ELECTROPHYSICAL PROPERTIES OF BINARY SILICON-GERMANIUM COMPOUNDS IN SILICON

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Abstract. *The article presents the electrophysical properties of Ge_xSi_{1-x} binary compounds in silicon, a new material widely used in the field of electronics and photovoltaics. The main parameters of semiconductor materials were calculated: resistivity, concentration and mobility of charge carriers were studied by the Van de Pauw method. In addition, the IR field of binary Ge_xSi_{1-x} compounds was studied using a spectrophotometer. We know that the mobility of electrons in germanium is μ=3000 Ohm*cm/s. Such a high mobility makes it possible to form a silicon-germanium bond on the surface and near-surface region of silicon and use it in the field of electronics and photovoltaic.*

Keywords: *germanium, binary compounds chemical cleaning, semiconductor, nanocluster, silicon*

At present, the fields of nanoelectronics, optoelectronics, and photoenergetics are rapidly developing and require the creation of semiconductor materials with new electrical, photoelectric, and optical properties [1-4]. However, the main fundamental parameters of the existing semiconductor materials silicon, germanium and composite semiconductors A^3B^5, A^2B^6 (band gap, charge carrier mobility, field structure) cannot be changed on the basis of existing technologies. At the same time, studies on the formation of heterovarigone structures in the silicon lattice with the participation of Group VI Ge atoms are of great scientific and practical interest to scientists and specialists.

Experimental and theoretical studies on the formation of nanosized structures and analysis of their properties by molecular beam epitaxy and ion implantation on the surface of semiconductor materials show the scale of this direction.

Basic Parameters

$Si_{1-x}Ge_x$ *Si. Electrical properties* and *Ge. Electrical properties*		*Remarks*
Breakdown field	$<3\cdot10^5$ V/cm	300 K
Mobility electrons μ_n	$\approx$(1396-4315x) cm^2 V^{-1} s^{-1}	$\mathbf{0 \le x \le 0.3}$, 300 K
Mobility holes μ_p	$\approx$(450-865x) cm^2 V^{-1} s^{-1}	$\mathbf{0 \le x \le 0.3}$, 300 K
Diffusion coefficient electrons	(36-112x) cm^2/s	$\mathbf{0 \le x \le 0.3}$, 300 K

Diffusion coefficient holes	(12-22x) cm^2/s	**0 ≤ x ≤0.3**, 300 K
Electron thermal velocity	≈2.4·10^5 m/s (x<0.85) ≈3.1·10^5 m/s (x>0.85)	300 K
Hole thermal velocity	(1.65+0,25x) m/s	300 K

The purpose of this work is to study the interaction of silicon-germanium atoms in the silicon lattice by the diffusion method.

Before the diffusion process, we calculated the distribution of the penetration depth (x) of germanium atoms into the silicon material using the MathCat program (Fig. 1). Theoretical calculations have shown that germanium atoms can penetrate more near the silicon surface at high temperatures and as a result of long-term diffusion.

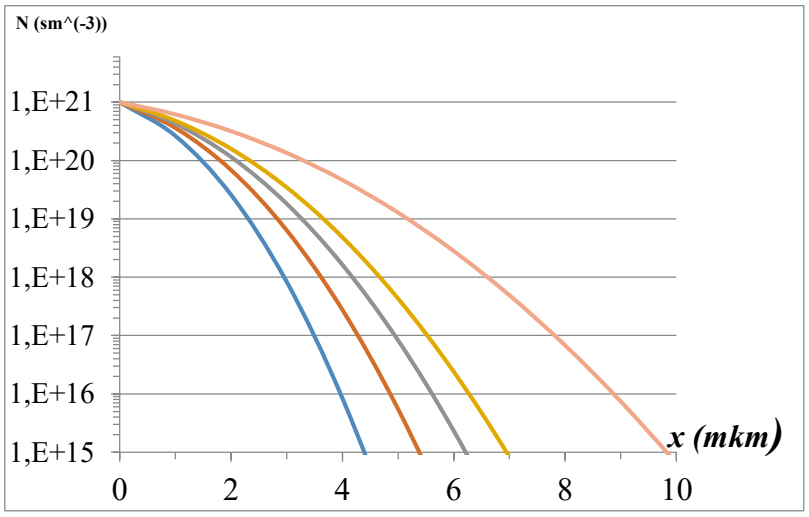

Fig.1. Distribution of the concentration of germanium alloy atoms in silicon at a temperature of T=1250°C according to the penetration depth.

To obtain the $Si_{1-x}Ge_x$ structure, we carried out studies using diffusion technology, single-crystal n-type silicon with a resistivity of 100 Ohm•cm was chosen as the starting material. The silicon samples had the same size V=8x4x1 mm^3. For diffusion, the low-temperature diffusion technology was chosen. The samples under study and a certain mass of the diffusant (determined by the volume of the ampoule) were placed in evacuated quartz ampoules (pressure in the ampoule~ 10^{-6} mm Hg). They were placed in a diffusion oven at T=300K.

