INTERFERENCE OF QUANTITIES OF INTERSTRIP CAPACITANCE AND INTERSTRIP RESISTANCES OF THE TWO-COORDINATE MICROSTRIP DETECTOR

N.I. Maslov, S.M. Potin, A.F. Starodubtsev

National Science Center "Kharkov Institute of Physics and Technology", Kharkov, Ukraine
e-mail: astarodubtsev@kipt.kharkov.ua

The dependence of interstrip capacitance of the double-sided microstrip detector on frequency of measuring is explored. Has been investigated at what frequency of measuring the observed value of interstrip capacitance is most in accord with quantity of interstrip resistance. By obtained results the conclusions about an opportunity of application of interstrip capacitance measuring for detection of defects of the microstrip detectors at stage of their characterisation are made.

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INTRODUCTION

Last time the silicon microstrip detectors received wide application in experimental physics. This type of detectors is used for tracking systems practically of all major experiments in high-energy physics [1-7]. For build-up of track system one uses from several hundreds up to several thousand microstrip detectors. Before application all these detectors should be tested for checkout of conformity to the requirements of the experiment. The optimum procedure of testing is developed for this purpose [8-10]. This procedure includes a gang of methods to gain the most complete detector characteristic by the least quantity of measurings. For the double-sided microstrip detector such procedure as a rule includes measuring interstrip resistance and (or) interstrip capacitance. These two parameters are the basic quantities defining quality of the detector. Interstrip resistance determines charge distribution between adjacent strips. In turn it determines level of useful signal and hence signals to noise relation and spatial resolution of the detector. Interstrip capacitance gives the basic contribution to a capacitive load of readout electronics. In modern track systems, in which the microstrip detectors are used, they are equipped by prompt readout electronic with shaping time about several microseconds and less. At such small shaping times the basic contribution to noise of system is defined by the capacitive load at the input of the preamplifier, which is defined in basic by interstrip capacitance.

The measuring of interstrip capacitance and interstrip resistance can be applied in several cases. In first, this is measuring of physical quantities, and in second, measuring for a detection of technological defects at a stage of characterization of the detector. Generally these defects represent different flaws of p^+ and n^+ implantations giving a low resistance between two strips (short circuit).

The measuring of the physical quantity of interstrip capacitance is used for an estimation of the contribution of interstrip capacitance in total capacitance of a strip

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and for definition of relation of quantity of interstrip capacitance and coupling capacitor. This kind of measurements should be executed most precisely, therefore it is necessary to use setup allowing to get rid from all parasitic capacitances and ensuring most precise measurement.

There are some works devoted to examination of frequency dependence of interstrip capacitance. Interstrip capacitance strongly depends on a construction of the detector and performances of materials used for its manufacture. Therefore frequency dependences of interstrip capacitance are various. So, for example in [11] the value of interstrip capacitance decrease at increase of frequency, whereas in [12] the value of interstrip capacitance practically does not depend at frequency, and in [13] and [14] the value of interstrip capacitance increase with increase of frequency of measuring, that is qualitatively in good agreement with results, obtained by us.

All examination of frequency dependence of interstrip capacitance carried out before was executed with the purpose of definition of frequency,that is optimum for measuring the physical quantity. With the purpose of optimization of a procedure of characterization of the microstrip detector and opportunity of application of measuring of interstrip capacitance for technological defects detection, we spent examination of interrelation of quantity of interstrip capacitance on different frequencies of measuring and quantity of interstrip resistance.

EXPERIMENTAL CONDITIONS

For examinations two types of detectors were used. one is double-sided detector with polysilicon biasing resistors. For an opportunity of a precise measurement of interstrip resistance the biasing resistors detached from a bias line on 12 strips. The second detector is double-sided detector with punch - through bias system. Both detectors have identical geometry and one type of a p^+ stop structure.

