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INVESTIGATION OF THE CHARACTERISTICS OF MICROSTRIP DETECTORS FOR THE VERTEX DETECTOR OF THE UCD

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The first experimental series of microstrip detectors for the microvertex detector of the UCD setup at UNK has been developed and produced. The full depletion voltage, determined by C-V-characteristics, is 380 V. This is in agreement with the calculated value for a 1.5 kΩ·cm resistivity of the silicon wafers and a thickness of 380 μm. The test shows that the yield of good diodes is between 80 and 99 per cent. The most probable leakage current is from 5 to 7 nA/strip.

The investigation has been performed at the Laboratory of High Energies, JINR.

Исследование характеристик микрополосковых детекторов для вершинного детектора УКД

В.И.Астахов и др.

Разработана и изготовлена первая опытная партия микрополосковых детекторов для вершинного детектора установки УКД (УНК). Напряжение, при котором наступает полное объединение, определенное из C(V) характеристик, составляет 380 вольт. Это согласуется с расчетным значением при резистивности исходного материала 1,5 кОм/см и при толщине детектора 380 микрон. Тестовые испытания показали, что доля годных полосок в детекторах составляет от 80 до 90%. Наиболее вероятное значение тока утечки составляет 5-7 нА.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Introduction

In connection with the proposal of the Universal Calorimetric Detector at UNK/1/, elements of the central tracking system are being developed at the Laboratory of High Energies.

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To reconstruct the decay vertex of short-lived secondary particles, the central tracking system includes a microvertex detector/2/. This detector consists of silicon wafers 380 μm in thickness, on which strip-like diodes operating at full depletion are made. The ionizing charge (holes) from a particle, which has passed the wafer, is accumulated on the strips arranged with a pitch of 25 μm. The charge spread to adjacent strips, caused by diffusion, allows one to reconstruct the coordinate of the particle with an accuracy of 3 μm/3,4/.

The construction, processing steps and electrical properties of the first series of detectors are described in this paper.

Detector Layout

Silikon wafers 76 mm in diameter and 380 μm thick with a [100] orientation and a specific resistivity of 1.5 kΩ·cm are used for the production of semiconductor microstrip detectors. The volume concent-

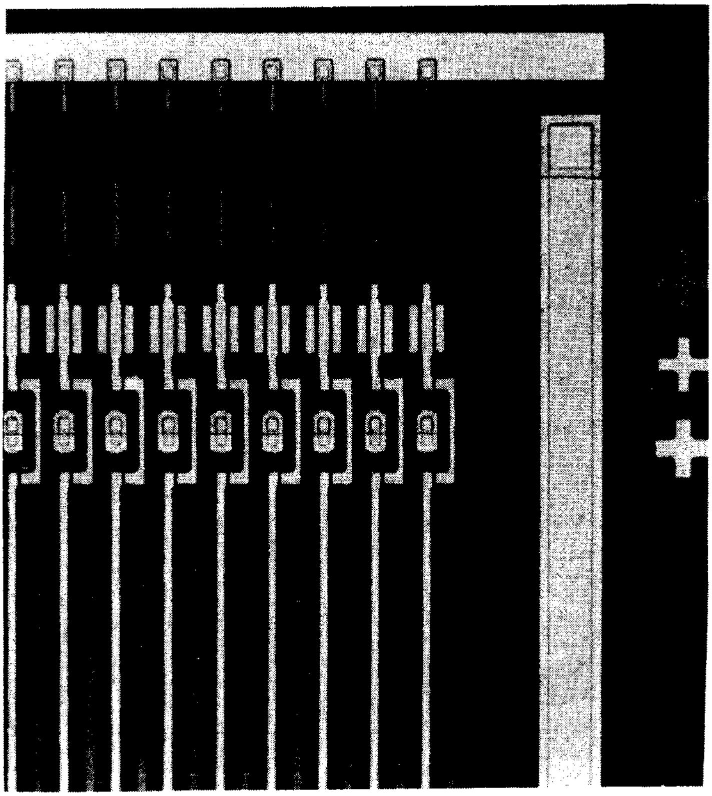

Fig.1. Connection of the active strips of the detector to the common bias line.

ration of n-type impurities (donors), measured by the Hall-method, is from $2.5 \cdot 10^{12}$ cm^{-3} to $3.0 \cdot 10^{12}$ cm^{-3}.

