INTERSTRIP RESISTANCE OF A SEMICONDUCTOR MICROSTRIP DETECTOR

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In this work the interelement (interstrip) resistance of the microstrip detector is studied. A few detectors with a different construction are investigated. The dependence of the interstrip resistance on the dose of detector irradiation with electrons is obtained. The possibility of application interstrip resistance measurement for the determination of the good strip yield is shown.
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1 INTRODUCTION

Interelement (interstrip) resistance is one of the most important parameters characterizing the quality of a microstrip as well as other multielement semiconductor detectors. The value of the interstrip resistance along with the interstrip capacitance determines a number of strips over which the charge produced by an ionizing particle is distributed (cluster) and, consequently, the spatial resolution of the detector [1]. One can conclude from the value of the interstrip resistance and its variation while a detector is affected by different factors on the state of its surface, defect content in silicon etc. Apart from this, the interstrip resistance at the ohmic side of the detector shows the quality of performance of the p^+-stop structure [2]. Measuring the interstrip resistance enables one to determine such detector parameters as depletion voltage, n^+-strip separation voltage, as well as a large number of technological defects these being the short-circuited strips in the simplest case.

2 METHOD OF MEASUREMENT

The problem of determining the interstrip resistance is not a trivial one because the measurements must be performed at the voltage of total depletion of the detector. While measuring the interstrip resistance one should provide for minimum distortions of electrostatic fields within the interstrip volume of the detector being under the voltage of total depletion. Usually the value of the interstrip resistance falls into the range from hundreds MΩ to tens GΩ depending on the detector design. In order to determine the interstrip resistance a method is used conventionally that permits to determine the interstrip resistance from strip leakage currents [3]. The essence of the method is in that first one measures the leakage current of one strip according to the scheme of fig. 1 a) at the voltage values U exceeding those of total depletion. One determines the voltage range within which the leakage current experiences small variation. Then an additional supply unit V is switched into the scheme such that V<<U' and U'+V=U and again leakage currents are measured according to the scheme presented in Fig. 1b). Then one plots the graphs from these measurements (see Fig. 3 and Fig. 4), from which the interstrip resistance is determined as a tangent of the inclination angle of the straight line.

It should be noted that these measurements furnish the accurate value of the interstrip resistance only in the absence of the bias resistor on the strip under measurement. In the presence of all resistors whose resistance does not exceed several tens MΩ, we will determine the total resistance of the circuit made up by two bias resistors and one interstrip resistors switched in parallel. Therefore for physical studies of the detector it is necessary to develop special microstrip test structures.

3 STUDING THE INTERSTRIP RESISTANCE

The studies were performed on four types of test structures. Test microstrip structures were manufactured simultaneously with the main detector and they differed from it only in the diminished number of strips. Test microstrip structures possess 64 strips instead of 768 for the main detector. Other parameters of the test microstrip structures are the same as the parameters of the main detector: thickness of 300 μm, strip length of 40 mm, step of 100 μm.

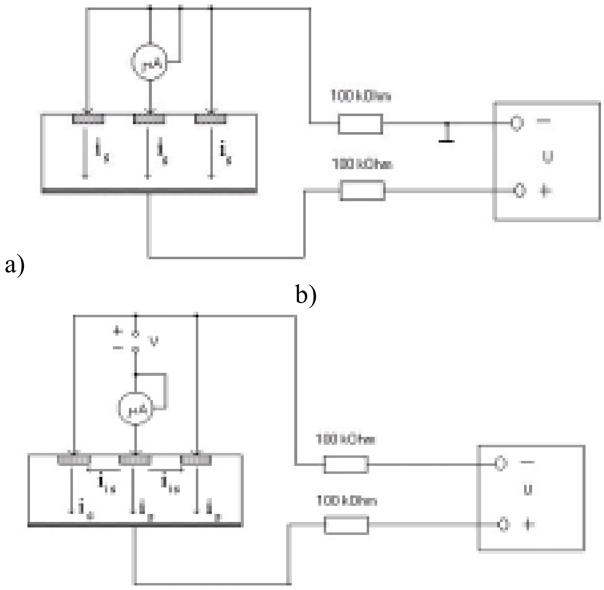

Fig. 1. Schemes employed for the determination of the interstrip resistance: a) measuring the strip leakage current; b) measuring the sum of currents (leakage current and interstrip currents).

