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MAIN TECHNOLOGICAL FACTORS AFFECTING THE PROPERTIES OF LOW-DOPED LAYERS AND TRANSISTOR n+-p0 – n0 STRUCTURES

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Abstract
In this work, a study was made of the features of obtaining high-voltage gallium arsenide p0–n0 - junctions by liquid epitaxy
The regimes of epitaxial growth are determined, which ensure the production of high-voltage p-n junctions based on lightly doped GaAs for the creation of submenu and picosecond semiconductor switches.
The influence of technological factors on the electro physical properties of epitaxial layers has been studied. It has been established that with an increase in the temperature of the onset of crystallization and the size of the growth gap, the thicknesses of the low-resistance part of the p0-region and the breakdown voltages n+-p0–n0 of the structures increase, while the values of the transmission coefficient decrease.
The influence of the main technological factors on the static and dynamic characteristics of the created devices has been studied. It has been established that a change in the thickness of the solution-melt from 1 mm to 3 mm, or the temperature of the onset of crystallization from 850 ⁰C to 950 ⁰C, leads to a decrease in the value of the transmission coefficient n+-p0–n0 of structures, an increase in the turn-on voltage, control current, and an increase in the voltage value the beginning of an abnormally rapid increase from 50 V to 400 V. There is a simultaneous increase in the duration of the current rise, a decrease in the stability of the switching moment, and an increase in the values of the residual voltage.

Introduction

At present, epitaxial methods for obtaining monocrystalline layers based on GaAs-AlGaAs are widely used for the manufacture of various high-voltage semiconductor devices. At the same time, the concentration of the main charge carriers lies within the range of ~1015 $^{cm-3}$ and less. A fairly common technology for obtaining such a material is liquid-phase epitaxy (LPE), which is carried out in a quartz container with forced cooling of a GaAs melt solution in Ga [1.2]. The physicochemical bases of LFE are well described in a number of monographs [3,4.5] [6,7,8].

The main problem in the creation of high-voltage assembled and pico-second GaAs-based switches is the production of layers with a given thickness of the base regions and a low concentration of dopant impurity. For this purpose, a study of the influence of technological factors on the basic properties of epitaxial layers and p-n junctions was carried out. In addition, when creating high-speed devices that switch high power, the factor of planarity of layer parameters over the entire area of the epitaxial structure is extremely important. The results of

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the study of technological factors ultimately lead to the choice of optimal technology and operational control of structures.

An optimal solution to the problem of obtaining p0-n0 transitions based on weakly alloyed **GaAs layers** with high values of electrophysical parameters and specified thicknesses of base layers for the creation of ultra-high-speed high-voltage pulse three electrode commutators with a photonic-injection mechanism for the transfer of non-basic charge carriers (NNP) has been found. At the same time, the limit value of the pulse power switched by three electrode semiconductor devices is The second range of durations is increased by two orders of magnitude, the operating frequency is extended to **300 kHz**, and the switching stability reaches **5÷10 ps.**

Method: LFE is an oriented crystallization of single-crystalline layers of semiconductor materials from solutions of these materials.

There are several ways of epitaxial cultivation from

Melt solution: growth from a limited volume and growth from a semi-limited volume of melt solution. The most common method is the method of growing epitaxial layers from a limited volume of melt solution. Under the conditions of crystallization from limited volumes of melt solutions, both a significantly higher yield of obtaining layers with a given thickness compared to crystallization from semi-limited volumes, and a higher degree of their planarity are achieved. In addition, the growth of layers from a limited volume of melt solution makes it possible to control crystallization rates and conduct the process under conditions closer to quasi-equilibrium. Fig. 1. The calculated dependence of the thickness of the epitaxial layer H, grown from the liquid phase with a thickness of H=1 mm, on the temperature of the beginning of crystallization Tn.cr., is given, and in Fig. As shown in Fig. 2, the calculated dependence of the layer thickness on the value of H, at different Tn.cr., is presented.