Four detectors are made on each wafer: the size of two detectors is 48x13.5 mm^2 and the size of two others (for test purposes) is 48x2.5 mm^2. Each detector is a matrix of diode strips 48 mm long, 10 μm wide and with a pitch of 25 μm. Figs.1 and 2 show photographs of two ends of the detector to a scale of 1200:1. Information is read out from each second strip. These strips, the so-called active strips, look brighter on the photograph. To avoid the influence of leakage currents on the amplifier input, signals from the strips are read out through a coupling capacitor/4/. This capacitor is formed directly on the implanted p-n junction by deposition of a SiO_2 layer 200 nm in thickness followed by aluminium deposition/5/. The active strips have a 40x50 μm^2 bonding pad at each end. Each strip can be connected to the amplifier input by this pad, and also a few wafers can be connected together to form a larger detector. Each strip is connected to a common 50 μm wide Al bias line through an individual 160 μm long poly-

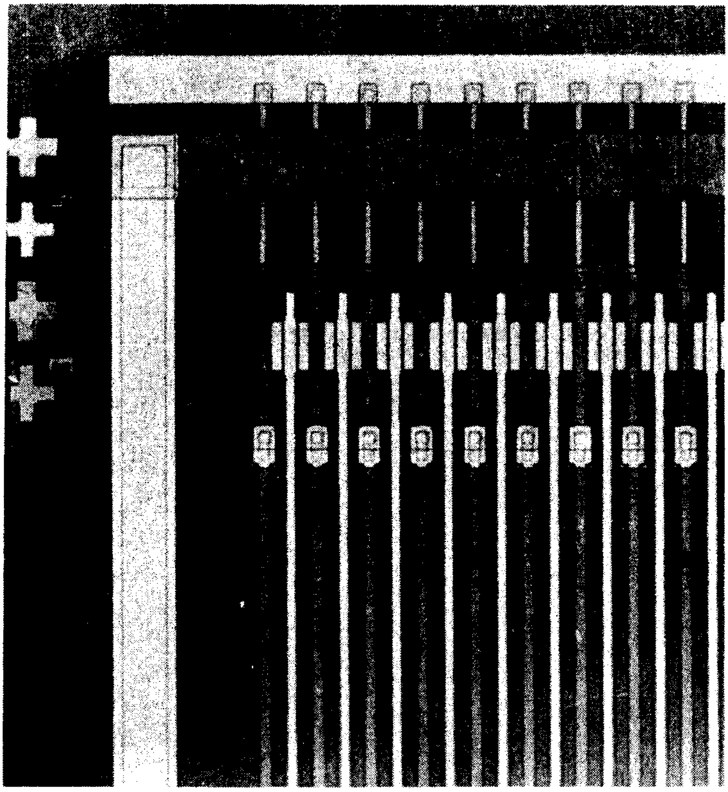

Fig.2. Connection of the passive strips of the detector to the common bias line.

silicon resistor with a resistance of 600 kΩ. A 50 μm wide guard ring is placed around the entire active detector area. The guard ring as well as the strips is in the form of p-n junction. To measure individual leakage currents, all the diodes have a 45x30 μm contact pad directly connected to the p-n junction. The whole detector area on the diode side is passivated with pyrolytic oxide.

Processing Steps

The detector wafers are processed by planar technology used for the production of integrated circuits and other microelectronic devices.