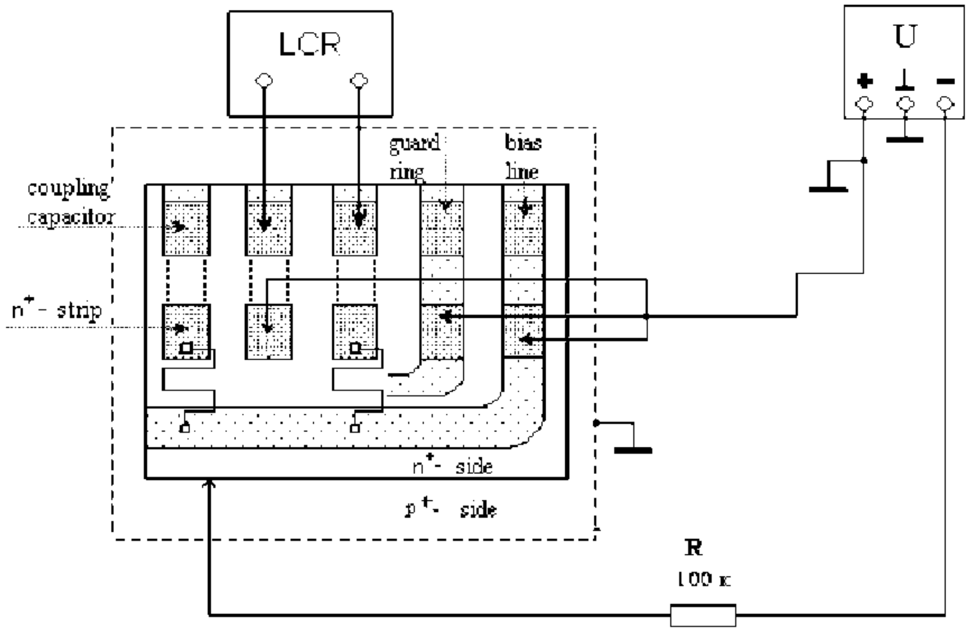

Fig. 1. *Setup of measuring of interstrip capacitance*

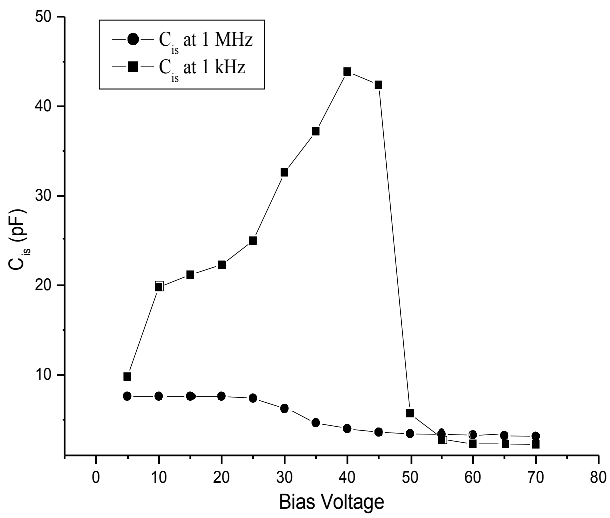

***Fig. 2**. Dependence of interstrip capacitance on the bias voltage*

DETECTOR WITH POLYSILICON RESISTORS

The examinations of the detector with polysilicon resistors were carried out in two stages.

First investigation phase were spent on the ohmic side of the double-sided microstrip detector. As on this side the interstrip resistance sharply varies only at achievement of a voltage of strips separation, therefore short circuit can be imitated, applying voltage that is less than separation voltage. For this purpose with setup showed in Fig. 1 the dependence of interstrip capacitance and dissipation factor from a bias voltage was measured. The measuring were carried out on frequencies 1 MHz and 1 kHz.

In Fig. 2 the results of measuring of interstrip capacitance, and in Fig. 3 - dissipation factor for two n^+ strips with high interstrip resistance are submitted. As it is visible from figures, at the moment of n^+ strips separation capacitance at frequency 1 kHz varies much more, than at frequency 1 MHz. Dissipation factor at change of frequency changes dependence on the voltage on opposite.

Fig. 4 displays dependence of interstrip resistance on the bias voltage for two strips, In Fig. 5 and Fig. 6 measurements of the same parameters are given, but only in the range close to the voltage of strips separation and with finer step to show clearly the moment of strips separation.

At the second stage the detector with actual technological defects was explored. For measuring 12 strips, with detached polysilicon resistors were chosen, among which there are as the strips with high, and with low interstrip resistance. The measuring were carried out at the voltage of a complete depletion of the detector. Interstrip resistance, and then interstrip capacitance was measured. The results of measurements are given in Fig. 7 and in Fig. 8.