On the basis of the above technology was carried out diffusion of germanium in silicon from the gas phase at a temperature of T=1250 ˚C for 10 hours. On fig. 1 shows a photograph of the end face of the sample obtained with a digital optical microscope (Digital Microscope-1600x). The thickness of the silicon layer enriched with germanium was determined, which is 5÷6 μm.

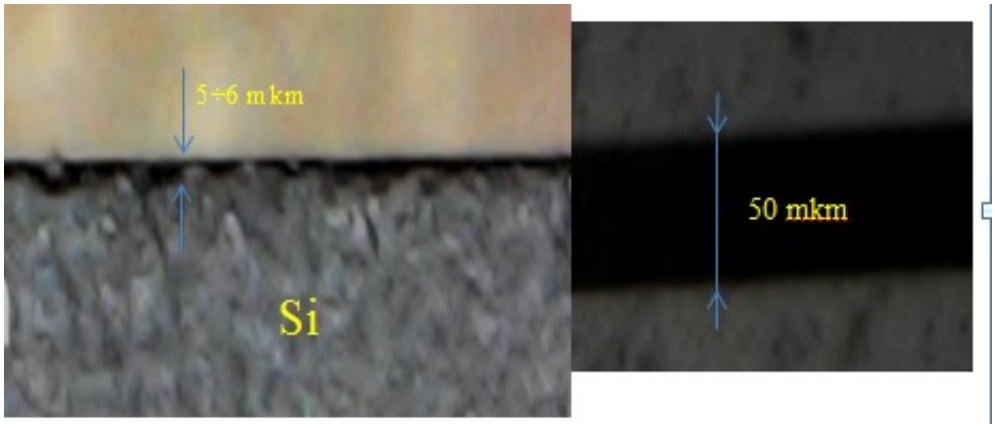

Fig.2. Photo of the end side of the sample

The results of measuring the absorption spectra on the Shimadzu 1900i setup confirm that the absorption spectrum of silicon with Ge_xSi_{1-x} binary compounds really differs from the original silicon (Fig. 2). From the absorption spectrum, the Tauc method can be used to estimate the band gap of the initial silicon doped with germanium atoms. The band gap values obtained were: initial silicon - 1.126 eV;

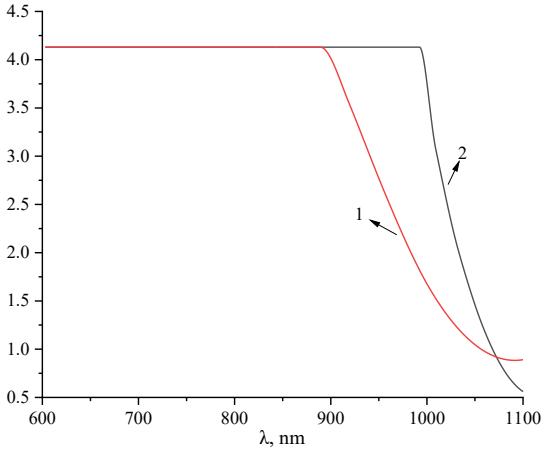

Fig.3. Absorption spectrum of original silicon (curve 1) and silicon doped with impurity atoms (curve 2) obtained on a Shimadzu 1900 i spectrometer.

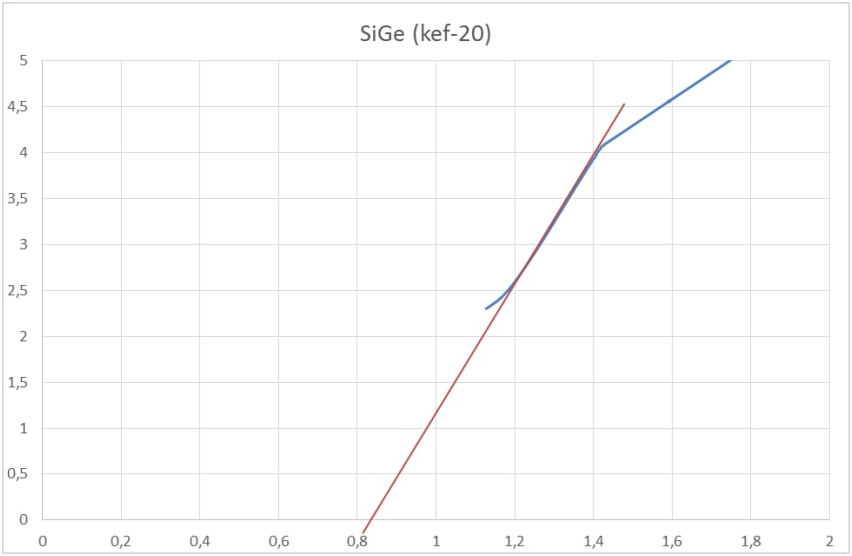

Fig.4. Absorption spectrum of silicon doped with impurity germanium atoms obtained on a Shimadzu 1900 i spectrometer.

