European Journal of Molecular & Clinical Medicine
ISSN 2515-8260 Volume 08, Issue 01, 2021

Features Of Self-Oscillatory Processes In A Strongly Compensated Silicon With Nanoclusters Of Impurity Atoms

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ABSTRACT:

Investigation of the features of the transition of self-oscillations of current from one type to another in highly compensated silicon doped with impurity atoms of manganese, zinc and sulfur is of great interest from the point of view of studying both the mechanisms of self-sustained oscillations of the current and the physics of nonequilibrium processes. Based on the results obtained and the analysis performed, it has been established that the observed self-oscillations of the current in strongly compensated silicon are associated with nanoclusters of primus atoms. A model of a strongly compensated semiconductor is proposed to explain the mechanism of self-oscillations of the current in strongly compensated silicon, taking into account the multi-charge character of nano-clusters of atoms.
It was found that the proposed model is in satisfactory agreement with the experimental results.

Key words: silicon, self-oscillation, manganese, zinc and sulfur, diffusion, electrical parameters, amplitude, frequency, nature of excitation

1. INTRODUCTION

A large number of studies have been devoted to the study of self-oscillations of current in semiconductor materials and structures. We, along with fundamental research of the electrical and photoelectric properties of silicon with nanoclusters of impurity atoms of manganese, zinc and sulfur, also comprehensively and comprehensively investigated self-oscillatory processes in strongly compensated silicon. The results of these studies showed that by controlling the concentration of boron and phosphorus in the initial silicon (KDB or EFC), it is possible to obtain nano clusters of pretext atoms of manganese, zinc, and sulfur with different charge states. The study of the influence of external influences (electric field strength, lighting, temperature, etc.), showed that it is possible to obtain several types of self-oscillations of the current in the same strongly compensated silicon, the nature of excitation and the mechanisms of which differ from each other.
Literary analysis has shown that up to now no current self-oscillations have been obtained by excitations of different natures in the same semiconductor material [1-2]. Therefore, the study of the features of the transition of current self-oscillations from one type to another is of great

interest from the point of view of studying both the mechanisms of current self-oscillations themselves and the physics of nonequilibrium processes [3-5].

2. EXPERIMENTAL TECHNIQUE

Investigations of self-oscillations of the current were carried out in samples of highly compensated silicon with nanoclusters of impurity atoms of manganese, zinc, and sulfur. The technology for producing highly compensated silicon is described in detail in previous works [6-10]. For the study, we obtained samples of strongly compensated silicon of both p-type and n-type conductivity with different resistivity in the range ρ = 102-2 * 105 Ohm * cm (at T = 300 K).

3. EXPERIMENTAL RESULTS

The results of the study showed that self-oscillations of current in strongly compensated silicon are observed in a fairly wide temperature range, and with a change in external conditions (lighting, temperature, electric field strength), self-oscillations of the current pass from one type to another [11-12].
The temperature regions of the existence of all three types of current instabilities in highly compensated silicon doped with impurity atoms of manganese, zinc, or sulfur can provide valuable information when refining the mechanisms of current self-oscillations.

