STUDYING ELECTRO-PHYSICAL CHARACTERISTICS OF DETECTING ELEMENTS ON THE OHMIC SIDE OF SILICON MICROSTRIP DETECTOR

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The results of studying the ohmic side of the double-sided microstrip detectors (DSMD) possessing the diode separating p^+ stop structure of different type and size are presented. The effect of the p^+ stop structure on the DSMD interstrip resistance and interstrip capacitance is considered.

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1. INTRODUCTION

Recently the silicon double-coordinate (double-sided) microstrip detectors won wide application in physics [1-7]. This type of detectors is used for tracking systems of almost all large experiments in high-energy physics. All large research centers carry out intensive studies of DSMDs. This is due, first of all, to that the detector characteristics should optimally match the conditions of the experiment in which this detector is used. DSMD studies are also performed to improve the detector characteristics in general. The interstrip capacitance and interstrip resistance of the double-coordinate detector are the most important characteristics of microstrip detectors. The interstrip capacitance and interstrip resistance determine mainly the noise and spatial resolution of microstrip detectors. The values of the interstrip capacitance and interstrip resistance on the DSMD ohmic side are determined by the characteristics, design and quality of a special diode stop structure.

Fig. 1 shows the design of the double-coordinate microstrip detector. The detector is a wafer of high-resistive silicon (generally of the n-type with the specific resistance of 1-10 kOhm×cm) on which the p-n junctions are made in the form of narrow parallel strips. The strip pitch is determined by the tasks of the experiment and it mostly varies from tens to hundreds micrometers. A reverse bias is usually applied between n^+ and p^+ sides chosen as a rule to extend the depletion zone over all thickness of the high-resistive silicon. Each strip is now operating as a separate independent p-i-n detector.

A strongly doped layer of n^+ silicon is created on the backside of the double-coordinate detector also in the form of strips. However a simple division of the n^+ into strips does not work because the electron accumulation layer always formed under SiO_2 on the surface of silicon due to the presence of static positive charge on Si - SiO_2 interface. On the p^+- side these electrons are forced back from the strips by the depletion regions of p-n junctions, and they disappear completely with the size of the depletion zone growing. On the n-side this electron layer just short-circuits n^+-strips between themselves. It was proposed [8] to separate n+ strips with p^+ regions. There exist two types of p^+ regions: p^+ spray and p^+ stop structure. However, p^+ spray has a number of shortcomings so that it is used more seldom than p^+ stop structure. The fundamentals of the p^+ stop structure operation can be seen in Fig. 1.

Several papers are devoted to the study of p^+ stop structures. Four types of p^+ stop structure and their influence on the interstrip capacitance and the charge collecting efficiency are considered in papers [9] and [13]. Papers [12] and [17] consider the dependence of the detector parameters on geometry of one type of p^+ stop structure.

As was already noted above, the interstrip capacitance in one of the main factors contributing into the detector noise [12]. To diminish the own noise of the detector it is necessary to make the interstrip capacitance as small as possible. Besides, value of a coupling capacitor should exceed the interstrip capacitance considerably to prevent the charge from getting on adjacent strips.

Interstrip capacitance strongly depends on geometrical size of strips. On the n-side apart from it depends on p^+ stop structure.

On increase the width of the p^+ stop structure, the decrease in the interstrip capacitance occurs, however in this case p^+ stop structure decreases the interstrip resistance because it has a finite resistance due to high impurity concentration. This leads to the charge distribution over a large number of strips, to the decrease of the useful signal and as a consequence to the deterioration of the signal/noise ratio and spatial resolution. Besides, the broad p^+ stop structure separating the strips decreases the effective area of charge collection, what also leads to the useful signal decreasing.

The combined type of the p^+ stop structure is the most promising for separation of n+ strip. In the combined p^+ stop structure the individual p^+ rings are separated, what permits to vary the distance between p^+ stop rings leaving their width unchanged. For this reason the combined p^+ stop structure was chosen for further studies.