The resulting epitaxial layers had a characteristic concentration profile with a change in carrier concentrations along the epitaxial layer within 1016÷1013 cm^{-3} [9,10]. The peculiarities of such a concentration profile are:

1. the presence of a region of p0 conductivity type is always present at the substrate;
2. complex nature of the distribution of carriers in this region, consisting of two parts: a low-resistance p-u of the substrate and a high-resistance i- with a resistivity ρ~106 Ohm·cm at the boundary with the n0 region;
3. placement of the OPP on the border of the i- and n0- areas of the structures.

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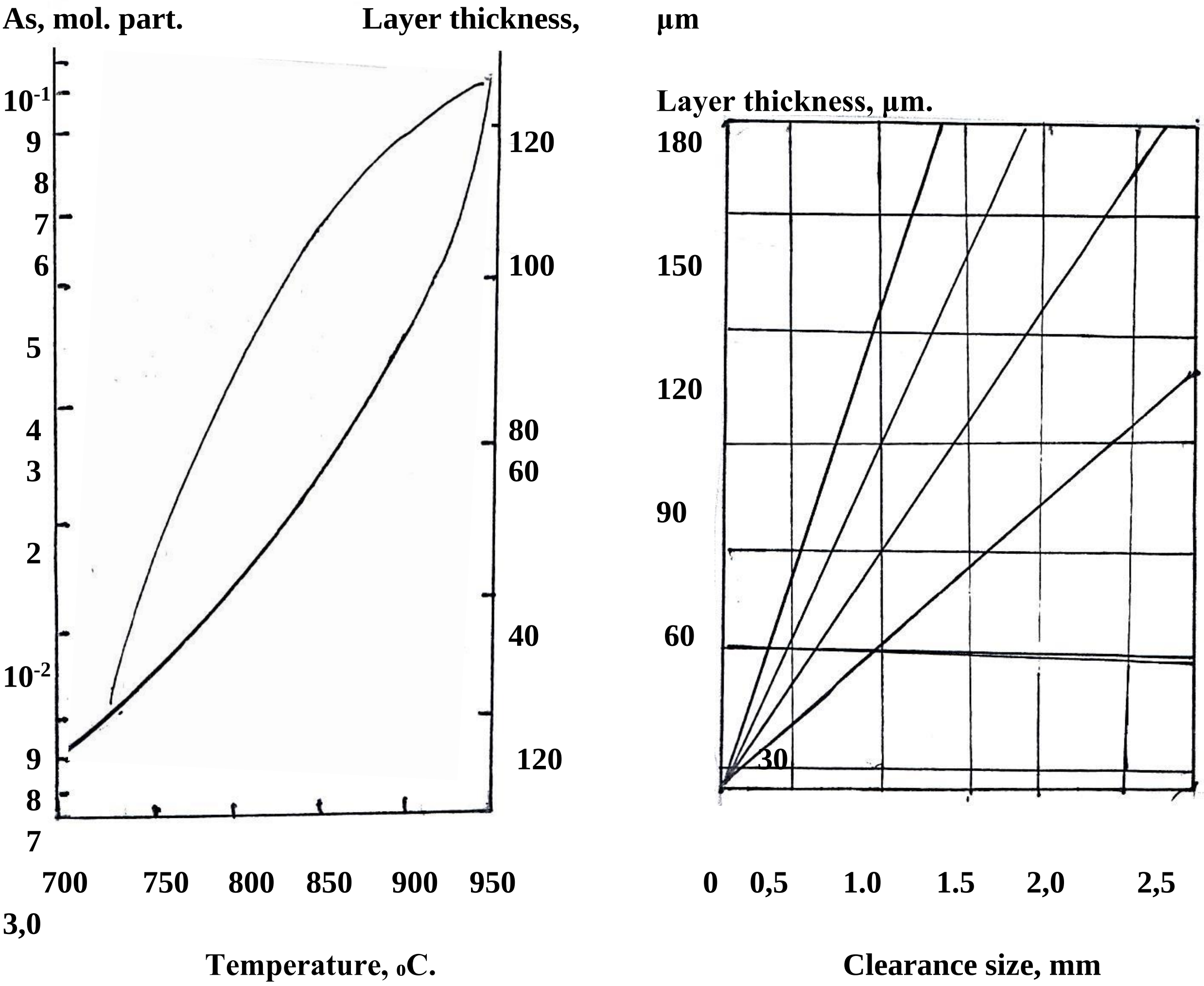


