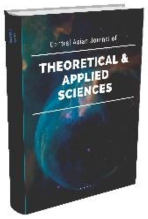

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Obtaining Sensitive Materials that Sense Light and Temperature

Mamarasulov Qudratbek Shuxratbek o'g'li
Andijan Institute of Mechanical Engineering, Uzbekistan, 170119, Andijan city. 56 Baburshokh Street,
mamarasulovqudratillo7@gmail.com

Nasriddinov Mashxurbek Baxtiyorjon o'g'li
Andijan Institute of Mechanical Engineering, Uzbekistan, 170119, Andijan city. 56 Baburshokh Street,
Grewhuk010197@gmail.com

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Abstract: *Mechanical treatment (cutting, physical and chemical cleaning, polishing) of semiconductor Si<B>-based material, introduction of Mn(Manganese) atoms through diffusion, formation of nanoclusters of various sizes and thus light and obtaining a sensitive material that senses temperature. Nanoclusters are materials in the transition from atomic properties to bulk material properties. Since it is possible to create new properties by obtaining nanoclusters of different sizes, by alloying Mn(Manganese) atoms to the Si<B>-based material at different temperatures, forming nanoclusters of different sizes, and studying their electrophysical parameters, light and temperature sensors is created. This work aims to calculate the infrared sensitivity of compensated silicon on IKS-21 and Hall effect measurement devices, generate graphic images and analyze them. The Mn atom was exposed to the KDB-3 element by diffusion, and a graph was created to determine its IR sensitivity at the nitrogen temperature of the IKS-21 device [1-7]. To calculate the electrical and physical parameters of the compensated silicon, the results were obtained in Hall effect measurement devices. The results of the experiments show that the number of manganese atoms is influenced by the specific resistance and conductivity of the sample, and that the properties of the infrared ray sensed alloy sample are p-type, ranging from 1.5–102 u.s.m. to 4–104 u.s.m. The sensitivity of the n-type sample was not observed regardless of any value of. The observation of such phenomena in obtained samples depends on the selection of the first samples used for the formation of the nano cluster [8].*

Keywords: *Light sensors, temperature sensors, nanoclusters, compensated silicon, ICS-21, Hall effect.*

INTRODUCTION: Today, light and temperature sensors are widely used in the field of electronics. The areas of their application are constantly expanding. There are problems such as increasing the sensitivity of sensitive materials, increasing the efficiency of the extraction technology, and reducing the cost [9]. Due to their sensitivity to infrared rays, these materials are used in making various electronic devices. Infrared photoreceptors can be effectively used in remote control devices, in medical temperature measurement and disease detection tomographs, in night vision devices, in the study and control of the content of solar energy, in the protection of various objects, and in the control of fire safety [10].

In modern electronics and optoelectronics, solving the problem of creating photoreceptors that sense and record low-power infrared rays is one of the urgent issues. Such photoreceptors are widely used in various fields of technology. Infrared photoreceptors can be effectively used in remote control devices, in medical temperature measurement and disease detection tomographs, in night vision devices, in the study and control of the content of solar energy, in the protection of various objects, and in the control of fire safety [11-14]. Infrared photoreceptors based on many semi-conducting materials, which work due to the change of photoresistance, cannot be widely used in various fields due to the limitations of their ability to detect low-power infrared rays. Especially in the presence of integral light, there are few photoreceptors that can detect infrared rays and their sensitivity is not good. In the presence of integrated daytime light, photoreceptors capable of sensing additional low-power infrared light can be used to exploit the photoconductivity effect observed in compensated silicon under the influence of infrared light.

The silicon material determined as a result of the experiment and compensated on the basis of scientific conclusions is illuminated with an integrated light at a relatively low temperature (T=77÷200 K), bringing it to a certain stable value of photoconductivity, and then additional infrared light if it is done, photoconductivity quenching is observed in the range of hν=0,4÷0,6 eV of incident photon energy. The extinction of photoconductivity under the influence of photon energy was If/(Ir+hn)=104÷106. Such sensitivity has not been observed in any photoreceptors based on currently available semiconductor materials. The extinction of photoconductivity under the influence of photon energy was $\frac{\mathcal{I}f}{\mathcal{I}r+h\nu}=10^4\div10^6$. Such sensitivity has not been observed in any photoreceptors based on currently available semiconductor materials [15-18].

The proposed infrared photoreceptor can work with an external electric field strength of E=10÷50 V/cm in the range T=77÷200 K. Sensing the energy of photons in photoreceptors is in the range of hν=0,4÷0,8 eV, and in the presence of an integrated background from a relatively large value, the power of photon energy is in the range of small values of $I=10^{-9}\div10^{-5}$ $Vt/sm^2\cdot s$ can sense infrared light. There are currently no ultra-sensitive photoreceptors capable of detecting such small amounts of infrared light energy [19-21].