DETECTOR WITH PUNCH - THROUGH BIAS SYSTEM

The punch - through bias system differs from the polysilicon resistor by that instead of the polysilicon resistor the bias resistance is ensured with a construction like p-n-p, which is implemented at existence of a gap of particular quantity between a protective ring and strips.

For examinations the detector having technological defects on the ohmic side also was chosen that has given in occurrence of some strips with low interstrip resistance. The examinations of this detector also were carried out in two stages. Frequency dependence of interstrip capacitance and dissipation factor at first was measured at the voltage of the complete depletion of the detector on the strip with high interstrip resistance for parallel and serial equivalent circuits of capacitance measuring. The results of these measurements are given in Fig. 9 and Fig. 10.

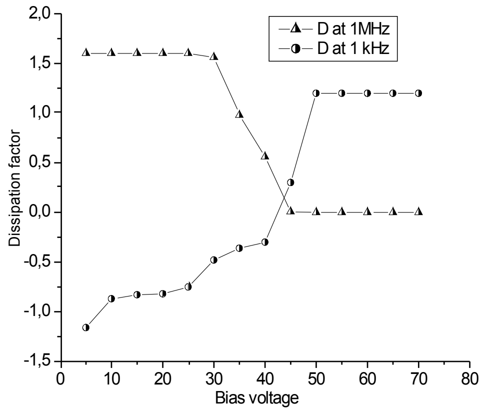

Fig. 3. Dependence of the dissipation factor on the bias voltage

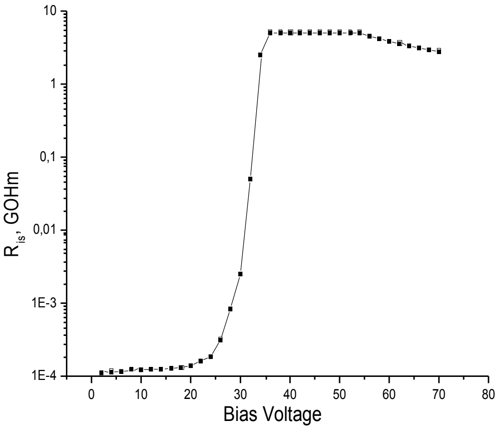

Fig. 4. *Dependence of interstrip resistance on the bias voltage*

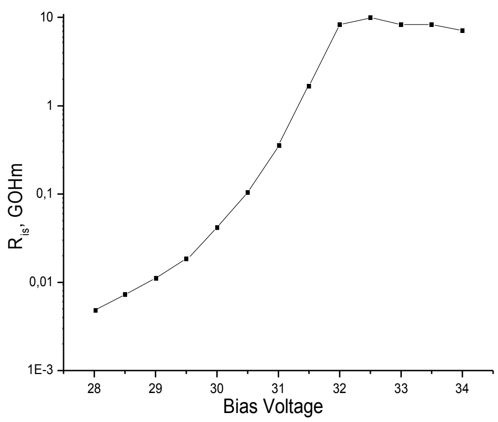

Fig. 5*. Interstrip resistance in the range close to the separation voltage*

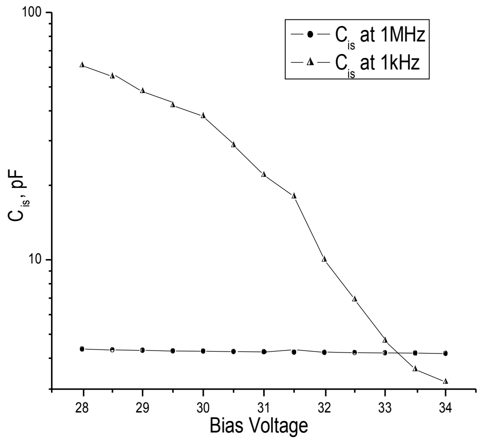

Fig. 6. *Interstrip capacitance in the range close to the separation voltage*

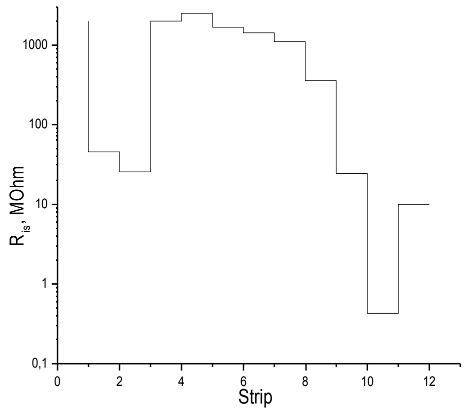

Fig. 7*. Distribution of interstrip resistance*

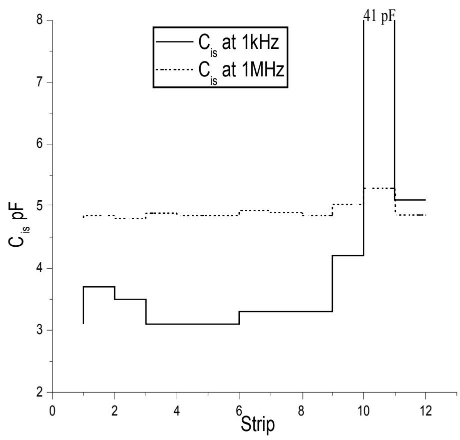

Fig. 8. *Distribution of interstrip capacitance*

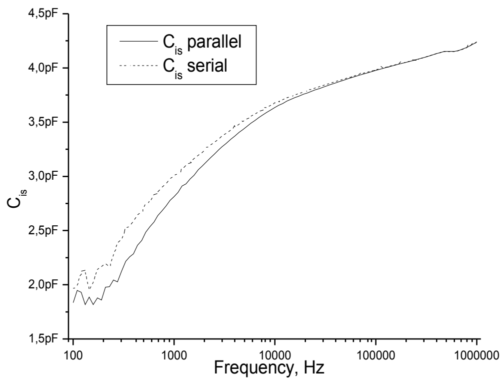

Fig. 9. *Dependence of interstrip capacitance on frequency at the voltage of the complete depletion*

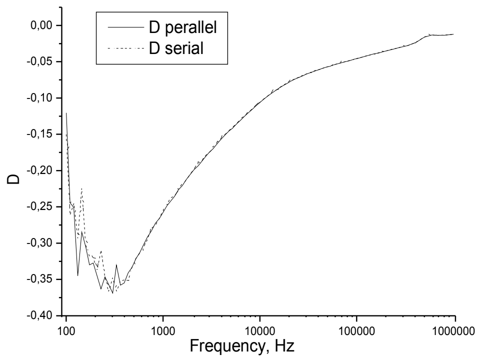

Fig. 10. *Dependence of the dissipation factor on frequency at the voltage of the complete depletion*

Then, as well as for the detector with polysilicon resistors, the dependence of interstrip capacitance and dissipation factor from the bias voltage on two frequencies 1 kHz and 1 MHz was measured. This test was executed for two equivalent circuits of capacitance measuring too. The results of measuring of interstrip capacitance and dissipation factor can be seen in Fig. 11 and Fig. 12 correspondingly. And, at last, measurements of interstrip capacitance on strips with actual defects were carried out. Fig. 13 displays distribution of interstrip resistance, and Fig. 14 and Fig. 15 show interstrip capacitances for the chosen part of the detector on frequencies 1 kHz and 1 MHz accordingly.