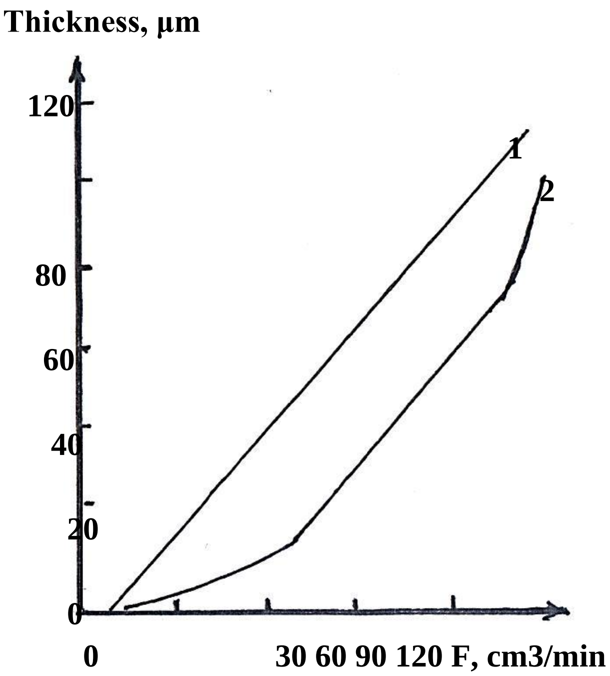
Rice. 1. Calculated thickness dependence Fig. 2. Design Thickness Dependence epitaxial layer grown layer of the value of H, at different from a liquid phase with a thickness of 1 mm from Tn.cr. values of Tn.cr. the temperature of the beginning of crystallization.

The main technological factors that determine the properties of the layers are the Tn.cr. Crystallization Onset Temperature, Duration and Duration annealing temperature of the molten solution, F is the hydrogen flow rate, H is the thickness of the growth gap. From the physicochemical bases of LFE, it follows that the total thickness of the layer is determined by the temperature of the beginning of crystallization and the thickness of the liquid phase (see Fig. 1). 2.) Consequently, these values will determine the gradients of the impurity concentration in different regions of the layers, and hence the reverse stresses of the p0-n0 junctions.

Methodology:

Therefore, in the course of the work, the influence of the temperature of the beginning of crystallization, the duration of annealing, the value of hydrogen consumption and the value of the growth gap on the properties of epitaxial structures was studied. In the course of the work, a sufficiently long low-temperature annealing at 750 ⁰C was chosen in order to obtain the smallest total concentration of residual impurities, as well as the time and velocity of the hydrogen flow did not affect it.

Fig. 3. The dependencies of hp and h_{p0} on the hydrogen flow rate are presented, which were obtained at two temperatures Tn.cr = 950 ⁰C and 900 ⁰C. In these experiments, the thickness of the melt solution was H=2 mm, and the annealing duration was 3 hours.



Rice. 3. Dependencies of h0-part 100
HP0 - Hydrogen consumption.
H=2 mm, Same = 900 ⁰C, .
1- 950 ⁰C, 2 = 900 ⁰C

As a result of annealing of the melt solution, it is purified from volatile impurities and oxides of the initial materials, which reduces the concentration of active impurities in the epitaxial layers by several orders of magnitude. Changes in the distribution of carrier concentration along the layer thickness depending on the duration of annealing of the liquid phase at hydrogen flow rate F = 70 cm3/min, H = 2 mm, Tn.cr = 900 ⁰C are shown in Fig. 4.