Due to the simplicity of the technology of creation of the proposed infrared photoconductors based on the compensated silicon material, low energy requirements, the wide range of spectral sensitivity and the ability to operate in a wide range of temperature values, modern electronics can be widely produced.

MATERIALS AND METHODS: Obtaining light- and temperature-sensitive materials based on compensated silicon by the diffusion method and studying their sensitivity to infrared rays.

1. Mechanical processing of semiconductor Si<B> based material (cutting, physical and chemical cleaning, polishing);
2. Diffusion of Mn atoms into the KDB-3 element;
3. Calculation of electrophysical parameters of samples sensitive to light and temperature as a result of diffusion;
4. To study the sensitivity of materials to infrared rays

The main issue in obtaining light and temperature sensitive materials is to increase their sensitivity to infrared rays. The ability to perceive low-power infrared rays depends on the diffusion process. It depends on the temperature range of 1030÷1050 ºC, the cooling rate of the capsule and the concentration of Mn atoms. That is, it is important to keep the same temperature, the degree to which the air is absorbed by the capsule, and the cooling rate of the capsule in exact values.

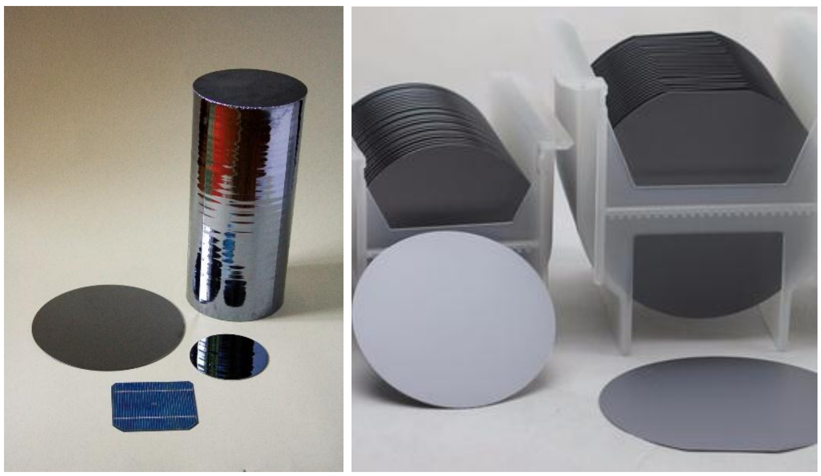
Methods of introducing dopant atoms into semiconductor materials:

The main way to control the physical properties of semiconductors, i.e., their conductivity, photosensitivity and magnetic properties on a very large scale, is to introduce dopant atoms into such materials in the required and precise concentration.

According to the current technology, the input atoms are introduced in 3 different ways. In the process of crystal growth, by diffusion and ion implantation method.

One of the most basic methods of growing single crystals in a given direction is the Chochral method.

A silicon monocrystal grown by this method is shown in Figure 1 below. In this case, polycrystalline silicon is a liquid semiconductor material in special quartz grains (T>1415 ºC), a thin single crystal (zatravka) is dropped. After it (Zatravka) touches the liquid semiconductor, it starts to move up slowly (1÷3) mm/min while rotating on its axis. As a result, the liquid body turns into a crystal in accordance with the direction of the growth.



1 - picture. Si single crystal obtained by Chochral method

In this case, the required amount of boron, phosphorus, arsenic or other input atoms is added to the liquid solution, which ensures the physical parameters of the future single crystal, and their even distribution throughout the liquid is ensured. This method of introduction of impurity atoms is used to obtain single crystals of different sizes, but with the same physical parameters.

