FULL DEPLETION VOLTAGE AND SEPARATION VOLTAGE FOR A DOUBLE-SIDED MICROSTRIP DETECTOR

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The results of investigation of the full depletion and separation voltages are presented. It is shown that these voltages do not always have similar values. The explanation of this effect is suggested.

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1. INTRODUCTION

A microstrip detector is one of the popular types of silicon coordinate detectors. It is used practically in all nuclear and high-energy physic experiments [1-7]. Silicon coordinate detectors are used for a tracking system. This system registers coordinates and ionization energy of charged particles. This type of detectors provides a high spatial resolution, which is not reachable by other detectors. Quick-action is another very important parameter that is used widely for triggering of the other detectors.

There are two types of the silicon coordinate detectors, one- and two-coordinate. The difference between them is that the one-coordinate detector can get a signal only from one side and in that way registers only one coordinate. The two-coordinate detector provides a signal from both sides and registers two coordinates, correspondingly.

One of the conditions for the detector successful use is the correct operation voltage. Usually, it is determined by a full depletion voltage. Strips separation on an ohmic side is another important condition for the two-sided detectors. One considers that the strips separation is reached automatically at the full depletion voltage.

Our search shows that for one detector these two parameters can differ significantly. This difference is very important because these parameters determine the operation voltage.

The operation voltage has to be determined very accurately. On one hand, the operation voltage must be sufficiently high to deplete all volume of the detector, provide full charge collection and stable functioning of the ohmic side. On another hand, the high operation voltage can lead to a detector breakdown. It increases noise from the leakage current and microdischarges, power consumption and heating [8].

2. TECHNIQUE OF RESEARCH

A following technique is used for this problem investigation. First, the full depletion voltage measurement on a test diode using standard methodology is performed. Then, using three different methods, the strip separation voltage on the ohmic side of the two-sided microstrip detectors is measured. Moreover, the calculations of the full depletion voltage for the diode and the microstrip detector are performed.

3. DETECTORS

Some test structures were selected for a testing. These are two-coordinate microstrip detectors of two series that have large difference on the strip separation voltage. We used also the one-sided diodes. These diodes are the standard test structures and have the same wafers as the detectors under test do. The diode and detector of series with higher strip separation voltage are marked as the Diode 1 and the Detector 1, while those of series with lower strip separation voltage are marked as the Diode 2 and the Detector 2, correspondingly.

Each detector has 128 strips. Some strips are manufactured without biasing resistors to perform precise interstrip resistance measurement. The test diodes are the standard planar diodes with square active area 5×5 mm.

All devices have been manufactured on n-type high-resistivity silicon (5500 Ohm/cm for first series and 9500 for second one). The thickness of devices is 0.3 mm.

4. FULL DEPLETION VOLTAGE MEASUREMENT

There is a standard method to measure the full depletion voltage using the diode [9]. This method is based on the fact that square of capacitance of the diode is inversely proportional to the bias voltage until the moment of the full depletion occurs. However, capacitance dos not depend on the bias after the full depletion voltage is reached. Using this fact, the full depletion voltage can be determined from the volt-farad curves. For the volt-farad measurement on the test diode, a standard circuit has been used.

5. STRIP SEPARATION VOLTAGE ON OHMIC SIDE

We used three different methods to determine the strip separation voltage. These are an interstrip resistance, an interstrip capacitance, and a strip leakage current measurement. These measurements are based on the fact that there exists a charged layer at the silicon-oxide interface; the layer is charged positively in the oxide and negatively in the silicon. The layer in silicon consists of electrons that connect strips together. From the diode side, this conductive layer is removed by the depletion region. From the ohmic side, special separation structures are used to interrupt this layer. However, these structures start working only when depletion region reaches the ohmic side. Until this moment, all strips on the ohmic side are shorted. Because of that, the measurements indicated above are sensitive to the moment of strip separation.

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5.1. INTERSTRIP RESISTANCE MEASUREMENT

The method of determination the interstrip resistance from the strip leakage currents is used [10]. Two-voltage sources are used for the measurement. The first one provides detector biasing; the second one provides a potential difference between the strips, which is required for the measurement of the interstrip current.