An increase in the temperature of the beginning of crystallization, other things being equal, leads to an increase in the thickness of only the low-impedance hp part of the p0 layer by the value Δh = f(ΔT), see Fig. 3., and the thickness of the high-impedance part of the hi- should not change.

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Fig.4. Change in concentration Nd–Na impurities depending on On the duration of heat treatment: 1 – 1 час, 2- 2 часа, 3 – 3часа

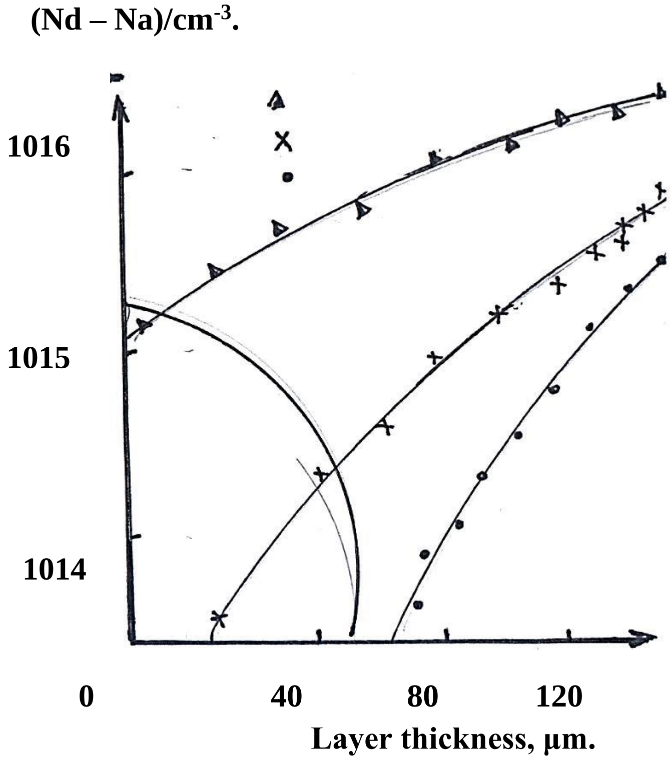

Fig. 5. The dependencies of hp and h are presented$_{p0}$ from Tn.kr..

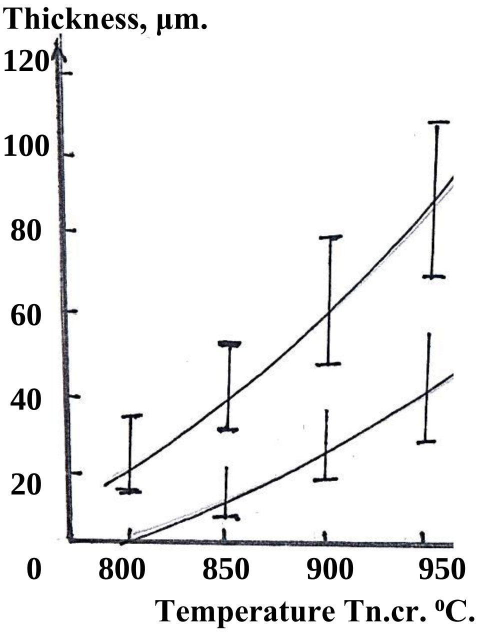

Fig.5. Dependencies of hp and hp0 on dependencies Tn.cr.. H = 2 mm, Totj. =3 hours, Thickness F = 70 cm3/min