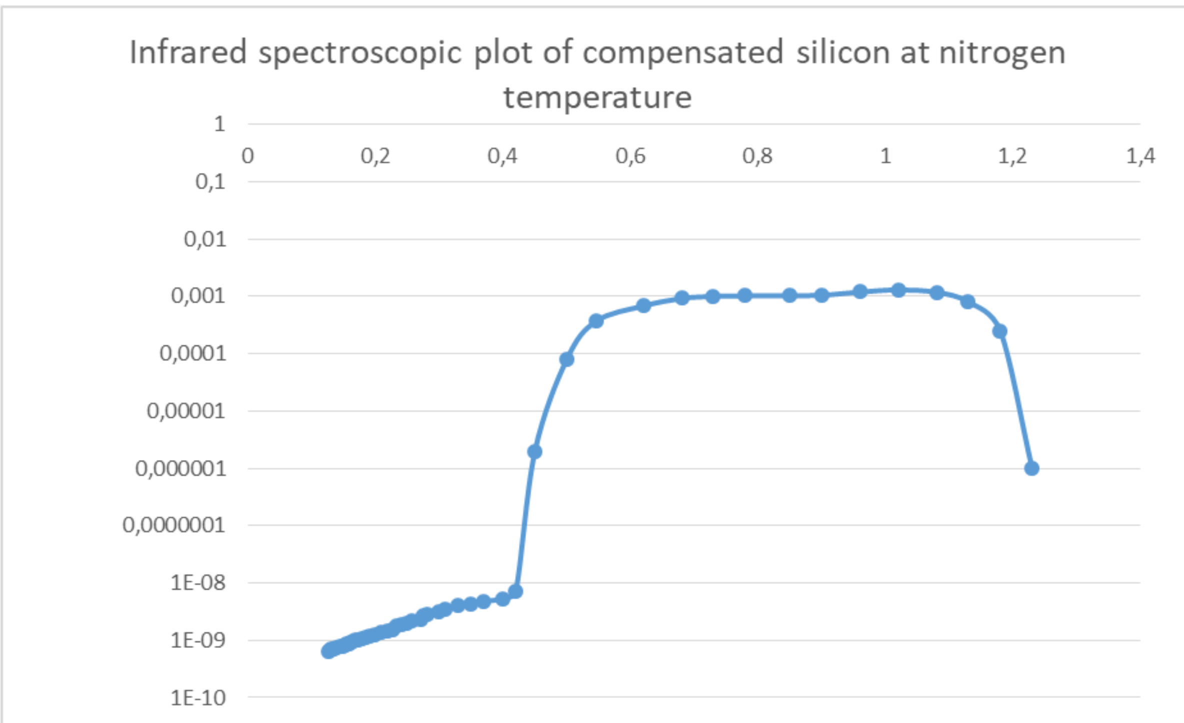
The second method of introducing dopant atoms into semiconductor crystals is done using the diffusion method [22].

In this method, it is mainly used to form the input atoms in certain thin layers. The concentration of input atoms introduced by the diffusion method depends on their solubility at the temperature of diffusion. How much thickness it penetrates is limited by the diffusion coefficient. The diffusion method is the main technological process in the creation of modern microcircuits and discrete semiconductor devices [23].

The third method of introducing dopant atoms is to bombard the crystal surface with ions of dopant atoms, increasing their energy in a vacuum in special ways.

As a result, in accordance with the energy of the ions, the entrance atoms penetrate from the surface to a depth of several 10 Å to several 100 Å, that is, a very thin layer on the surface of the semiconductor material is enriched with entrance atoms. In order to make the introduced atoms electrically active in this way, the crystal is heated to a certain temperature, in addition, when bombarded with the ions of the incoming atoms, radiation defects are formed until the incoming atoms reach, if the energy and dose of the ions is high, then the surface of the crystal becomes amorphous. can come Using this method, it is possible to create the desired concentration of dopant atoms on the surface of the crystal [24].

RESULTS AND DISCUSSION: A material based on the semiconductor Si<B> is selected and after mechanical processing, pure metal manganese, whose mass is determined in relation to the volume of the quartz ampoule, and the studied samples are placed in a quartz ampoule with air sucked inside it (the pressure in the ampoule is 10-6 mm .wire above) is placed, the ampoule is placed in the SOUL-4 diffusion furnace at room temperature (T=300 K). The temperature of the previously studied diffusion furnace, along with the temperature of the quartz ampoule placed inside it, is increased step by step at a rate of 5 degrees/minute. After the samples reach the temperature T=550÷700 ºC, the samples are kept at the same temperature for t=10÷20 minutes. The temperature of the diffusion furnace rises to the temperature T=1030÷1050 ºC at a speed of 150÷200 ºC/min. At the same temperature, the samples are kept for t=5÷10 minutes, then the quartz ampoule containing the samples is cooled by throwing them into special oil at a speed of 200 ºC/second from the diffusion furnace (the safety oil used for rapid cooling of heated objects is a high-quality raw material). Then the obtained new material was ground (polished) and the oxide layer (SiO2) was removed. The sensitivity of the new material to light and temperature was studied. After diffusing Mn atoms into the KDB-3 semiconductor material, the obtained sample was found to be p-type. We examined the ability of the sample taken with the help of the IKS-21 device to detect low-power infrared rays at nitrogen temperature, i.e. 90÷100 K.