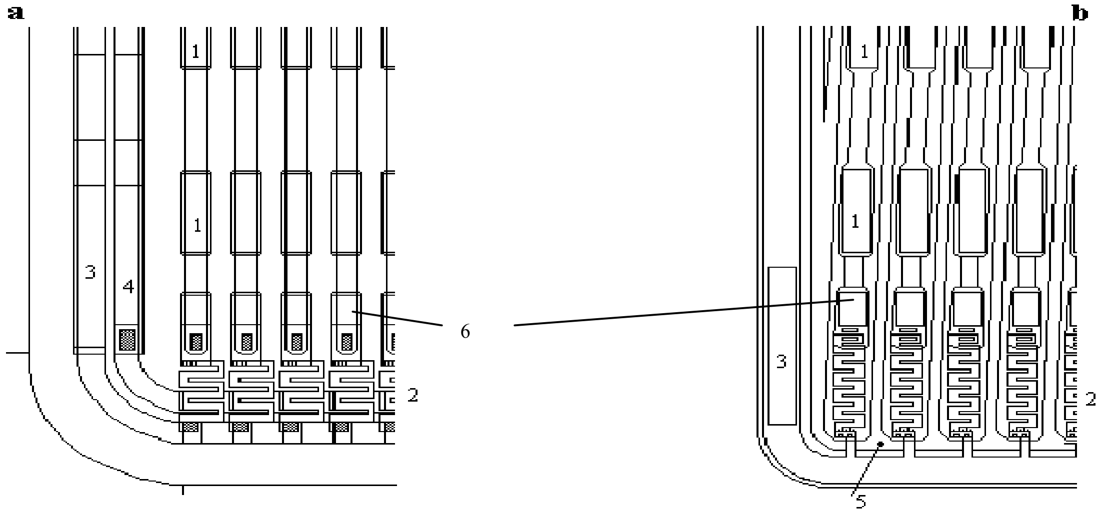

Fig. 2. Corner of multichannel microstrip detectors (a- p^+ detector, b- n^+ detector): 1 - contact pad of integrated capacitors, 2 - polysilicon resistors, 3 - basing pad of microstrip active elements, 4 - p^+-guard ring, 5 - p^+-stop structure, 6 - contact pads of microstrip active zone.

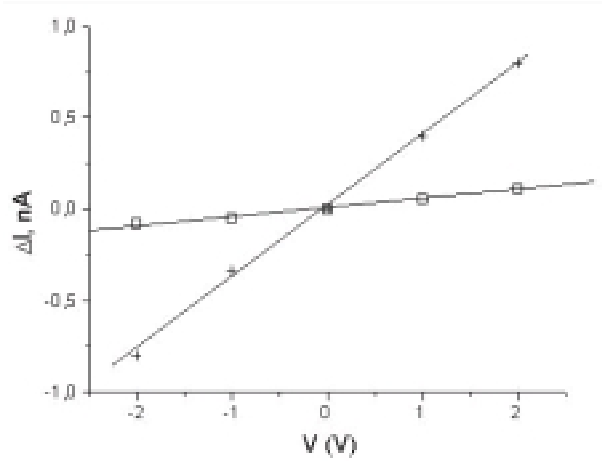

Fig. 3. Interstrip currents of the test 64-strip P-detector.