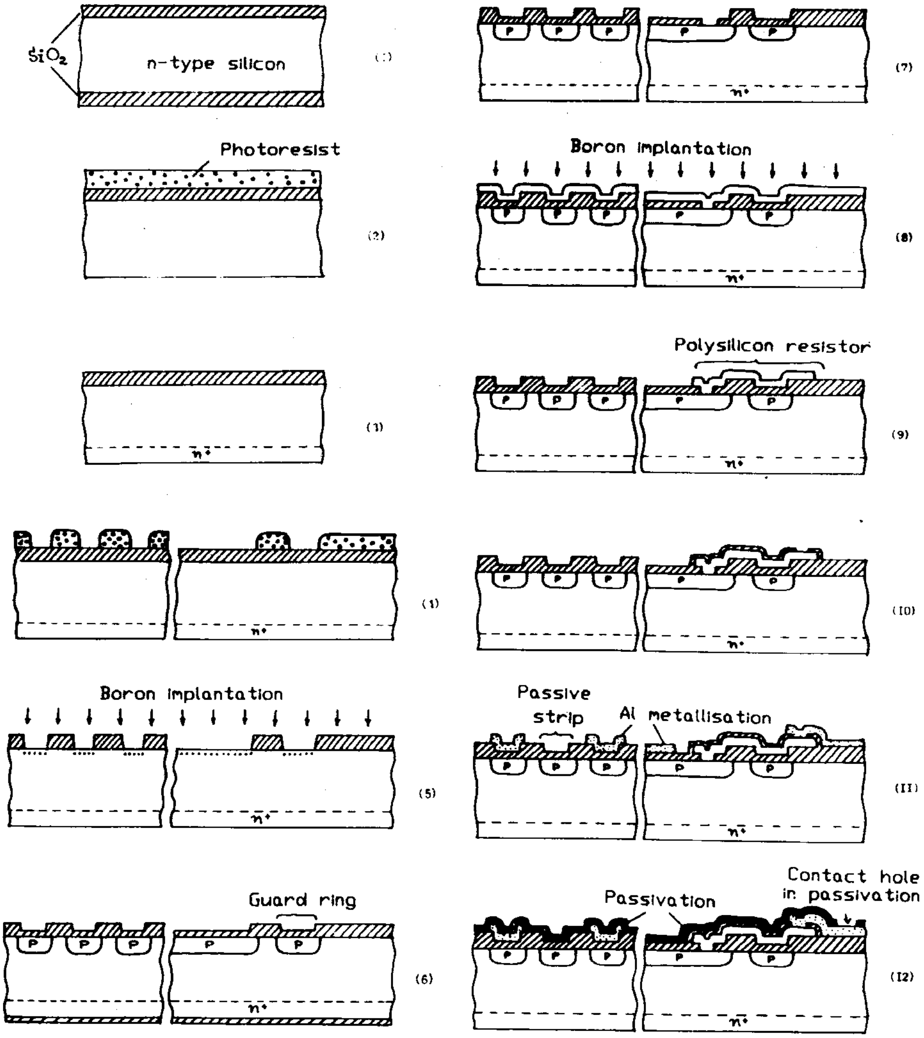

Fig.3. Processing steps.

The following processing steps are used for the manufacture of microstrip detectors:

1. Wet oxidation at a temperature of 1000° C (fig.3-1).
2. Twofold covering of the front side with photoresist. Etching of oxide on the back side using a buffered etchant HF and NH_4F solution in H_2O), fig.3-2.
3. Removing of photoresist in Caro's acid. Phosphorus deposition on the back side. Low temperature annealing (fig.3-3).
4. Photolithography No.1 "Diodes" (fig.3-4). Two cross sections: across (left) and along (right) the strips (fig.3-4 and all the following ones).
5. Etching of oxide in a buffered etchant. Removing of photoresist. Boron implantation at an energy of 25 keV (fig.3-5).
6. HCl oxidation at a temperature of 1000° C (fig.3-6).
7. Photolithography No.2 "Contact holes for polysilicon resistors". Oxide etching. Removing of photoresist in Caro's acid (fig.3-7).
8. Refreshing (short oxide etching) before polysilicon deposition. Polysilicon deposition. Boron implantation (fig.3-8).
9. Photolithography No.3 "Resistor". Chemical wet etching of polysilicon. Removing of photoresist in Caro's acid (fig.3-9).
10. HCl oxidation at a temperature of 1000° C. Photolithography No.4 "Contact holes". Etching of oxide. Removing of photoresist in Caro's acid (fig.3-10).
11. Refreshing before aluminium sputtering deposition. Aluminium deposition. Photolithography No.5 "Metallization". Aluminium etching (H_3PO_4, HNO_3, CH_3COOH solution in H_2O). Removing of photoresist in monoethanolamin (fig.3.11).
12. Deposition of pyrolytic oxide as passivation (fig.3-12). Photolithography No.6 "Passivation". Passivation etching. Removing of photoresist in monoethanolamin. Sintering of aluminium at a temperature of 300° C for 15 min in an argon atmosphere.

Measurement Results

To determine the working voltage for full depletion, the capacitance of the reverse biased p-n junction as a function of bias voltage is measured. An E7-12 C-meter is used for these measurements. The summary capacitance of all 512 detector strips as a function of bias voltage is shown in fig.4. From this figure one can see that the full depletion of the p-n junction is reached at 380 V. The presented behavior confirms the fact that the specific resistivity of the detector material is 1.5 kΩ·cm.

