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DEFINITIONS OF THE COORDINATE DISTRIBUTION OF LOCAL INHOMOGENEITIES IN THE VOLUME OF A SEMICONDUCTOR

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Abstract:
A method has been developed for determining the two-coordinate (x and y) distribution of local clusters of impurity atoms in the volume of semiconductor materials. The developed method is used in the preliminary selection of homogeneous materials for the production of semiconductor devices.

Keywords: semiconductor material, n-p junction, impedance, local inhomogeneities, grid ohmic contacts.

1. Introduction

The technology of creating semiconductor devices is the most important component of rapidly developing nanotechnologies, one of the main aspects of which is the development of a method for studying local accumulations of impurity atoms in the volume of semiconductor materials. Methods of quality control of semiconductor material are known based on electron microscopy [1], probe measurements of specific resistance, [2] chemical selective etching and decoration [3]. The listed methods allow obtaining information of a purely near-surface nature. Their use for studying the bulk properties of semiconductors is associated with the successive destruction of the single crystal (for example, constant etching or grinding), which determines their unsuitability for rejecting material used for the manufacture of devices. The traditional approach to studying the influence of a certain concentration of various point imperfections of the crystal structure (impurity levels, dislocations, point centers of adhesion) on physical processes in semiconductor devices is insufficient to meet modern requirements of semiconductor instrument engineering. Research is needed to identify fluctuations in their distribution in the volume of the semiconductor, determine the local inhomogeneity of such distribution and study the role of such local inhomogeneities on the properties of modern semiconductor devices.

2. Material and method

A method for identifying local inhomogeneities in a semiconductor material based on the type of frequency dependence of the impedance of structures [3], the essence of which is that a n-r junction is made on a semiconductor material and the frequency dependence of the impedance of the n-r junction is measured in a wide frequency range and, based on linear diagrams, the integral value of local inhomogeneities in the form of high-resistance layers in the entire volume of the sample is determined. This method cannot determine the coordinate distribution of local inhomogeneities. A new method is proposed that allows one to determine the coordinate distribution of local inhomogeneities. To determine the distribution of local inhomogeneities along two coordinates l_i (X_i,Y_i), rectifying contacts are created on two opposite side surfaces of the sample, the frequency dependence of the structure impedance is measured, and the total size of all local inhomogeneities in the entire volume of the sample $(\sum l_i)_0$ is determined, then grid omics contacts are applied on two opposite sides of the sample through a mask with a width and pitch exceeding the largest size of the in homogeneities (Fig. 1). After this, a constant voltage is applied in turn to each opposite pair of contacts, the coordinates of which are known, the value of which is determined from the electric field strength [4] from the formula:

$E_{cr} \approx 4/3\cdot[\pi\cdot\rho/\varepsilon]\cdot 2R$

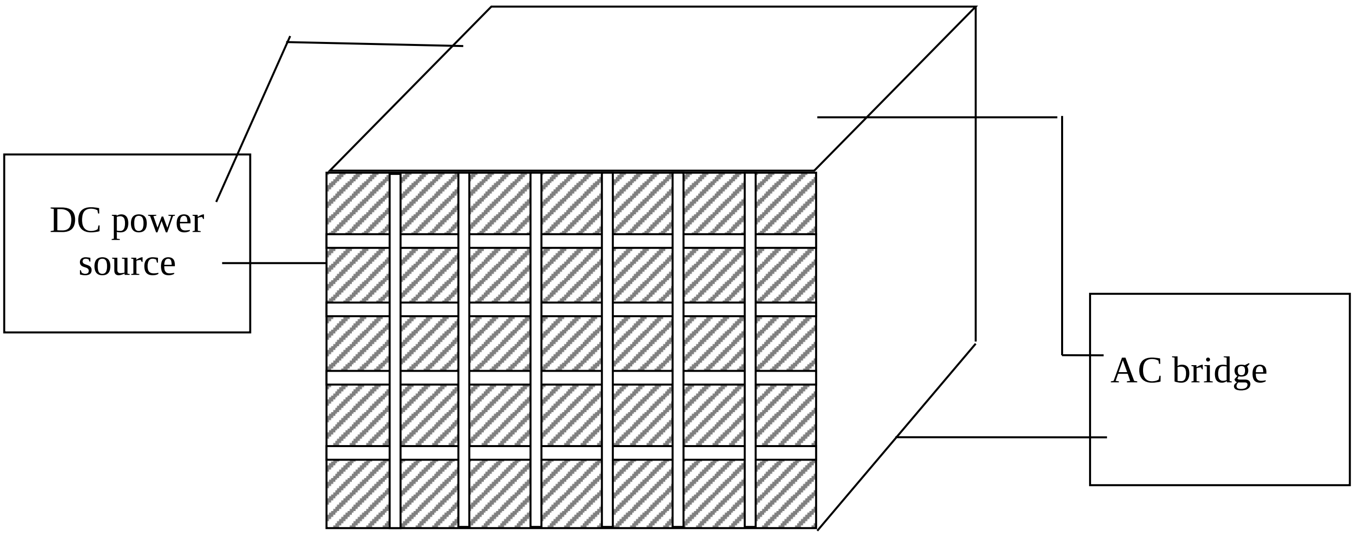
where, ρ- is the density of the negative volume charge arising in the p-region; 2R --is the linear size of local clusters of impurity atoms of the region in the direction of the electric field lines. Additionally, the frequency dependence of the impedance is measured for each pair (Fig. 1). Based on the linear diagrams, the total effective size of the inhomogeneities is determined without taking into account the region determined by the coordinates of the contacts to which a constant voltage $\sum l_i$ is applied. The desired distribution of local inhomogeneities by coordinates l_i (X_iY_i) is determined by the difference in the total effective sizes of the inhomogeneities before and after applying the constant voltage.