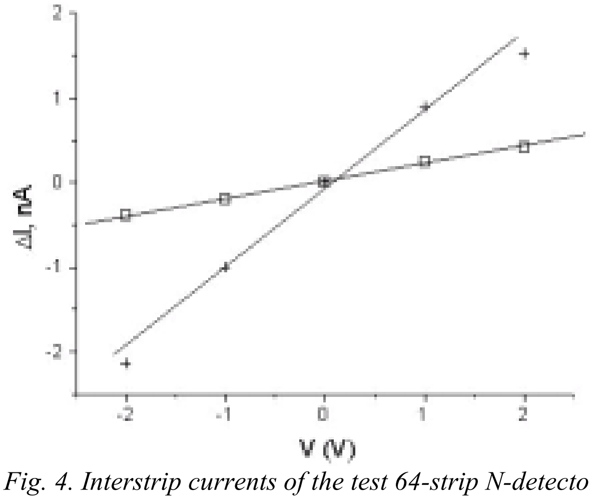

Fig. 4. Interstrip currents of the test 64-strip N-detector

To ensure the accurate measurement of the interstrip resistance the test structures 1 and 2 are made without bias resistors, and the structures 3 and 4 lack 3 resistors each. Structures 1 and 2 are the test structures of one-sided p^+ microstrip detector. The surface of silicon of test structure 1 is covered with a silicon oxide layer, besides, structure 2 has an additional layer of Si_3N_4 insulation. Structure 3 is a test structure of p^+ side, and structure 4 is a test structure of the n^+ side of a double-sided microstrip detector. Structures 3 and 4 possess single-layered SiO_2 insulation. Fig. 2 shows the view of the 3 and 4 test structures.

The studies were performed to reveal the effect of design peculiarities of detectors on the interstrip resistance. The behavior of the interstrip resistance under irradiation of detectors was also performed. To this end the test detectors were irradiated with a beam of 20 MeV electrons. Detectors 1 and 2 were irradiated in 4 stages up to the dose of 2.1 Mrad. Detectors 3 and 4 were irradiated once up to the dose of 200 krad.

Fig. 3 and Fig. 4 show the interstrip resistance of detectors 3 and 4 before and after irradiation. Consider the difference of the interstrip resistance for p^+- (detector 3) and n^+- (detector 4) sides. As is seen from the figures, the resistance of detector 3 (p^+-side) is higher than the resistance of the detector 4 (n^+-side). This is attributed to the design peculiarities of the n^+-side. Owing to the presence of the positive static charge at the Si-SiO_2 interface, a layer of electrons is formed under SiO_2 at the surface of the n-silicon. At the p-side these electrons are pushed away by the depletion regions and disappear completely with the growth of the depletion region size. At the n^+-side this layer simply short-circuits n^+-strips between themselves. To overcome this difficulty the n^+-strips are separated with p^+-regions called p^+-stop structures [5]. In this case the interstrip resistance is determined by the width of the p^+-stop structures and their design, whereas at the p^+-side it is determined by the distance between adjacent strips. As the width of the p^+-stop layer is less than the distance between the strips, the interstrip resistance at the n^+-side is less than that at the p^+-side.

Fig. 5 depicts the dependence of the interstrip resistance on the irradiation dose for detectors 1 and 2. As is seen from the figure, the interstrip resistance of detectors 1 (squares) and 2 (crosses) differed strongly.

The lesser interstrip resistance of detector 2 is attributed to the additional Si_3N_4 insulating layer increasing the contribution of the detector surface into the total leakage current and into interstrip currents [4]. This is probably associated with the existence of the generation-recombination centers at the boundary dividing SiO_2 and Si_3N_4. Under irradiation the difference in the interstrip resistance values for the detectors with single-layer and double-layer insulation disappears practically. In order to explain the dose dependence of the interstrip resistance, let us consider the variation in leakage currents under irradiation of detectors with single-layer and double-layer insulation.

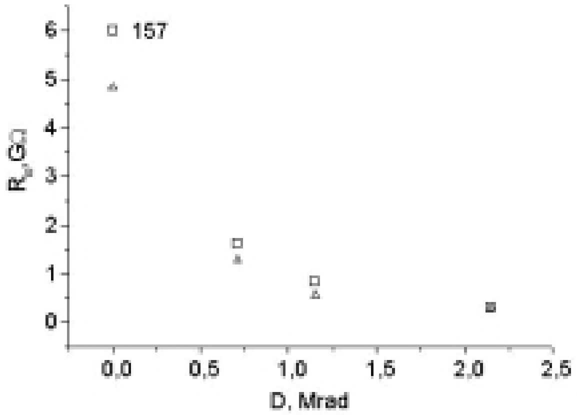

Fig. 5. Interstrip resistance of 64-strip detectors with (2) and without (1) Si_3N_4 against the irradiation dose by 20 MeV electrons.