ANALYSIS OF RESULTS

As have shown frequency measurements (Fig. 9 and Fig. 10), the quantity of interstrip capacitance essentially depends on frequency of measuring. It is explained to that any physical capacitor can be presented as serial and parallel equivalent circuits. These circuits are submitted in Fig. 16. Both these circuits represent effects of leakage of insulator and resistance of materials of capacitor plates. R_s influences quantity of capacitance. For an estimation of this influence there is such parameter as dissipation factor, D, that is determined under equation:

$D=-2\pi fCR_s$

where f is frequency of measuring, C is quantity of capacitance and R_s is serial resistance.

As it is visible from the formula, the dissipation factor is directly proportional to quantity of serial resistance, that is, it displays "purity" of measuring of capacitance. It is obvious, that for the ideal condenser $R_s=0$. The value R_s is higher, the distortion is greater that it imports to quantity of capacitance. However for the detection of strips with low interstrip resistance the defining role has the responsivity of measuring to a different kind of short circuits but not the accuracy of capacitance measurement. This responsivity increases with growth of the contribution of serial resistance

At measuring frequency 1 kHz measured capacitance has the much more contribution of resistance and, hence, major responsivity to low interstrip resistance, than at frequency 1 MHz. So, for example, at frequency 1 MHz C_{is}=4,2381 pF and D=−0,0119 and at frequency 1 kHz C_{is}=3,67411 pF and D=−0,10582. Then according to equation quantities of serial resistance for 1 MHz and 1 kHz will be equal 447 Ohms and 459 kOhm accordingly. As it is visible, the serial resistance strongly depends on frequency. Probably, it is concerned with frequency dependence of conductance of materials, of which the detector manufactured.