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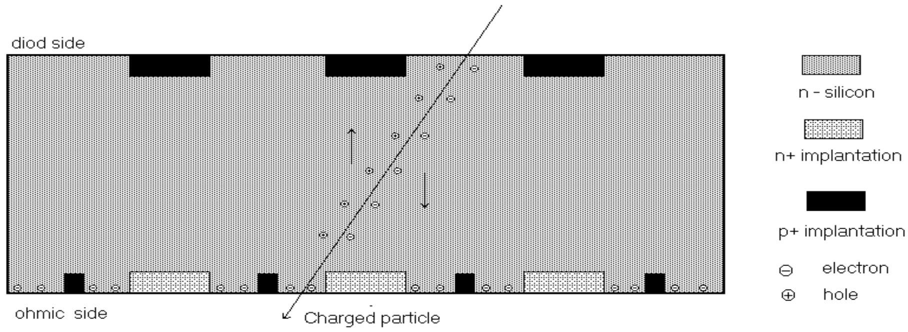

Fig. 1. *DSMD design and fundamentals of operation*

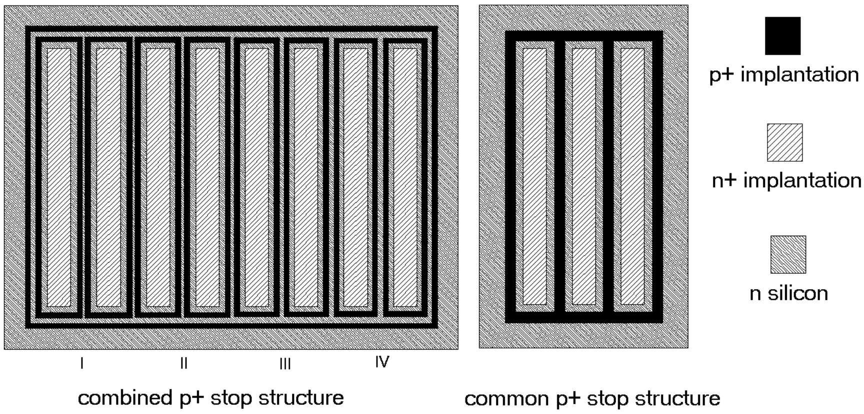

Fig. 2. *Types of p^+ stop structure*

2. EXPERIMENTAL CONDITIONS

For studies the DSMDs were manufactured with a common and combined p^+ stop structures. Diode sides of both DSMDs were identical. In Fig. 2 the geometry chosen for studying the combined p^+ stop structure can be seen. The combined p^+ stop structure consists of individual rings around each n^+ strip and a common p^+ stop ring around all strips. The n^+ side of the DSMD with the combined p^+ stop structure is split into four sections. The spacing between individual rings in each of the sections is 5, 7, 9 and 11 µm (they are denoted with numbers I, II, III and IV, respectively). The strip width of individual rings is 10 µm and it is equal for all DSMD. The strip width of the common p^+ stop structure is 20 µm. Thus the width of the p^+ insulation between two n^+ in both types of the p^+ stop structure is 20 µm.

The differences in the interstrip capacitance and resistance on the n^+ side were studied.

3. INTERSTRIP CAPACITANCE

The interstrip capacitance was measured according to the scheme in Fig. 3. The measurements were performed at frequency 1 MHz.

Fig. 4 shows the dependence of the interstrip capacitance on the bias voltage for the common and combined p^+ stop structures. As is clear, after the voltage of 60 V the difference between the values for common and combined p^+ stop structures remains practically unchanged and amounts approximately to 0.4 pF. Therefore dependence of the interstrip capacitance from geometry combined p^+ stop structure was measured at one voltage of 60 V and with usage of the same measuring scheme.

Calculations of interstrip capacitance have been lead at a voltage of the complete depletion. There are two approaches to calculation of interstrip capacitance. The first approach [17] uses calculation of interstrip capacitance like capacity between two charged wires, which are long L, diameter d and parted in the distance g, by formula:

$$C_{is} = \frac{2\pi \varepsilon_0 \varepsilon L}{\ln[\frac{g}{d} + \sqrt{(\frac{g}{d})^2 - 1}]}, \tag{1}$$

where accordingly L is a strip length, g distance between strips and d is depth of the implantation formative the strip.

