METHOD FOR DETERMINING THE CONDUCTIVITY DISTRIBUTION OF DOPED SAMPLES

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ABSTRACT

This work describes a four-probe method for measuring the resistivity of semiconductor materials doped with different dopant atoms. The article presents the requirements for the size and shape of the samples that are the object of research.

Keywords: semiconductor, conductivity, four-probe method, silicon, transition elements.

INTRODUCTION

Currently, an urgent problem is the study of physical processes occurring both in the bulk and on the surface, and in the near-surface layers of a single-crystal semiconductor, in particular, silicon in the process of diffusion doping with impurities that create deep levels (DL). First of all, the need for these studies is due to the fact that in the process of diffusion doping of a semiconductor material—silicon—it is possible to obtain compensated materials with specified electrophysical, photoelectric and optical properties.

METHOD

To measure the conductivity distribution profile over the thickness of the samples under study, we used a four-probe method of measuring resistance [1].

The schematic diagram of the measurement method is shown in Fig. 1b [2]. The probes were made of electrolytically sharpened tungsten. The source of direct current was a B5-48 device, an F-30 ampere-volt-ohmmeter was used as a current device, and a B7-30 was used to measure the potential difference on the middle probes 2 and 3. A small measuring current from a current generator was passed through the outer zones 1-4, and the inner probes served to measure the corresponding voltage drop.

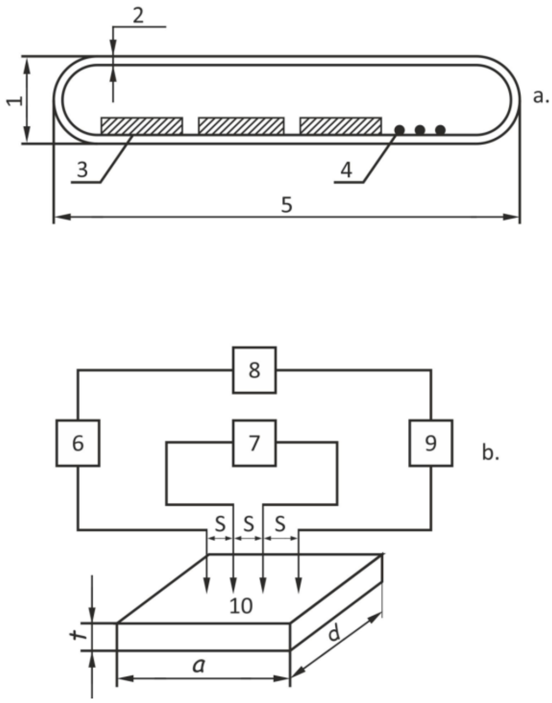

Fig.1. Size of sample ampoules (a) and diagram of a four-probe method for measuring crystal resistance (c).

From the measured values of the potential difference between probes 2,3 and the current flowing through probes 1, 4, it is possible to determine the surface resistance of the sample, according to [3] the formula:

$$R_s=\frac{V}{I}\cdot CF=\frac{\pi}{ln2}\cdot\frac{V}{I}=4,53\,\frac{V}{I}\ , \qquad (1),$$

where Rs is the surface resistance (Ohm/kV), V is the voltage drop across probes 2 and 3 (V); I - current flowing through probes 1 and 4 (A); CF is the geometric coefficient. Volume resistivity ρ, assuming homogeneity of material properties across thickness, is related to Rs by the ratio:

$$\rho=R_s\cdot\Delta t\ , \qquad (2)$$

where ρ is the volume resistivity, Δt is the thickness of the removed layer.

RESULTS AND DISCUSSION

When applying this method, the dimensions of the crystal used corresponded to the requirements of four-probe measurement, namely: with a linear arrangement of the probes, the distance between the probes is s = 1 mm, the crystal length a = 10÷30 mm corresponds to the graph in Fig. 2 with a crystal width d = 5 mm.

The value ρ, calculated by formula (2) for a layer with a non-uniform distribution of charge carrier concentration, corresponds to the volumetric resistivity of the layer averaged over its thickness (Δt). To determine the distribution of resistivity over the depth of the sample, measurements were taken after each crystal removed from the surface layer, while layers with a thickness of 3-5 microns were removed by grinding with M5 micropowder or diamond paste. The found values of the specific surface resistances Rs1 and Rs2 of two layers, differing by thickness Δt, make it possible to calculate the surface and volume resistivity of the removed layer:

$$\overline{R_S}=\frac{R_{S1}\cdot R_{S2}}{R_{S1+R_{S2}}}, \quad \bar{\rho} = \overline{R_S}\cdot\Delta t \quad . \qquad (3)$$

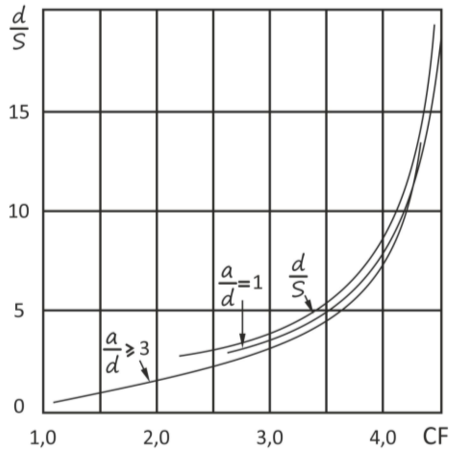

Fig.2. Geometric coefficient for calculating resistivity using data from the four-probe method [1].

The uniformity of the removed layer (layer thickness) was assessed by measuring the thickness of the crystal at various points on the surface. The crystal thickness was monitored with a micrometer with an accuracy of ±1 μm. In this case, the deviation of the crystal thickness at different points varied within ± 3 μm. Errors in measuring resistivity and surface resistance were determined indirectly as the product of several quantities measured by direct methods

$$A=B^{\kappa} C^{m} D^{n}\ldots \qquad (4)$$

where k,m,n... are constant numbers, then the maximum possible relative error of indirect measurement will be

$$\delta_A = |\kappa\delta_B| + |m\delta_C| + |n\delta_D| + \ldots, \qquad (5)$$

where $\delta_B, \delta_C, \delta_D$ are, respectively, the relative errors in measuring the quantities B, C, D, ... [3].

For example, when determining the error RS from (1), expression (4) will take the following form:

$$R_S=V\cdot I^{-1}\cdot CF \qquad (6)$$

Since B=V, C=I, D=CF, k=1, m=-1, n=1.

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