# SILICON STRIP DETECTORS FOR DETERMINATION OF RADIONUCLIDES IN VARIOUS SUBSTANSES

P.Litovchenko , V.Pugatch, L.Barabash, O.Zinets , Yu.Pavlenko, A.Rosenfeld

Institute for Nuclear Research, Kiev, Ukraine

*Abstract.* Silicon strip detectors for the coordinate determination of short-range particles can be effectively used for measurements of radionuclide spectra in various substances because of their high energy resolution. In comparison with usual detectors they have much lower noise level at the same value of the sensitive area.

## INTRODUCTION

Silicon strip defectors are widely used for the coordinate determination of ionizing particles in high energy physics (1-3). They were also applied for measurements of alpha-particles spectra with high spatial resolution (3-6]). Strip detectors allow to obtain higher energy resolution in comparison with usual large area detectors (for instance , surface barrier detectors) because the capacitance and reverse current of a strip, which determine the energy resolution , are much smaller than those of usual detectors. In the present communication the main attention is paid to measurements of energy spectra of alpha -active nuclides by silicon strip detectors.

## DETECTOR FABRICATION

Detectors were fabricated on the base of ( 111) oriented wafers of high resistivity n-type silicon. The $p^+$-n junction were made by the ion implantation of boron and rearside $n^+$ -n junction was obtained by the ion implantation of phosphorus with subsequent aluminium metallization ( aluminium layer thickness was 0.3 μm). Passivating $SiO_2$ layers have thickness 0.15 - 0.20 μm . Some other characteristics of silicon strip detectors are presented in Table 1.

Table 1. Characteristics of fabricated strip detectors.

| Detector type | 1 | 2 | 3 | 4 | 5 *) |
|---|---|---|---|---|---|
| Resistivity , kOhm·cm | 1.0 | 12.5 | 4.0 | 4.0 | 4.0 |
| Wafer thickness , μm | 280 | 340 | 330 | 280 | 330 |
| Numbers of strips | 28 | 40 | 128 | 8 | 32 |
| Pitch , μm | 250 | 350 | 330 | 3100 | 3100 |
| Strip width, μm | 200 | 300 | 280 | 3000 | 3000 |
| Interstrip distance, μm | 50 | 50 | 50 | 100 | 100 |
| Strip length, cm | 2.5 | 40 | 42 | 42 | **) |
| Strip capacitance, pF | 1.9 | 3.7 | 3.8 | 50.6 | **) |
| Energy resolution, keV | 25 | 15 | 4 | 20 | 20 |
| Full depletion voltage, *V* | 250 | 29 | 85 | 62 | 85 |
| Testing source | $^{226}Ra$ | $^{241}Am$ | $^{106}Ru$ | $^{90}Sr + ^{90}Yr$ | $^{90}Sr + ^{90}Yr$ |

*)the annular strip detectors.
**)Strip length and capacitance are dependent on the strip radius.

## RESULTS AND DISCUSSION

The experimental set up and the measurement technique were described in details in ref .(3). Fabricated detectors were tested with alpha sources $^{226}$ Ra , $^{241}$ Am and minimum ionizing particles (m.i.p.) from sources $^{106}$Ru and $^{90}Sr + ^{90}Yr$ .

Fig. 1 shows the result of measurements of charges $Q_i$ and $Q_{i+1}$ collected at two neighboring strips. The total charge collected at the strips $Q = Q_i + Q_{i+1} = const(E)$ represents events from particles of the same fixed energy *E*. Charge generated in the detector by short-range particles ( alpha particles of $^{226}$ Ra and $^{241}$Am ) was collected at one or two strips. Hence, the capacitance and the reverse current for strip detectors are much smaller than those for usual detectors with the same total sensitive area.Four loci in Fig.1 correspond to the following alpha particle energies 7.69, 6.0 , 5.49 and 4.82 MeV ($^{226}$ Ra source) .