The second approach [18] uses the electrostatic calculations fulfilled for the strip between two semi-infinite plates from which it is separated with a gap $(p-w)$ where w it is a strip width and p is a strip pitch. At calculations it is supposed, that detector thickness is greater than strip pitch. For $0,10<w/p<0,55$ the following relation is received:

$$C_{is} = \left(0.9 + 1.7\frac{w}{p}\right) pF/cm\,. \tag{2}$$

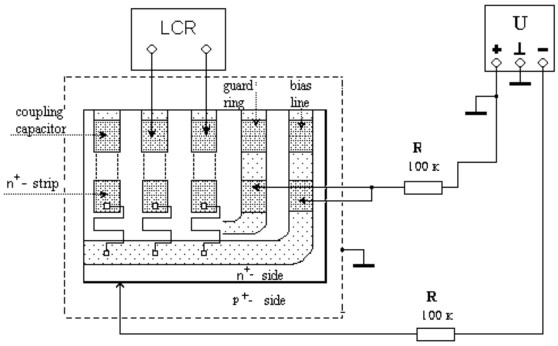

***Fig. 3**. Interstrip capacitance measuring scheme*

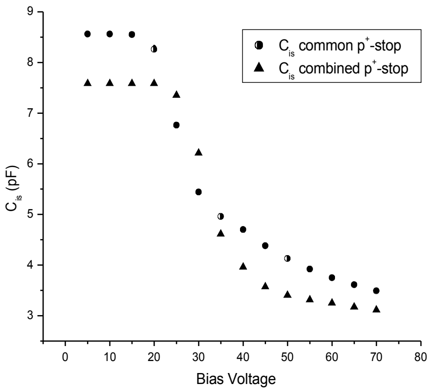

***Fig. 4.** Interstrip capacitance against bias voltage for common and combined p^+ stop structures*

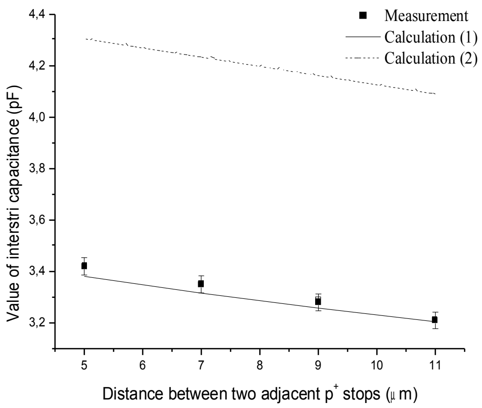

***Fig. 5.** Interstrip capacitance against distance between two adjacent p^+ stops*

As formulas are given for the diode side of the detector for their application on the ohmic side we had been made one approach. For distance between strips we accepted not distance between n^+ strips, but distance between individual rings p^+ stop structure and the doubled width of a ring. For calculations the following quantities were used: strip length is of 40 mm., pitch is 95 micron, distance between strips varies from 25 up to 31 micron, and width accordingly from 64 up to 70 micron, depth of an implantation is 1 micron, detector thickness is 300 micron.

On Fig. 5 dependences of interstrip capacitance on distance between p^+ stop rings measured (points) and calculated under formulas 1 (continuous direct) and 2 (dotted direct) are shown. Apparently from the diagram, the more distance between two adjacent rings combined p^+ stop of structure, the less interstrip capacitance and this dependence has the linear character. At the given geometry of the detector, change of distance between two adjacent rings with 5 up to 11 μм gives in diminution of interstrip capacitance from 3,42 till 3,22 pF. For matching interstrip capacitance of common p^+ stop structure of the same width makes 3,65 pF. Calculated quantities of interstrip capacitance in the given range of distances between two adjacent rings p^+ stop structure differ. While calculation by Eq. (1) is well compounded with the experimental data, calculation by Eq. (2) has given considerably larger quantity of interstrip capacitance. It can be stipulated the several reasons. In first, the relation *w/p* for our case lays over the range from 0,67 up to 0,74 that a little bit above the range for which the formula is given. In second, for this equation the approach made by us can be unacceptable. And, at last, by some experimenters it is noted, that the formula badly works for rather large strip pitch. So for example in [19] calculations are badly compounded with experiment already at the pitch 120 micron. Thickness of the detector makes 320 micron.