From the graph above, we can conclude that at a temperature of 90 K, the "beginning of light absorption" began to appear in the region of *h*ν≥0,4 eV (λ≤ 3 μm) in such samples. As the photon energy increases, the photocurrent changes continuously and jumps and reaches its maximum value at *h*ν=0,73÷1,02 eV (λ≈1,25 μm). At this time, the ratio of the light current to the dark current reaches 7-8 degrees, that is, anomalous photosensitivity is observed in the λ=1,25 μm region of the spectrum.

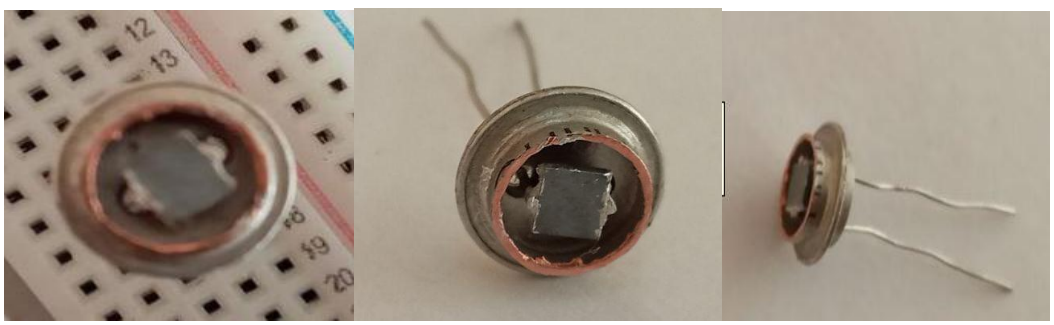
connection	U_{NS}, mv	U_{SN}, mv	U_0, mv	U_σ, mv	I, µA	d, mm	l, mm	b, mm
+	447	445	472	367	119	0,85	2,1	3,9
-	674	656	685	237	94			

Table 1 Hall Effect Compensated Silicon Material Measurement Results.

- Hall's constant Rx= 131121 sm^3/ c
- Concentration of charge carriers n= $4{,}7 \cdot 10^{14}$
- Relative resistance ρ = 349 (ohm*sm)
- Mobility μ= 376 $sm^2/(V \cdot s)$

We calculated the electro-physical parameters of the sample taken in the Hall effect device. Based on the results, we can conclude that in order for the infrared sensitivity of our compensated silicon element to detect especially low-power infrared rays, their electro-physical parameters, specific resistance, conductivity, mobility should be proportionate and their currents should be 50÷500 μA when a voltage of 5V is applied. Range, must be p-type.

IR sensors were made on the basis of samples of nanocluster silicon with a surface of S=0.5 sm^2, a thickness of 0.15 sm, and they were installed in a hermetic case with a glass hole.



IR sensors mounted in a silicon-based hermetic housing with multi-charged nanoclusters of manganese atoms

CONCLUSION: The results of this study show that, from all calculations, the laws established for the diffusion coefficient and solubility of manganese in silicon do not work under low temperature diffusion conditions. The solubility of manganese in silicon at the given temperature T=550÷700 ºC is $N_{Mn} \sim 10^{10}$ cm^{-3}, the diffusion coefficient is $D=2 \cdot 10^{-8} \div 5 \cdot 10^{-8}$ cm^2/s, in which samples with a thickness of 1 mm for the same alloying, $t = \frac{l^2}{4 \cdot D} = \frac{0{,}1^2}{4 \cdot 2 \cdot 10^{-8}} = 10^5$ it takes about a second, i.e. t=3 hours.

Our new technology requires a total of 3 hours for the diffusion process. The concentration of manganese atoms in the volume is $N_{Mn} \sim 10^{10}$ cm^{-3}, which is 5 orders of magnitude higher than expected. Based on the obtained results, it can be confirmed that in the low-temperature region, diffusion occurs between the nodes, and the entry atoms are located between the nodes. Additional evidence is that the concentration of vacancies $N = N_S \exp\left(-\frac{3}{kT}\right)$ in low-temperature diffusion is $N_V \sim 10^7$ cm^{-3}, that is, it is $10^7 \div 10^8$ degrees smaller than the concentration of manganese between the nodes.

The developed IR sensor was shown to be more sensitive than currently available and able to accurately measure photon flux over a wide temperature range. Such IR sensors allow for long-term practical use, as well as the simplicity of the technology of creation, low energy consumption. The concentration of such clusters of manganese atoms in silicon is N~10^{15} sm^{-3}. To study the photoconductivity of the samples, they were placed in a cryostat installed on the IKS-21 device, the cryostat has two polished silicon filters, which serve as protection against background and private light. The power of the IR beam was changed using a special filter device, these filters were calibrated using an IMO-2N type "Laser Beam Average Power Meter". This picture shows its spectral sensitivity at different temperatures through IR rays with light power P=10-6 W.

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