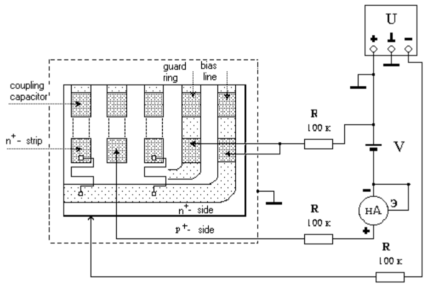

Fig.1. Circuit for interstrip resistance measurement

First, the leakage current of one strip is measured using the circuit in Fig.1. Then we remove the voltage source V, and measure the leakage current again. The difference between these currents is an interstrip current i_{is} because of the additional voltage source V. The interstrip resistance can be calculated using Ohm low (1):

$$R_{is} = \frac{V}{i_{is}} \tag{1}$$

5.2. ONE STRIP LEAKAGE CURRENT MEASUREMENT

Each strip is connected to a common bias line by a bias resistor. The conductive layer connects all n^+ strips together until the moment of separation occurs. Measuring the single strip current before the separation we measure, in fact, the current of several strips connected by the conductive layer. This current is much higher than the current of the single strip. After separation, we measure only single strip current. In that way, the single strip leakage current decreases dramatically at the moment of the strip separation. For these measurements we used the same circuit as we did for the inerstrip resistance measurements with the voltage source V removed.

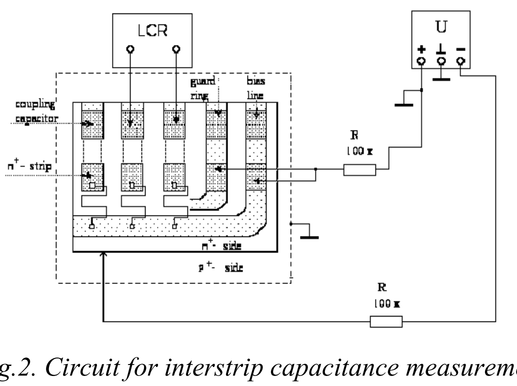

Fig.2. Circuit for interstrip capacitance measurement

5.3. INTERSTRIP CAPACITANCE MEASUREMENT

A standard technique is used for the interstrip capacitance measurement [10]. The circuit presented in Fig.2 is used for these measurements. The capacitance is measured at a frequency 1 kHz because at this frequency the measurement is the most sensitive to the separation moment. The capacitance is measured between two adjacent strips.

6. CALCULATION OF FULL DEPLETION VOLTAGE

For the full depletion voltage calculation, the well-known equation (2) is used [11]:

$$V_d = \frac{d^2}{\rho \mu_e 2\varepsilon_0 \varepsilon_{Si}}, \tag{2}$$

where ρ is the silicon resistivity, μ_e is the electron mobility, ε_0 and ε_{Si} are the vacuum and silicon dielectric constants, respectively, and *d* is the depletion depth.

7. RESULTS

A special measuring complex has been used to perform these investigations.

Results of the full depletion voltage on the test diodes 1 and 2 are presented in Fig.3. For the diode 1 the full depletion voltage is 28.8 V and for diode 2 it is 50 V.

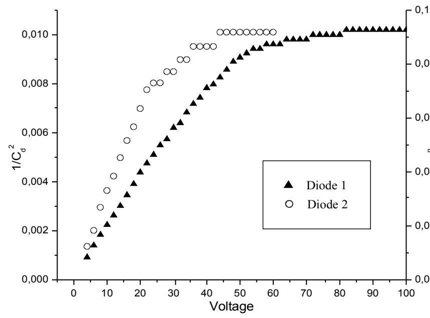

Fig.3. C-V curves for test diodes

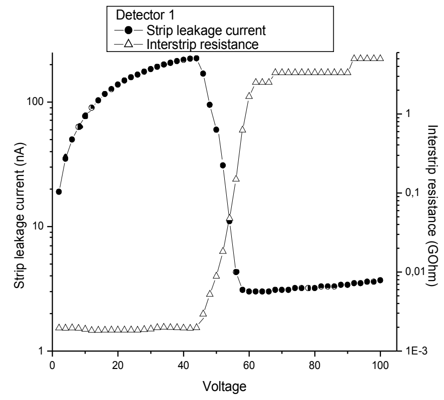

Fig.4. Strip leakage current and interstrip resistance for Detector 1

All results for both series

Series	Full depletion voltage		Separation voltage measured by:		
	Calculation	Diode	strip current	interstrip resistance	interstrip capacitance
1	51.3	50	60	60	60
2	29.7	28.8	30	30	30

