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Issue Article

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INVESTIGATION OF THE FEATURES OF THE DISTRIBUTION OF RESISTIVITY OVER THE THICKNESS OF A SILICON WAFER

***Abstract**: The high level of integration achieved in the modern microelectronics industry has led to the creation of devices with high speed and an unprecedented level of interconnection between elements. Such a rapid development of semiconductor electronics dictates the tightening of requirements for the perfection of the crystal structure and uniformity of the distribution of electrical properties in the bulk of the material. A serious problem in obtaining large-diameter single crystals without dislocations is the need to reduce the size of the microdefects involved in them. Because they significantly affect the performance of integrated circuits. The real prospects for creating extremely high-frequency circuits based on epitaxial heterostructures arouse the interest of researchers in the problems of obtaining layered structures and quantum-scale nanostructures.*

***Key words**: resistivity, silicon wafer, microelectronics.*

***Language**: English*

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Introduction

Determining the homogeneity of semiconductor materials has always taken an important place both in the study of their physical properties and in the design of multi-purpose devices used in various areas of solid-state electronics. Along with other semiconductor materials, this also applies to silicon. It occupies a special place among other materials as the most interesting material for deep fundamental research and has great potential for practical applications. In this work, determination of microhardness and specific resistance spatial distribution of silicon substrates with donor and acceptor additives was considered.

3 brands of silicon substrates differing in their electrophysical parameters were studied: 1. ESEC-0.01 type n-Si (additive element Sb) with specific resistance $\rho = 0{,}01$ Ohm·cm; 2. SDB type p-Silicon with specific resistance $\rho = 0{,}005$Ohm·cm (additive element B-boron); 3. 16.5 SEF-4 type epitaxial structure with $\rho = 4$ Ohm·cm (additive element phosphorus-P). With the methodology described in [1-2] and developed by us, wedges (left-hand slides) were obtained on these bases and specific resistance (ρ) was measured on them. ρ was measured on 5 boards from each brand. After the last chemical-mechanical polishing, the bases are for removal of the damaged layer after special mechanical treatment.

2. In SDB-0.05 type plates, the specific resistance is more evenly distributed along the thickness of the base. The results obtained from layer-by-layer etching also prove this (corresponding points are marked with circles) (Fig. 3).

3. As can be seen from Fig. 4, the specific resistance in the p-region on the 16.5 SEF-4 type epitaxial structure decreases significantly towards the p-n junction, and in the n-region, the specific resistance gradually increases depending on the thickness of the substrate. Note let's say that the nature of the distribution of specific resistance in epitaxial layers is very complex and may depend on many factors: for example, the level of substrate doping, the concentration in the layer, the distribution of dopants, etc. besides, the distribution profile of ρ in epitaxial layers is strongly influenced by the following reasons: 1) diffusion of additives from the substrate to the layer and vice versa; 2) self-precipitation of the layer due to the movement of additives through the gas phase. According to the works of [3,4,5,6,7,8,9], at the initial stage of the growth of epitaxial silicon plates, instead of two-dimensional sprouts in stationary growth conditions, the formation of three-dimensional ones is preferred. These results show that mechanical factors play an important role in the initial stage of epitaxial layer growth. The latter are related to elementary processes on the substrate surface and determine the formation of three-dimensional sprouts. When the system reaches equilibrium, the kinetic factors related to surface reconstruction become secondary and the growth mechanism changes, in other words, two-dimensional growth prevails. In this case, it can be expected that the concentration of charge carriers will decrease monotonically to the level determined by stationary growth conditions. According to [8], the above-mentioned factors lead to an uneven distribution of the concentration of electrons along the thickness of the plate. The nature of dependence shows the uneven distribution of additives on the thickness of the epitaxial plate.

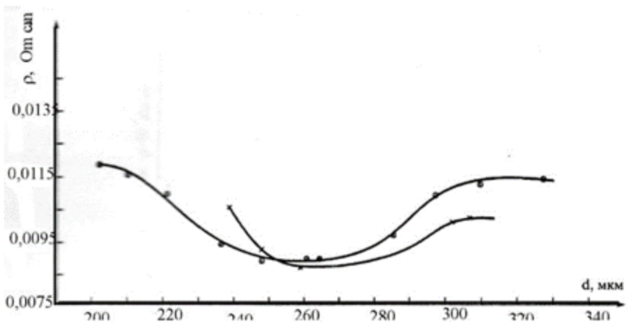

Fig. 1. Dependence of the specific resistance of the ESEC-0.01 type silicon plate on the thickness of the etched layer

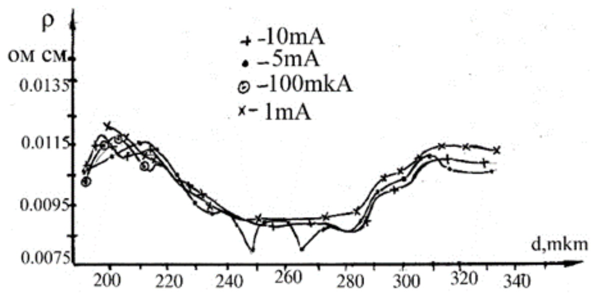

Fig. 2. Erosion of specific resistance at different values of electric current for ESEC-0.01 type silicon wafer dependence on the thickness of the applied layer

