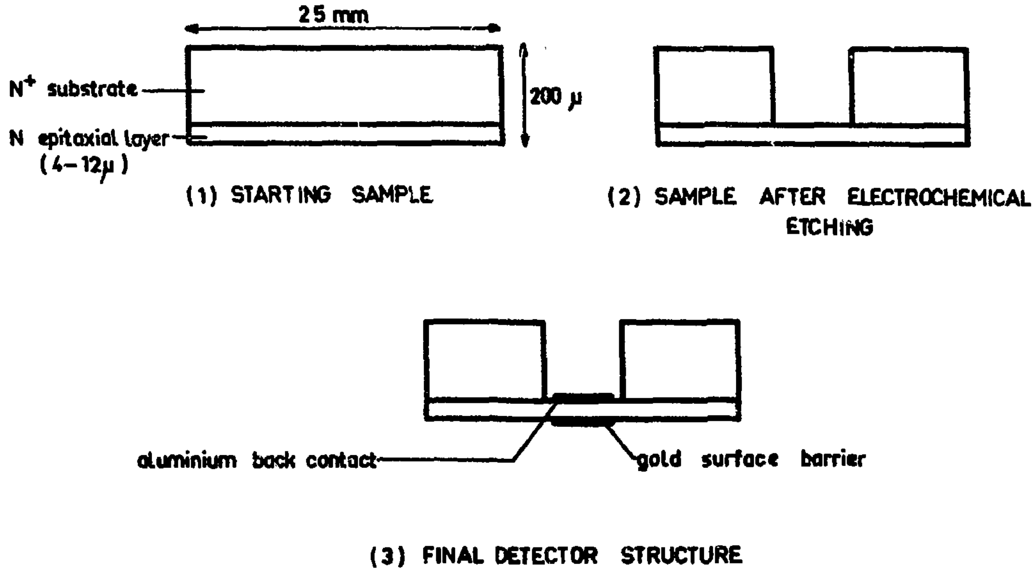

25 mm
N+ substrate
N epitaxial layer
(4–12μ)
200 μ
(1) STARTING SAMPLE
(2) SAMPLE AFTER ELECTROCHEMICAL ETCHING
aluminium back contact
gold surface barrier
(3) FINAL DETECTOR STRUCTURE

Fig. 1

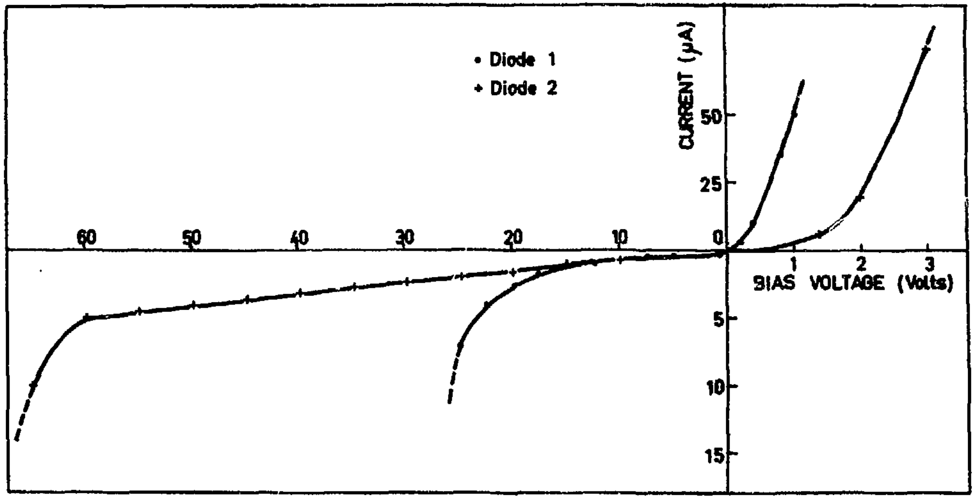

• Diode 1
+ Diode 2
CURRENT (μA)
50
25
0
5
10
15
60
50
40
30
20
10
1
2
3
BIAS VOLTAGE (Volts)