Resistivity, mobility and charge carrier concentration of Ge_xSi_{1-x} samples in silicon were measured several times using a modern van der Pauw instrument (Hemis-300) [5]. In this case, a thickness of 1 μm was removed from the surface of the sample by grinding using diamond powder. The sample thickness was measured using a high precision digital micrometer. On fig. 2 shows the concentration distribution of germanium atoms in silicon after the diffusion process at T=1250°C, t=10 hours. As can be seen from the experimental results, when the concentration of germanium on the surface is $N_{Ge}=9•10^{19}$ cm^{-3}, its concentration decreases to ~10^{14} cm^{-3} at a depth of x=6-8 μm. This is fully consistent with the literature data. Figure 5b shows the dependence of charge carrier mobility on penetration depth, which is another key parameter of semiconductor materials. We know that the mobility of electrons in germanium is μ=3000 Ohm*cm/s. Such a high mobility makes it possible to form a silicon-germanium bond on the surface and near-surface region of silicon and use it in the field of electronics and photovoltaic.

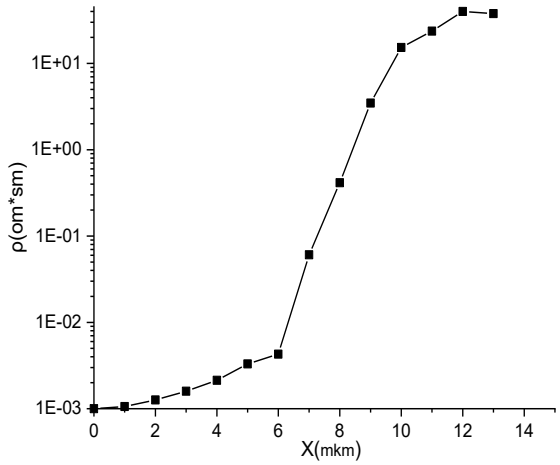

Fig. 5. Distribution of resistivity $Si_{1-x}Ge_x$ (KEF-100)

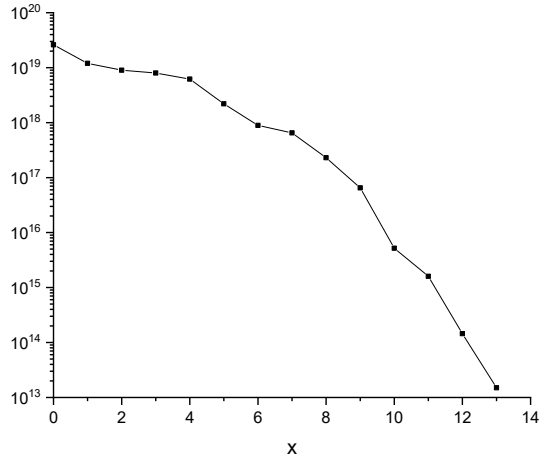

Fig. 6a Concentration depth distribution T=1250° C t=20 h ρ=100 ohm*cm

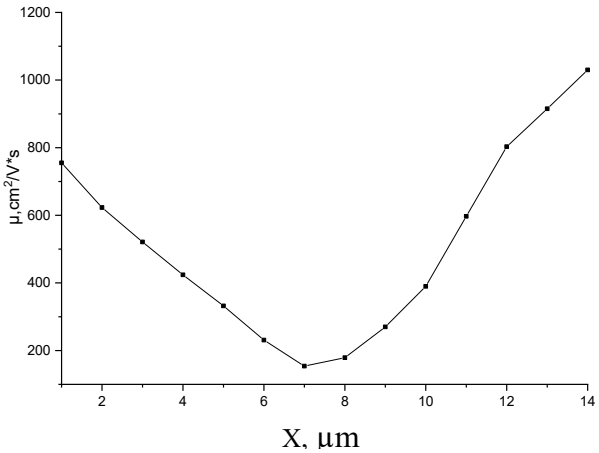

Fig. 6b Mobility of charge carriers in depth after diffusion T=1250° C t= 20 h ρ=100 ohm*cm

Analysis of the results of the experiments showed the combination of atomic silicon and germanium and lattice silicon [6-8]. Changing the fundamental parameters of the original silicon allows you to control the electrical, photoelectric and optical parameters of silicon, which gives you the opportunity to get a new material with unique photoelectric and optical properties.

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