$l_i\ (X_i, Y_i) = (\sum l_i)_o - \sum l_i$

where $(\sum l_i)_o$ is the total effective size of the inhomogeneities before applying constant voltage.

$(\sum l_i)$ is the total effective size of the inhomogeneities after applying constant voltage.

3. Results and discussion. In the example, the method is tested on p-Si with a specific resistance of ρ-



1000 Ω·cm. The dimensions of the sample are 10x8x2.5 mm. Nickel contacts are applied to two opposite side surfaces of the sample by chemical deposition, and grid omics contacts are applied to two opposite sides of the sample by gold sputtering through a mask, the width and length of each cell is 200 µm, the distance between the contacts is 100 µm. The frequency dependence of the impedance is measured and the magnitude of local inhomogeneities in the form of high-resistance layers with a specific resistance and an effective size in the entire volume of the sample is determined. The sizes and specific resistance of the local in homogeneities are given in Table 1. By summing up the sizes of local in homogeneities, we determine $(\Sigma l_i)_o$, the total effective size of in homogeneities in the entire sample. Then, a constant voltage of 3 103 V/cm is applied to the omics opposite contacts in turn, each time the frequency dependence of the impedance is measured and Σli is determined without taking into account the region determined by the coordinates of the contacts to which the voltage is applied. The desired distribution of local inhomogeneities l_i (X_i, Y_i) is determined by the difference in the total effective sizes of inhomogeneities before and after applying the constant voltage. Table 2 shows the distribution of local inhomogeneities by two coordinates li (XiYi).

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Fig. 1. Scheme of measurement of coordinate determination of local inhomogeneities.

Table 1. Dimensions and specific resistance of local inhomogeneities

№ s.n.	⍰$_i \cdot 10^6$ Ω·cm	l_i microns
1.	0.28	4.3
2.	0.65	3.1
3.	1.32	1.6
4.	1.73	2.8
5.	2.3	9.6
6.	2.76	8.3
7.	3.4	4.5
8.	6.4	2.7
9.	7.3	4.2
10.	8.51	6.8
11.	9.6	5.6
12.	11.7	3.2

Table 2. Distribution of local inhomogeneities by two coordinates l_i (X_i, Y_i).

№ s.n	l_i, microns	X_i,mm	Y_i,mm
1.	1.6	0.2	6.5
2.	2.7	0.5	2.0
3.	9.6	0.8	7.4
4.	8.3	2.0	0.2
5.	6.8	2.6	1.1
6.	4.5	3.5	4.7
7.	2.9	4.1	3.8
8.	4.3	5.3	0.5
9.	3.2	5.6	6.7
10.	5.6	6.2	2.3
11.	3.2	6.5	5.9
12.	4.2	7.7	5.0

The use of this method in the preliminary screening of material at an early stage of the technology of manufacturing semiconductor devices, in particular semiconductor nuclear radiation detectors, increases the yield of detectors with improved electrophysical and spectrometric characteristics.

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