Fig. 2

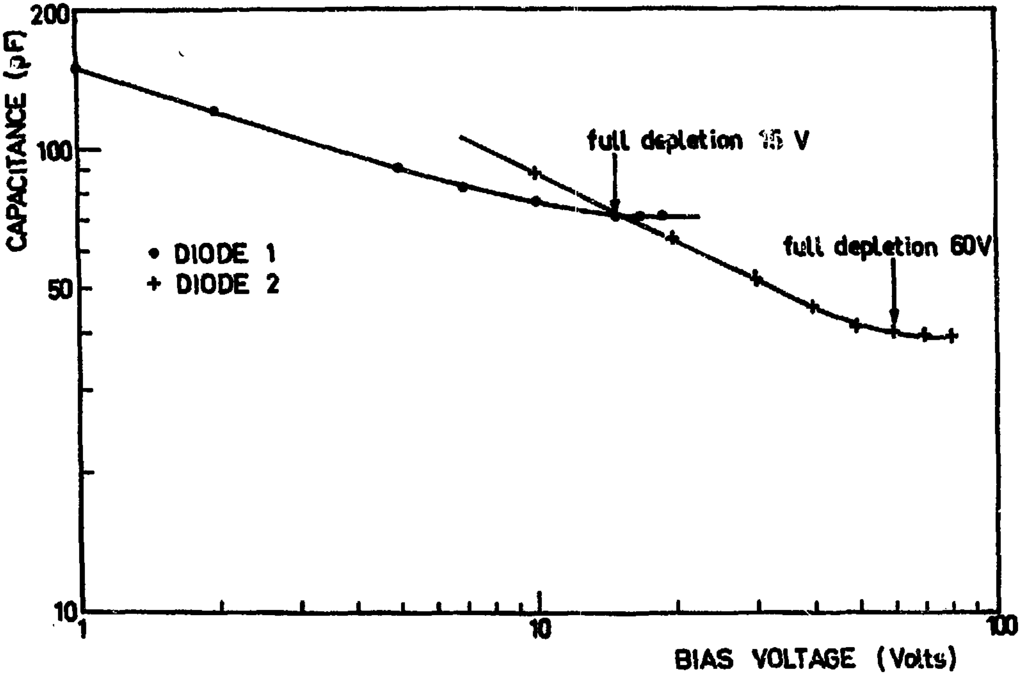
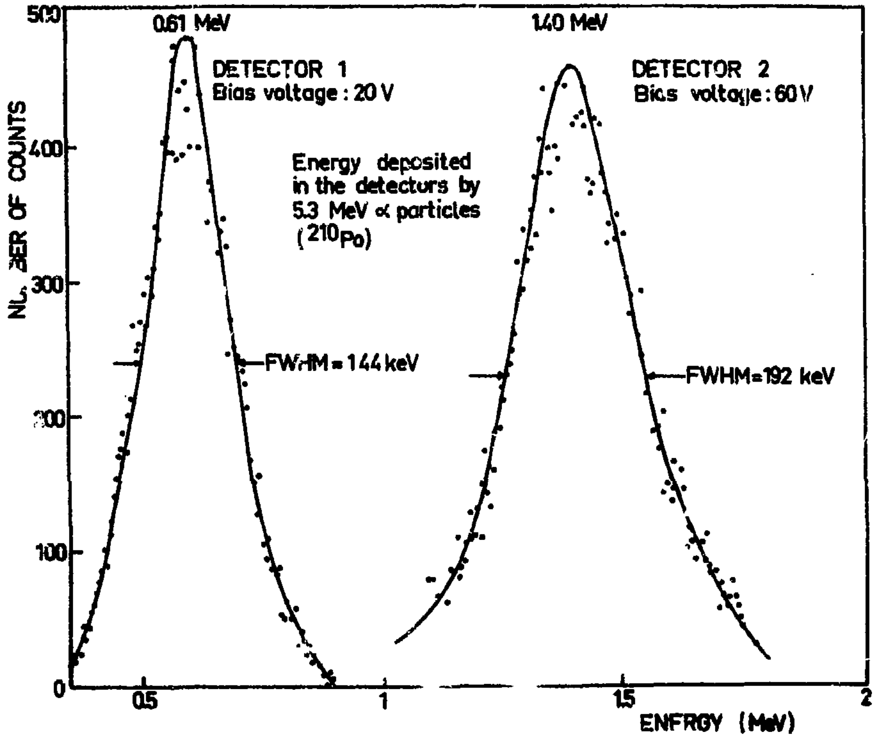

200
CAPACITANCE (pF)
100
50
10
• DIODE 1
+ DIODE 2
full depletion 15 V
full depletion 60V
1
10
100
BIAS VOLTAGE (Volts)

Fig. 3



0.61 MeV
1.40 MeV
DETECTOR 1
Bias voltage : 20 V
DETECTOR 2
Bias voltage : 60 V
Energy deposited
in the detectors by
5.3 MeV α particles
(210Po)
FWHM = 144 keV
FWHM = 192 keV
NUMBER OF COUNTS
500
400
300
100
0
0.5
1
1.5
2
ENERGY (MeV)

Fig. 4

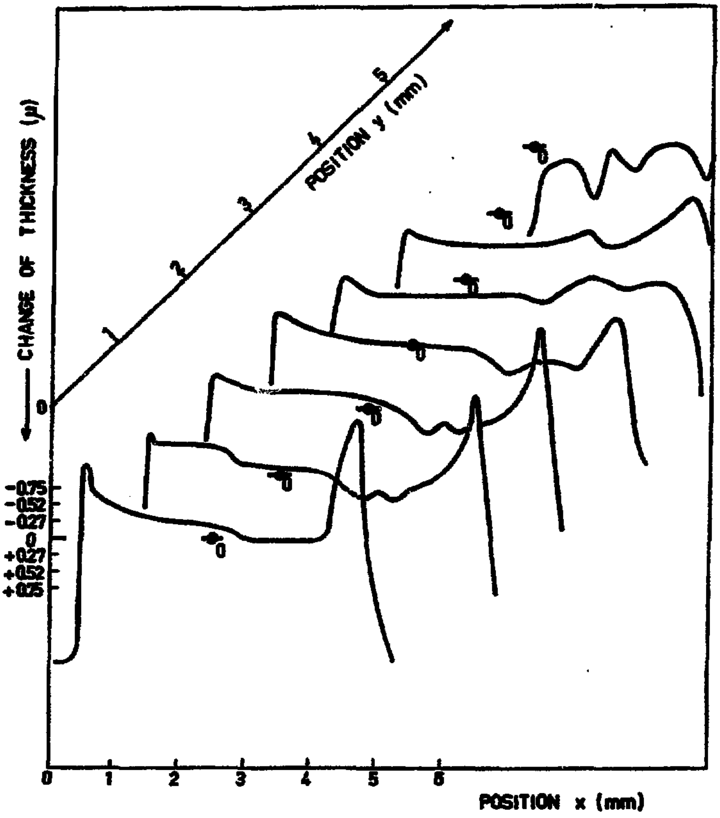

CHANGE OF THICKNESS (μ)
POSITION y (mm)
1
2
3
4
5
0
-0.75
-0.52
-0.27
0
+0.27
+0.52
+0.75
0
1
2
3
4
5
6
POSITION x (mm)

Fig. 5