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The Fabrication of High Quality Silicon Junction Detectors by Low Energy Ion Implantation

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High quality silicon junction detectors have been made by implantation of boron and phosphorus ions into silicon wafers. Resolutions of 20 keV for Po α-particles were obtained.

MARTIN and coworkers reported the fabrication of silicon $p-n$ junctions by ion implantation doping [1,2]. However, the detectors produced with boron and phosphorus ions of 100 keV energy exhibited resolutions of about 80 keV (FWHM) for 5.48 MeV α-particles, which has to be compared with 30 keV typically obtained with surface barrier counters. The high reverse currents of the implanted devices indicate that the carrier life time had been reduced considerably.

This can be avoided by reducing the radiation damage level and by keeping the temperatures well below 500 °C for all post bombardment treatments[3].

We used boron and phosphorus ions with energies between 2—5 keV to produce highly doped layers in n-type silicon. The beam was extracted from a Penning source and magnetically separated. Annealing at 400 °C removed most of the radiation damage as judged by resistivity measurements of the implanted layer. At total doses of about 10^{14} ions/cm^2 it was possible to apply mechanical contacts.

Detectors were made by implanting boron and phosphorus into the front resp. back surface of the wafer. Though no protection against surface currents was made, about 50% of the diodes exhibited resolutions of about 30 keV. The best resolution obtained at room temperature was about 20 keV for ^{208}Po and ^{210}Po α-particles (Fig. 1). It seems that the carrier life time had not decreased considerably. Effective window

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[1] MARTIN, F.W., W.J. KING, and S. HARRISON: IEEE Trans. Nucl. Sci. NS-**11**, No. 3, p. 280 (1964).

[2] MARTIN, F.W., S. HARRISON, and W.J. KING: IEEE Trans. Nucl. Sci. NS-**13**, No. 1, p. 22 (1966).

[3] WALTER, F.J., and D.D. BATES: IEEE Trans. Nucl. Sci. NS-**13**, No. 3, p. 231 (1966).

thicknesses of about .2 μ were found by measuring the energy loss of α-particles penetrating the implanted layer under varying angles. Especially noteworthy is the behavior of the fully depleted counters which do not show any increase in current due to injection of carriers from the back contact; even "Überspannung"[4] was applied without observing any marked increase. The full depletion was proved by capacitance measurements and by exposing the n^+-contact to α-rays.

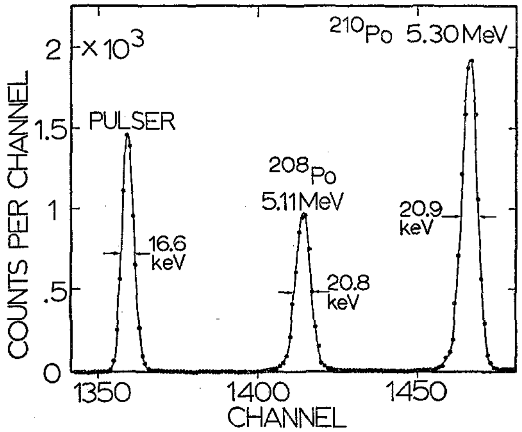

Fig. 1. Spectrum of the ^{208}Po and ^{210}Po α-particles measured with a p^+-n-n^+ detector at room temperature. Parameters of the counter: 9250 Ω cm n-Si, 10^{14} ions/cm^2 of B resp. P of 2—5 keV, 10 mm diameter of the implanted area, annealed at 400 °C for 1/2 h, bias 50 V, reverse current .5 μA, 1.6/1.6 μsec RC-pulse shaping

These results show clearly that by implantation counters can be made with resolutions equal or even better than by diffusion or surface barrier techniques.

Finally we would like to stress the ease and the low expense in time for making the implanted p^+-n-n^+ structures. A wide field of application seems to be open to this technique.

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The ion source and the analysing magnet were built by Mr. E. Heinicke and H. Baumann. We gratefully acknowledge their cooperation, which made this work possible.

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[4] Meyer, O., and H. J. Langmann: Nucl. Instr. Meth. **39**, 119 (1965)