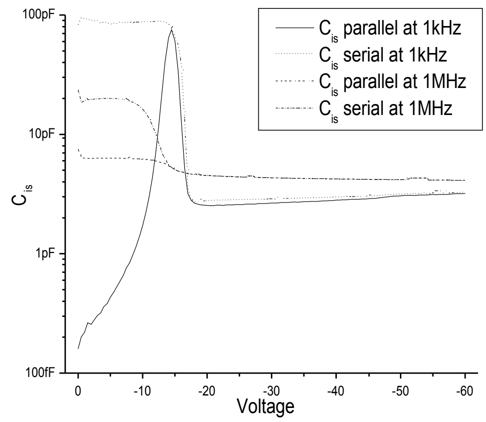

Fig. 11. *Dependence of interstrip capacitance on the bias voltage*

All carried out measurements are qualitatively compounded with the above-stated explanation. As it is visible from Figs. 2-4,11,12, interstrip capacitance at frequency 1 MHz practically does not vary at the moment of n^+ strips separation, whereas at frequency 1 kHz varies considerably, that confirms by measurements of the dissipation factor and is in the good coordination with behavior of interstrip resistance. From Figs. 11,12 it is possible to see, that at the same frequency more sensing is measuring capacitance on the serial equivalent circuit, whereas it does not influence the dissipation factor.