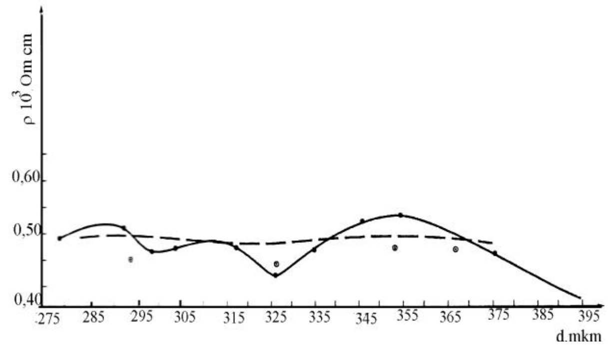

Fig. 3. Dependence of the specific resistance of the SDB-0.005 type silicon plate on the thickness of the eroded layer

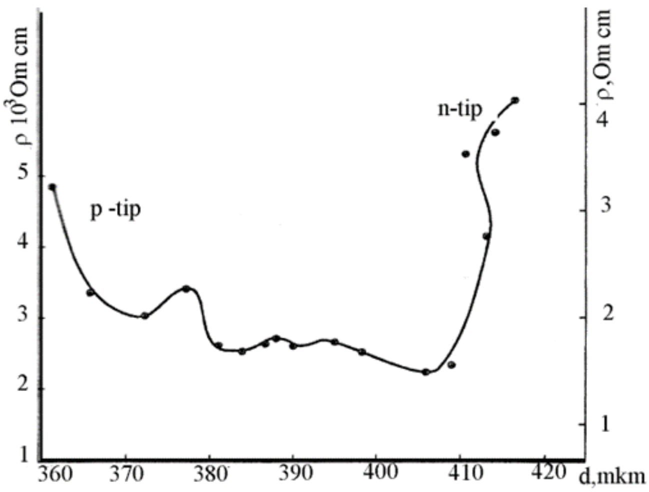

Fig. 4. Dependence of the specific resistance on the thickness of the eroded layer

In order to obtain more detailed information about the properties of semiconductor substrates, studies have been conducted that study the effect of some factors on their specific resistance. The following were studied: a) the effect of the current passing through the single crystal on the value of ρ, b) the effect of illumination on the course of the curve of dependence of the resistance on the current, c) the effect of the distance between the probes on the value of ρ . SEF and SDB type silicon plates with different specific resistances and thicknesses were studied (Fig. 5a,b). From the pictures, the following characteristics were found for the dependence of specific resistance on current: 1) regardless of the type of conductivity, at small values of current $\dot{I} < 1 \cdot 10^3 A$ $\rho = f(I)$ The dependence of f(I) is non-linear, more precisely, with increasing current, the value of ρ decreases sharply, 2) the value of the specific resistance depends on the value of the current at values of current passing through the sample $\dot{I} < 1 \cdot 10^3 A$ doesn't happen.

To clarify the reason for the non-linearity of the $\rho = f(I)$ dependence, verification experiments were carried out both in light and in the dark. The photoconductivity caused by illumination does not provide an opportunity to explain the non-linear nature of the $\rho = f(d)$ dependence. The observed feature of the $\rho = f(I)$ dependence cannot be explained by the influence of the probe-semiconductor contact. Probably, such dependence $\rho = f(I)$ is related to the uneven distribution of additional centers in the volume of the single crystal. Also, it can be monotonous and jump

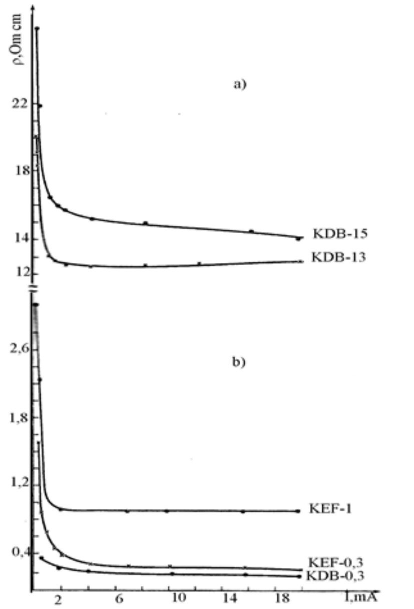

Figure 5. Dependence of specific resistance on current strength.

According to [9,10], when additives are unevenly distributed in a single crystal, an electric field whose intensity is given by the following equation is created:

$$E = \frac{kT\,(\mu_p \dfrac{dP}{dx} - \mu_n \dfrac{dn}{dx})}{e(\mu_n \cdot n + \mu_p \cdot p)} \qquad (1)$$

Here, E is the intracrystalline field intensity; k-Bolsman constant; T-absolute temperature; e-electron charge; concentration of p-holes; concentration of n-electrons; μ_n and μ_p - charge of electrons and holes; dp/dx and dn/dx are the longitudinal gradients of holes and electrons.

It can be seen that at small values of the current passing through the sample, that is, at small external fields, the internal field of the crystal due to the uneven scattering of the above-mentioned dopant centers has the same design as the external field, and as a result, the dependence of the specific resistance on the current has a unique form for different samples. Besides, the nonlinear dependence $\rho = f(I)$ observed in the experiment is most likely due to the non-additive connection of the internal and external electric fields of the crystal.

The observed current dependence $\rho = f(I)$ can be applied to estimate the dopant distribution, and in this case it is necessary to take it into account in the design of semiconductor devices. In addition, 4

In the measurement of specific resistance by the -probe method, it is necessary to get the dependency $\rho = f(I)$ experimentally, and it is necessary to determine ρ in the area of $\rho(I) = const$. This will allow to reduce the errors made during the measurement of the specific resistances of the primary substrates. This is also important because resistances and usable output are significantly reduced in both conventional and large integrated circuit designs.

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