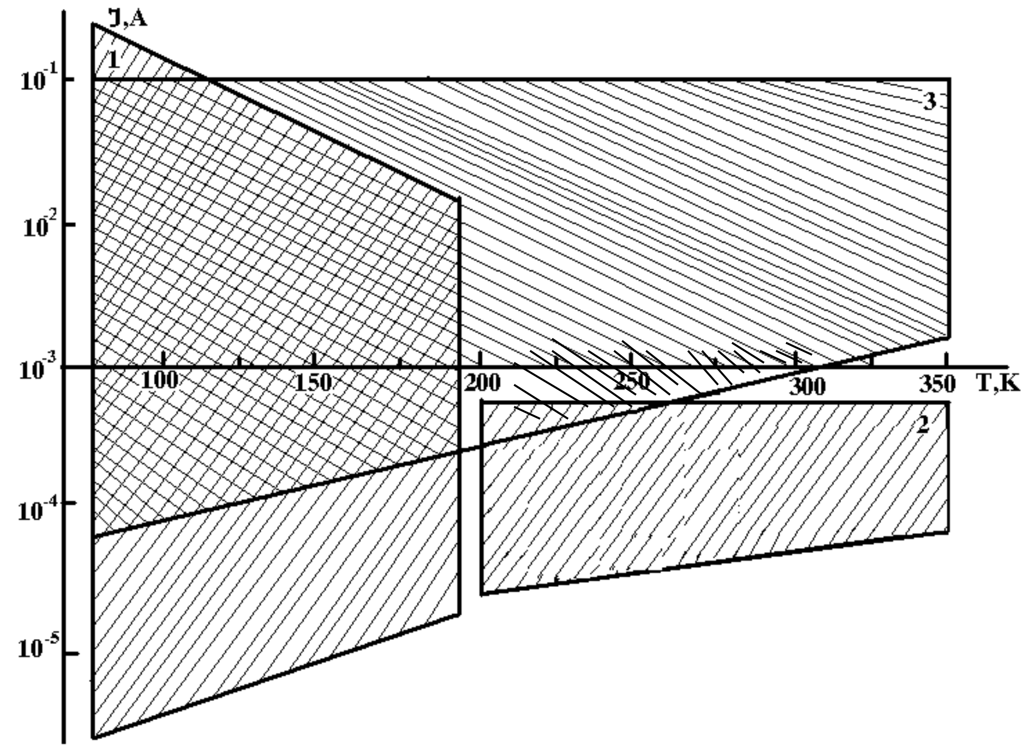

Fig. 1. Graph of the dependence of the maximum and minimum values of the amplitude of self-oscillations of the current on temperature, ρ = 5·104 Ohm * cm. 1-heating element (temperature-electrical instability); 2-PB (recombination waves); 3-IN (injection instabilities).

Of the three types of investigated auto-oscillations of the current, recombination waves are of particular interest [13-16]. Therefore, we determined the temperature regions of the existence of recombination waves depending on the resistivity and the type of conductivity of the sample of strongly compensated silicon (Fig. 1).
Then this leads to the appearance of regular current fluctuations of a certain nature. In most such cases, quasi-harmonic self-oscillations of the current are excited in the circuit, which, with further changes in the parameter, pass into other forms characteristic of oscillations of this type.

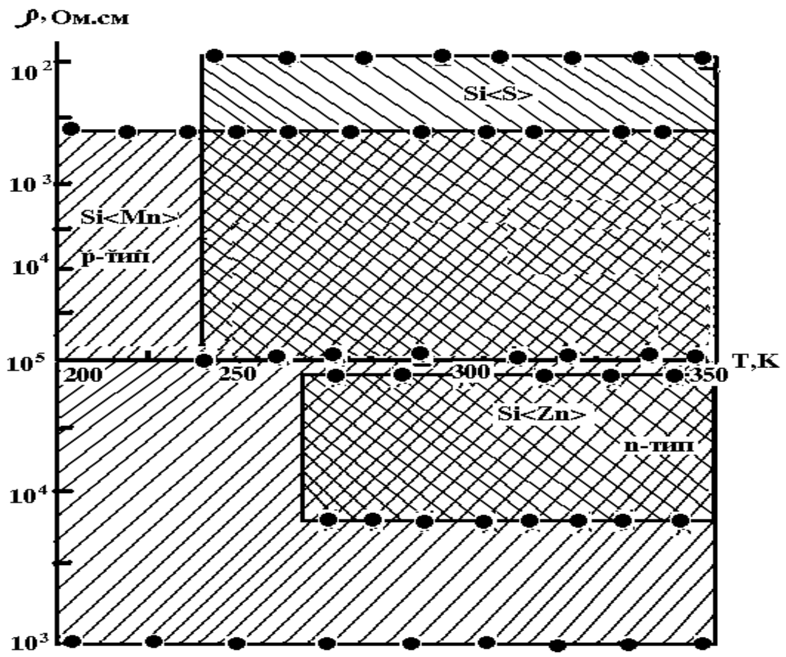

Fig. 2. Plot of temperature regions of existence of recombination waves depending on the resistivity and the type of conductivity of highly compensated silicon with nanoclusters of impurity atoms of manganese, zinc or sulfur.

4. DISCUSSION

Based on the results obtained and the analysis performed, it can be said that the self-oscillations of the current detected in strongly compensated silicon are associated with the formation of nano-clusters of impurity atoms of manganese, zinc, or sulfur. A change in the spatial distribution or a change in the charge of these nano clusters leads to the appearance of inhomogeneities in the bulk of strongly compensated silicon. To explain the mechanism of self-oscillations of the current in strongly compensated silicon, taking into account the inhomogeneous distribution of nano-clusters of impurity atoms, we proposed a model of strong Coulomb inhomogeneity of a strongly compensated semiconductor [17-22]. It was found that the proposed model is in satisfactory agreement with the experimental results. This gives grounds to believe that the results obtained can be used to create a unified physical model of self-oscillatory processes observed in semiconductor materials with nanoclusters of impurity atoms, and also shows the possibility of using these phenomena to create sensors and functional electronic devices.
We are grateful to Academician M.K. Bakhadyrkhanov. for participation in, discussion of the results obtained and valuable advice.

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