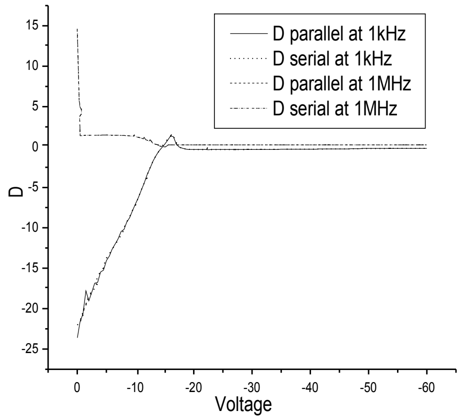

Fig. 12. *Dependence D from the bias voltage*

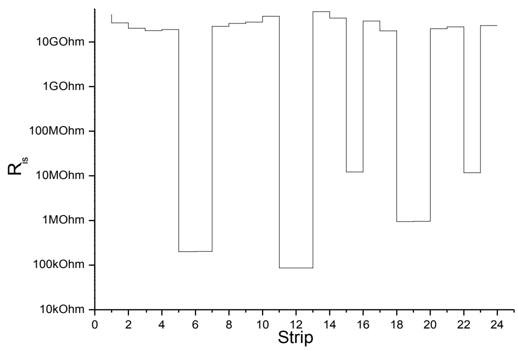

Fig. 13. *Distribution of interstrip resistance*

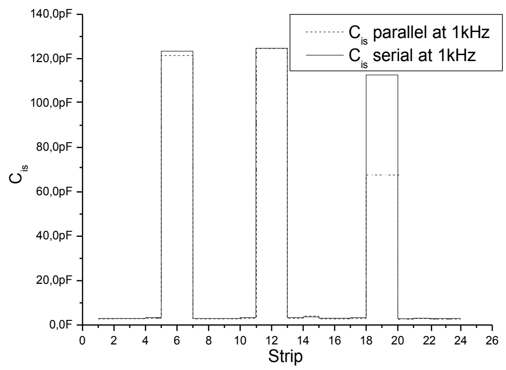

Fig. 14. *Distribution of interstrip capacitance at frequency 1 kHz*

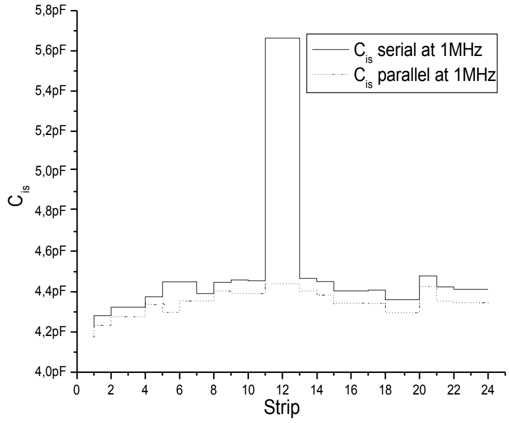

Fig. 15. *Distribution of interstrip capacitance at frequency 1 MHz*

At measuring capacitance of strips having low interstrip resistance, has appeared, that capacitance at frequency 1 MHz has practically identical quantity on strips with low and high interstrip resistance. Capacitance at frequency 1 kHz varies on an order of magnitude at diminution of interstrip resistance up to 0.5 MOhm and on 30…50 % at diminution of resistance up to several tens MOhm (Fig. 7,8,13-15).

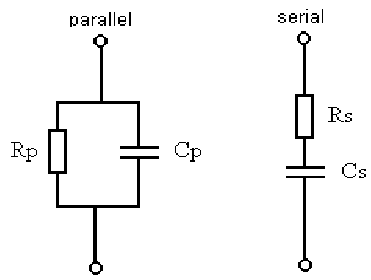

Fig. 16. *Equivalent circuits of the capacitor*

As was found out at testing the detector with punch - through bias system, the measuring of interstrip capacitance is not capable reveal all types of defects of this detector. As it is visible from Fig. 13 and Fig. 14, we have higher value of interstrip capacitance only on "pair" strips with low resistance, whereas "single" strips have normal capacitance. It is possible to explain as follows: at low interstrip resistance on two next strips we have a break of the p^+ stop structure between these strips. It is natural influences on quantity of interstrip capacitance and resistance. At low interstrip resistance on one strip we have the break of the p^+ stop structure between the strip and a bias line. This defect is defined at measuring of interstrip resistance by virtue of specificity of the used circuit, but any way does not influence in interstrip capacitance. On detectors with polysilicon resistors this type of defect misses because of constructional features.

CONCLUSIONS

The carried out examinations and obtained results show that interstrip capacitance strongly depends on measuring frequency. At low frequency (1 kHz) behavior of the interstrip capacitance is in good agreement with behavior of the interstrip resistance. At high frequency value of the interstrip capacitance practically dos not depend on the value of the interstrip resistance and is most "clean" physical value. One can make conclusions that for measuring interstrip capacitance it is necessary to choose different frequencies depending on the purpose of measurements. So for physical measurements of quantity of interstrip capacitance it is necessary to use the peak frequency, in our case 1 MHz, as thus the contortions imported to measuring by serial resistance, are minimal. As to use of measurements of interstrip capacitance for the detection of technological defects, the low frequency is more appropriate. The spent examinations have shown an opportunity of the technological defects detection for the detector with polysilicon resistors. For the detector with punch - through bias system such use has appeared of restricted because of the measuring of interstrip capacitance on this type of detectors does not detect all defects, which can be detected at measuring of interstrip resistance.

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ВЗАИМОВЛИЯНИЕ ВЕЛИЧИН МЕЖСТРИПОВЫХ ЕМКОСТИ И СОПРОТИВЛЕНИЯ ДВУХКООРДИНАТНОГО МИКРОСТРИПОВОГО ДЕТЕКТОРА

Н.И. Маслов, С.М. Потин, А.Ф. Стародубцев

Исследована зависимость межполосковой емкости двухстороннего микрополоскового детектора от частоты измерения. Изучено, при какой частоте измерений результаты измерений межполосковой емкости наиболее согласуются с величиной межполоскового сопротивления. По полученным результатам сделаны выводы о возможности применения измерения межполосковой емкости для обнаружения дефектов микрополосковых детекторов на этапе их тестирования.

ВЗАЄМОВПЛИВ ВЕЛИЧИН МЕЖСМУГОВИХ ЄМНОСТІ ТА ОПОРУ ДВОХКООРДИНАТНОГО МІКРОСМУГОВОГО ДЕТЕКТОРУ

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

Досліджено залежність міжсмугової ємності двостороннього мікросмугового детектора від частоти вимірювання. Вивчено, при якій частоті вимірювання результати вимірювання міжсмугової ємності найбільш співпадають зі значенням міжсмугового опору. По отриманим результатам зроблено висновки про можливість застосування вимірювання міжсмугової ємності для знаходження дефектів мікросмугових детекторів на етапі їхнього тестування.