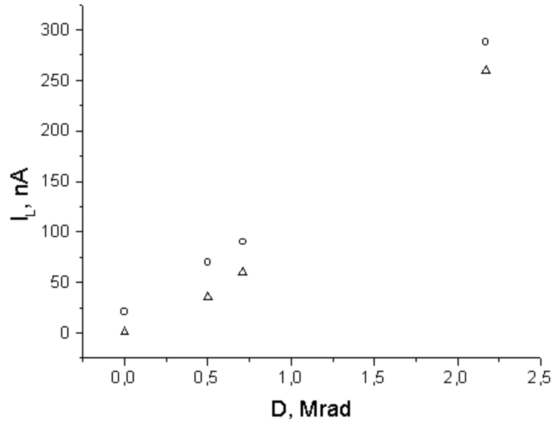

Fig. 6. Leakage currents of the detectors with Si_3N_4 (triangles) and without Si_3N_4 (squares).

Fig. 6 shows the variation of leakage currents under irradiation of detectors with an additional Si_3N_4 insulation layer and without it. The difference between the leakage currents for the detectors with an additional Si_3N_4 insulation layer and without it before irradiation was about of 25 nA. It is seen from the figure that the difference between the leakage currents is constant within the total range of irradiation doses. Under irradiation the leakage currents of the detectors with the additional Si_3N_4 insulation layer and without it are increased due to the increase of the volume component of the leakage current. This is attributed to the increase of the concentration of generation-recombination centers in the silicon volume. The density of surface generation-recombination centers does not change within the dose range under study. Therefore the difference between the leakage currents for the detectors with an additional Si_3N_4 insulation layer and without it is constant.

With large irradiation doses the total leakage current of the detector and, consequently, the interstrip resistance is determined by the increased volume generation-recombination current [5]. Therefore with the dose increasing the interstrip resistance values of both detectors become practically equal.

Apart from the physical studies of the interstrip resistance that require obtaining the accurate value of the resistance, other measurements are possible. Specifically, in the process of technological measurement of the good strip yield one employs measuring the interstrip resistance. As these measurements are made not on test structures but on main detectors, all strips possess the bias resistors. As was already mentioned above, in this case we measure the resistance of the circuit made up of two bias resistors and a single interstrip resistance. As the resistance of the bias resistor is much less than the interstrip one, the resulting resistance is equal approximately to the double value of the bias resistor (some tens MΩ). Usually in the presence of a defect between the strips the value of the resulting resistance doe not exceed some hundreds kΩ and it may be used for discovering defect strips.

4 CONCLUSIONS

The interstrip resistance is one of the most important parameters indicating the quality of a microstrip detector. The value of the interstrip resistance may give the information on the spatial resolution of a detector. Studying the behavior of the interstrip resistance one can determine such electrophysical characteristics of the detector as the depletion voltage, the n^+-strip separation voltage and the quality of the performance of the p^+-stop structure. While determining the yield of good strips the measurement of the interstrip resistance enables one to reveal technological defects of a detector.

REFERENCES

1. F.Retiere at al. *Performances of Double-Sided Silicon Strip Detectors for the ALICE experiment at LHC*. ALICE/99-36 Internal Note/SIL 21 July 1999.
2. A.P. de Haas, P.Kuijer, V.I.Kulibaba, N.I.Maslov, V.L.Perevertailo, V.D.Ovchinnik, S.M.Potin, A.F.Starodubtsev. Characteristics and radiation tolerance of a double-sided microstrip detector with polysilicon biasing resistors // *Problems of Atomic Science and Technology. Issue: Nuclear-Physics Research* (36). 2000, v. 2, p. 26-33.
3. N.L.Bruner at all. Characterization procedure for double-sided silicon microstrip detectors // *NIM*. 1995, v. A 362, p. 315-337.
4. N.Maslov, V.Kulibaba, S.Potin, P.Kuijer, A.Starodubtsev, A.P. de Haas, V.Perevertailo. Radiation tolerance of single-sided microstrip detector with Si3N4 insulator // *Nuclear Physics B (Proc. Suppl.)*. 1999, № 78, p. 689-694.
5. A.G.Chilingarov. *Coordinate semiconductor detectors in the elementary particle physics*. Preprint 90-113, Novosibirsk, 1990 (In Russian).