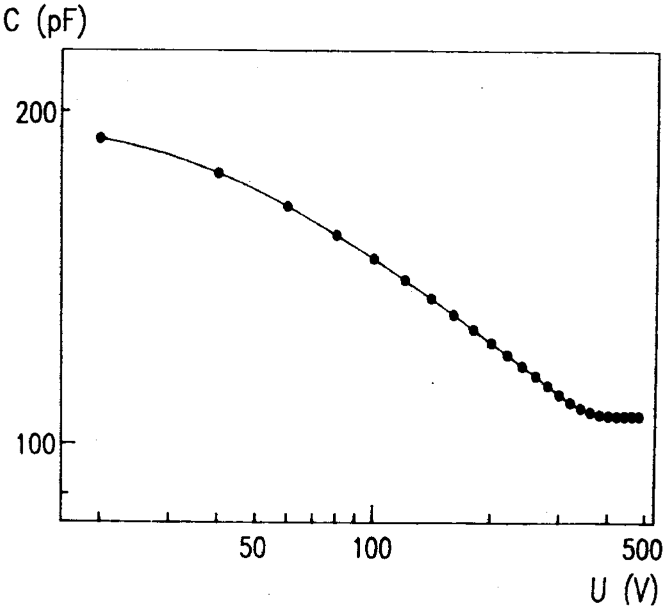

Fig.4. Summary capacitance of all 512 detector strips as a function of bias voltage.

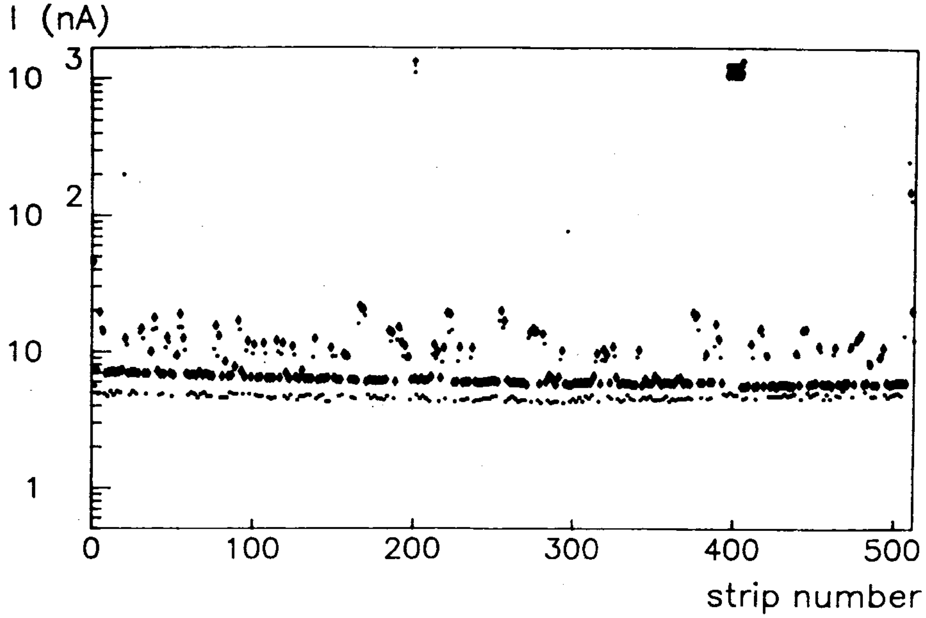

Fig.5. Current distribution on individual strips (points denote the leakage current of passive diodes;and arrows,the leakage current of more than 1 μA).

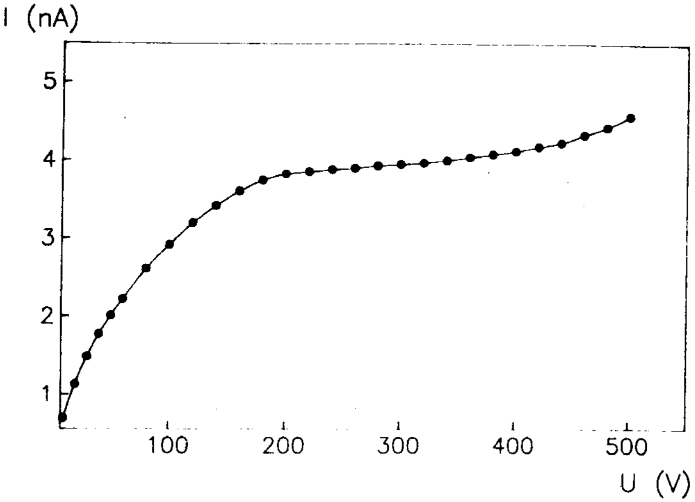

Fig.6. I-V characteristic of a typical single diodes.

Figure 5 shows the leakage current of individual strips at a bias voltage of 400 V (points denote the leakage current of non-aluminized strips). The most probable leakage current per strip is from 5 to 7 nA. This value of leakage current is satisfactory because its noise contribution in this case does not exceed the noise of the front-end amplifier of the data-acquisition system. However, about 2 per cent of the strips have a leakage current of more than 100 nA. The diodes with a leakage current of more than 1 μA are designated by arrows.

The I-V-characteristic for one typical strip is shown in fig.6.

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