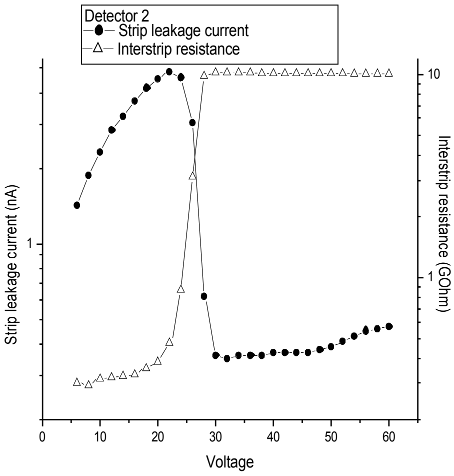

Fig. 5. Strip leakage current and interstrip resistance for Detector 2

The interstrip resistance and single strip current measurements for the Detector 1 are presented in Fig.4. The same characteristics for the Detector 2 are indicated in Fig.5. The interstrip capacitance dependences on bias voltage for the Detector 1 and the Detector 2 are shown in Fig.6.

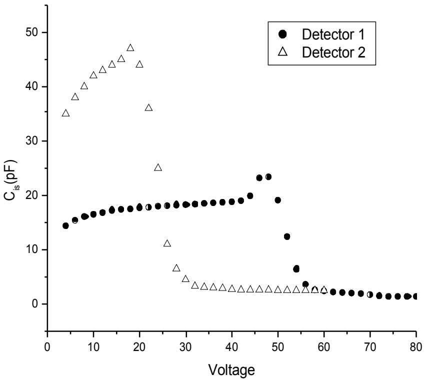

Fig. 6. Interstrip capacitance dependences on bias voltage for Detector 1 and Detector 2

All the results are presented in a table. One can see there is a difference between the first and second series. This difference is due to the different resistivity of silicon that was used for these series production. Obtained results show that for the first series the measurements on the detector and diode and calculation are in good agreement with the calculations. For the second series, the full depletion voltage measured on the diode is in agreement with the calculation, but the separation voltage measured on the detector is higher.

8. CONCLUSION

One can see that the full depletion voltage and separation voltage are not always identical. In our case, the separation voltage is higher than the full depletion voltage. The reason can be in too high charge in silicon oxide. Silicon oxide is used widely as an insulator. The charge may be generated at the silicon-oxide interface during plasma treatment. This charge usually is positive in oxide and negative in silicon. From ohmic side this charge shields the field of depletion. To get rid of this effect, an additional voltage is needed. This assumption requires further investigations.

The choice of measurement type for operation voltage is very important for the two-sided detectors. Wrong operation voltage can cause incorrect functioning of a detector or leads to its break.

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НАПРЯЖЕНИЕ ПОЛНОГО ОБЕДНЕНИЯ И НАПРЯЖЕНИЕ РАЗДЕЛЕНИЯ ДЛЯ ДВУХСТОРОННЕГО МИКРОСТРИПОВОГО ДЕТЕКТОРА

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Представлены результаты исследования напряжения полного обеднения и напряжения разделения. Показано, что эти напряжения не всегда имеют близкие величины. Предложено объяснение этого эффекта.

НАПРУГА ПОВНОГО ЗБІДНЕННЯ ТА НАПРУГА РОЗДІЛЕННЯ ДЛЯ ДВОСТОРОННЬОГО МІКРОСТРИПОВОГО ДЕТЕКТОРУ

М. Маслов, О. Стародубцев

Представлені результати дослідження напруги повного збіднення и напруги розділення. Показано, що ці напруги не завжди мають значення яки е близькими. Запропоновано пояснення цього явища.