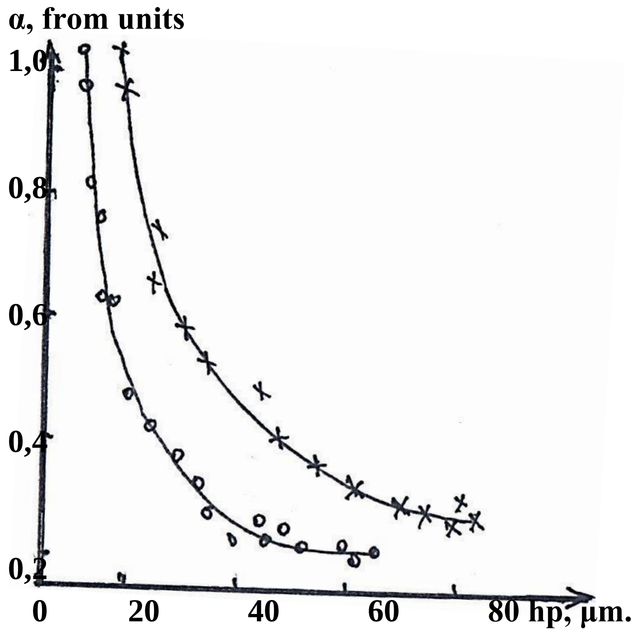

Fig.6. Transmission coefficient N+-P0-N0 Structures from Low Resistance Parts of HP0 are areas.

For transistors to work efficiently, the thickness of the hp part must beat as small as possible, a special role in the technology of obtaining N+-P0-N0 is played by

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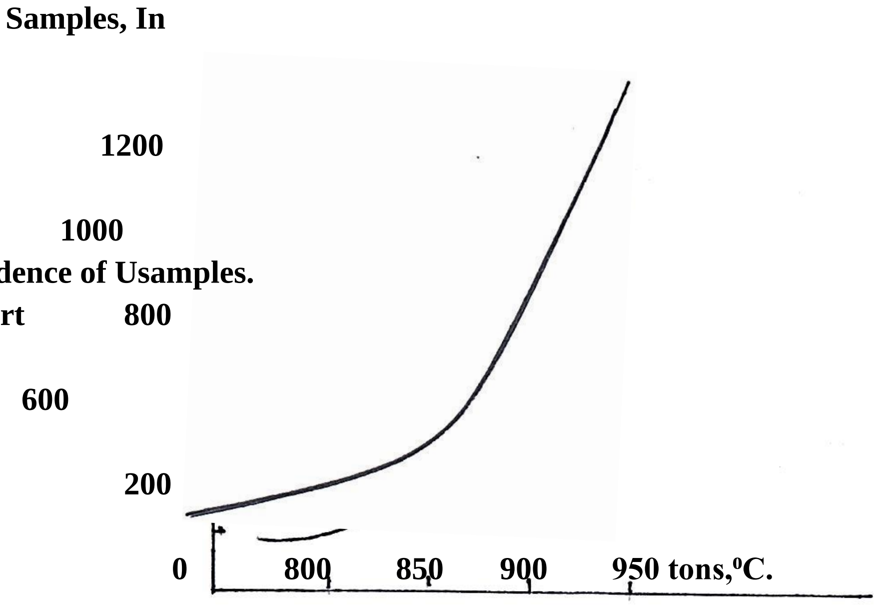
The size of the growth gap. With a decrease in H, the gradients of changes in the segregation coefficients of residual impurities increase (see Fig. 5).

On n+-p0-n0 structures obtained under different process conditions, the transmission coefficients and their temperature dependencies, as well as the permissible stresses of the collector junction, were measured.

Fig.6. The obtained results of the dependence of the transmission coefficients of such structures on the thickness of the low-resistance part of the p0-region and on the annealing temperature are presented. It can be seen that the value of α drops sharply already at the thickness of hp ≈ 30 μm, regardless of the conditions for obtaining n+-p0-n0 structures. In the area of low α values and large hp thicknesses, there is a correlation between α and production technology.

Influence of Cultivation Technology Features on Breakdown Stresses of Usamples. high-voltage P0-N0 junctions have been studied on diode P+-P0-N0 structures [1, 11]. However, in a transistor structure, the voltage of the collector junction must be $(1–α)^{1/n}$ times less Usamples. of a single p-n junction.