Noise of detectors strongly depends on the capacitance and reverse currents of strips. The strip capacitance $C$ at applied voltage $V$ in the case $V < V_{depl}$ ($V_{depl}$ is the full depletion voltage) is equal to (see ref.(7) )

$$C = 1.054\ S/d\ ,\ d = (2\varepsilon\mu_e\rho V)^{1/2}\ ,\ V_{depl} = w^2/(2\varepsilon\mu_e\rho)\ ,$$

where $\varepsilon = 1.054\ 10^{-12}$ F cm$^{-1}$, $\mu_e$ is the electron mobility, $\rho$ -is the silicon resistivity, $S$ is the strip area. $d$ - is the depletion layer thickness. The main contribution to the reverse current of a strip gives the generation- recombination current (7)

$$I_{gen} = qn_i\Omega/(2\tau)\ ,$$

where $q$ is the elementary charge, $n$ is the intrinsic concentration, $\tau$ is the lifetime, $\Omega = Sd$ is the volume of the depleted region.

Capacitances and reverse currents in strip detectors are in $S_{strip}/S_{total}$ times smaller than in large area detectors , so one can expect a higher energy resolution for strip detectors. However, a real gain was smaller because a limiting factor was the input capacitance of preamplifiers and observed values of reverse currents were larger than current estimated by expression for $I_{gen}$ . This indicates a significant role of the edge effects and inhomogeniety of original silicon as well as some decrease in lifetime $\tau$ during the detector fabrication. The measured energy resolution was $\Delta E$ = 25 keV for type 1 detector ( $E$ = 5.8 MeV) and $\Delta E$ = 15 keV for type 2 detector ( $E$ = 5.8 MeV).These values are much better than those obtained with large area detectors ($\Delta E$ = 70 keV for a detector with area of 4 cm × 4 cm). The equivalent noise measured by means of m.i.p. Landau distributionwas in the range of 4 keV for different detectors ( the signal to noise ratio ≈ 20).

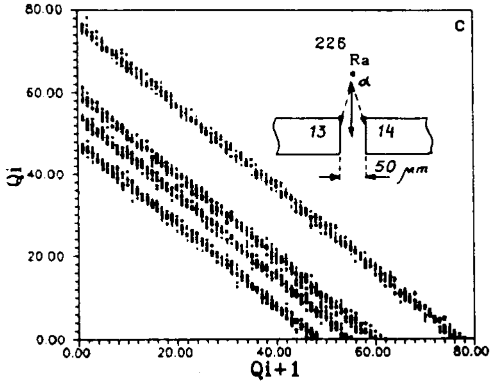


Figure 1. The two-dimensional distribution of charges $Q_i$ and $Q_{i+1}$ collected by neighboring strips ( charges are in arbitrary units) .

## CONCLUSIONS

Investigated silicon strip detectors have some advantages over usual detectors with the same total area. They have a better signal to noise ratio which is determined by much smaller capactance and reverse current of one strip. Such detectors can be used for determination of the alpha spectra of various substanses. They also can give information on spatial location of alpha sources with high position accuracy.


## ACKNOWLEGEMENTS

We express our gratitude to Dr. Frolov and V.Pervertaylo for the fabrication of some strip detectors (the firm " Detector". This research has been partly supported by the International Atomic Energy Agency under research contract No. 7200/R2/RB.

REFERENCES

1. E.H.M.Heijne, L.Hubbeling, B.Hyams et al. *Nucl. Instr. and Meth.*, 178, 331-343 (1980).
2. B.Hyams, U.Koets, E.Belau et al., *Nucl. Instr. and Meth.*, 205, 99-105 (1983)
3. T.Sugitate, W.Matsumoto, T.Michigani et al. *Nucl. Instr. and Meth.*, A244, 495-500 (1986).
4. V.M.Pugatch, A.B.Rosenfeld, P.G.Litovchenko et al., *Ukr. Fiz. Zhur.*, 35, 12-19 (1990)
5. A.B.Rosenfeld, V.M.Pugatch , O.S.Zinets et al. *Nucl. Instr. and Meth.*, A326, 234-238 (1993).
6. G.Evseev, A.B.Rosenfeld, V.L.Pervertaylo et al. *New Trends in Nuclear Physics*, (Proc. of 3-rd Kiev's Intern.School on nuclear physics) , vol.2, 472-476 (1993).
7. S.M.Sze, Physics of Semiconductor Devices, 2nd Ed., New York, 1981.