The picked geometry of the detector provides for the interstrip capacitance of 0,805 pF/cm, under the condition that the interstrip capacitance is equal to 0,5 of the capacitance between one strip and all others. For example, in [9] the interstrip capacitance amounts to 0,63 pF/cm with the n^+ strip pitch of 80, width of 16 and size of p^+ stop structure of 2x18 μm and in [13] it is 0,55 and 0,45 pF/cm with the n^+ pitch of 141, width 20 and size of the p^+ stop structure of 2x20 and 2x45,5 μm, respectively. A similar p^+ stop structure was also used in [11], the values of the interstrip capacitances was there 0,74 pF/cm with the n^+ strip pitch of 75, width of 16 and size of the p^+ stop structure of 2x16 μm.

In our case larger interstrip capacitance results from that at a similar strip pitch in [9] and [11] we have almost twice higher strip width that is 40 microns and smaller width of p^+ stop structure 2x10 microns. Except for it for these data such parameter as depth of an implantation, which as renders major effect on quantity of interstrip capacitance is not known.

4. INTERSTRIP RESISTANCE

The problem of determining the interstrip resistance is not a trivial one because the measurements should be performed at the voltage of the total depletion of the detector. The value of the interstrip resistance usually lies in the range between hundreds MOhms and tens GOhms depending on the detector design. On measuring the interstrip resistance it is necessary to provide for minimum distortions of the electrostatic field in the interstrip volume of the detector being under the total depletion voltage. Two techniques from [10] and [11] were employed for determining the interstrip resistance permitting to get this from the leak currents of the strips.

The measurements performed have shown that the values of the interstrip capacitance registered with both techniques are equal and they amount to about 15 GOhm for both types of the p^+ stop structure. The difference in the interstrip resistance for the strips with various geometry of the combined p^+ stop structure was not found.

5. CONCLUSIONS

As a result of the lead examinations the data showing that usage of various geometry combined p^+ stop structure allows reducing interstrip capacitance without diminution of interstrip resistance are received. Difference in interstrip resistance for common and combined p^+ stop structure is not revealed. Combined p^+ stop structure ensures smaller interstrip capacitance, than common one.

The received results show an opportunity of diminution of a capacitive load of readout electronics and a capacitive coupling between strips without change of an insulation resistance between strips. It allows optimizing and refining a construction of the microstrip detector for obtaining higher detector characteristics, such as noise of the detector and the spatial resolution.

The carried out measurings are in the good consent with the theoretical calculations, which have been carried out by Eq. (1) in offered approach. The given approach can be used for theoretical estimated calculations of interstrip capacitance on the ohmic side of the two-coordinate microstrip detector.

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ИССЛЕДОВАНИЕ ЭЛЕКТРОФИЗИЧЕСКИХ ХАРАКТЕРИСТИК ДЕТЕКТИРУЮЩИХ ЭЛЕМЕНТОВ НА ОМИЧЕСКОЙ СТОРОНЕ КРЕМНИЕВОГО МИКРОСТРИПОВОГО ДЕТЕКТОРА

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Представлены результаты исследования омической стороны двухсторонних микростриповых детекторов (ДСМД), имеющих диодные разделяющие p^+ стоп структуры различных типов и размера. Рассмотрено влияние p^+ стоп-структуры на межстриповую емкость и межстриповое сопротивление ДСМД.

ДОСЛІДЖЕННЯ ЕЛЕКТРОФІЗИЧНИХ ХАРАКТЕРИСТИК ДЕТЕКТУЮЧИХ ЕЛЕМЕНТІВ НА ОМІЧНІЙ СТОРОНІ КРЕМНІЄВОГО МІКРОСТРИПОВОГО ДЕТЕКТОРА

М.І. Маслов, С.М. Потін, О.Ф. Стародубцев

Представлено результати дослідження омічної сторони двосторонніх мікрострипових детекторів (ДСМД), які мають діодну розділяючу p^+ стоп-структуру різного типу та розміру. Розглянуто вплив p^+ стоп-структури на міжстрипову ємність та міжстриповий опір ДСМД.