Rice. 7. Graph of the dependence of Usamples. Ot Tn.kr. Temperature Start Crystallization

Therefore, the n+-p0-n0 structure was studied for the possibility of obtaining p-n junctions, the permissible stresses are determined by the impurity concentration gradient in the transition region and the n0-region thickness. With the help of the electro-optical effect, it was found that when the reverse voltage is applied, the OPP expands symmetrically in both directions only up to 300 V, and then the expansion goes only to the n0 region. Therefore, the gradient of the concentration of the carriers and the thickness of the n0 region determine the
Breakdown voltages P0-N0 of the junction.

Measurement of Usamples. In this work, it was carried out on mazes obtained using the photolithography technique with a diameter of 1 mm. The dependencies of U probes are presented. from the temperature of the beginning of crystallization.

Conclusions:

The modes of epitaxial cultivation have been determined, providing reproducible production of high-voltage p0-n0 junctions based on weakly doped GaAs for the creation of assembled and picosecond semiconductor switches.

The influence of technological factors on the electrophysical properties of epitaxial layers has been studied. It has been established that with an increase in the temperature of the beginning of crystallization and the value of the growth gap, the thickness of the low-resistance part of the hp0-region and the breakdown stresses n increase$^+$- p^0- n0 structures, and the values of the transmission coefficient decrease.

On the basis of the obtained epitaxial layers of weakly doped GaAs Second-second photonic-injection pulse switches have been manufactured and researched, and assembled [10].

REFERENCES

1. Stepanova M.N. Development of a technology for obtaining weakly alloyed GaAs and creating power diodes and thyristors based on it. Diss. on the COIS. Scientific step. Cand. Phys.-Math. Sci. Leningrad, 1981. 218 p.
2. Nikitin V.G., Rachinskaya I., Seel K.R., Stepanova M.N., Tretyakov D.N., Federonko T.P. Features of the formation of p-n transitions in gallium arsenide and its solid solutions during doping with phonovim impurities. Tez. Doc. III All-Union Conf. In Phys. Proyessam in semiconductor structures. – Odessa, 1982, vol. 3, p. 103.
3. Alferov Zh.I. Semiconductor heterostructures. FTP. 1977. II, pp. 2072-2083.
4. Steiniger J. Thermodynamics and calculation of the liguidussolidus gap in homogeneous monotonic alloy systems, - J/ Appl. Phys., 1970, v. 41, № 6, p. 2713.
5. Glazov V.M., Zemskov V.S. Physico-chemical foundations of semiconductor doping. Moscow, Nauka Publ., 1967.
6. Folbert O. Review of Some Physicochemical Properties of A3B5 Compounds in Connection with State Diagrams. New Semiconductor Materials. Under. Red. M. Metallurgizdat, 1964, p. 5.
7. Chistyakov Y.D. Physical and Chemical Research6 of the Mechanism of Oriented Growth of Metals and Semiconductors. Doc. Diss. Moscow, MISiS Publ., 1967.
8. Andreev V.M., Dolginov L.M., Tretyakov D.N. Liquid Epitaxy in the Technology of Semiconductor Devices.- Moscow, S. Radio., 1976.
9. Zolotarevsky L.Ya., Kivi U.M., Nikitin V.G., Stepanova M.N., Tagasaar M.A., Timofeev V.N., Tretyakov D.N. Distribution of impurities in large-area gallium arsenide structures grown by liquid epitaxy. Materials of the doc. V All-Union Coordinats. meetings. Semiconductor. Hetero-structures", Tallinn, 1979, p. 66-73.
10. Sultanov A.M. Development of technology for the creation and study of photonic injection switches based on GaAs+AlGaAs hetero structures. Ph.D., St. Petersburg, 1992.
11. Raitsyn A.B. Creation and Study of Fast-Acting Thyristors Based on Hetero Structures in the GaAs-AlAs System. Ph.D., Ph.D., Ph.D., Ph.D., Ph.D., 1983.