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Gallium Arsenide Czokhralski Crystal Growth with High Oscillatory Influences

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The influence of ultrasound introduced into the melt during the growth of single crystals of gallium arsenide. Ultrasonic vibrations had a frequency of 820 kHz and amplitude of 0.1-0.2 micrometer. Found an increase in the homogeneity of impurity distribution of the bands growth without change of the dislocation structure of single crystals. In the simulation result of the ultrasonic wave interaction with the melt in the crucible on the basis of the theory of formation of phases is established that nucleation rate associated with the frequency and amplitude of the ultrasonic vibration acting on the melt.

Keywords: Crystal growth, Ultrasonic vibration, Homogeneity.

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1. INTRODUCTION

Witt and Morizeyn 60 years ago described the possibility of increasing the homogeneity of single crystals of semiconductors by ultrasonic treatment. Hayakawa and other scientists in Japan have conducted research on the effect of ultrasonic vibration frequency of 10 kHz crystal growth InSb, $In_xGa_{1-x}Sb$ by the Czochralski method [1-8]. It has been found that the introduction of ultrasonic output of 30 watts in a melt of 250 g eliminated "effect of the edge" crystals grown in a direction (111). One cannot but agrees with the conclusion of the authors [1] that the effect of ultrasound on the growth of single crystals studied very small. In this regard, many problems in the implementation of this work were investigated for the first time.

2. EXPERIMENTAL AND RESULTS

We studied the effect of ultrasonic treatment on the crystal uniformity on crystal gallium arsenide by the Czochralski method under the layer of boron oxide in the [001] direction when subjected to melt sonication frequency of about 820 kHz and an amplitude of 0.1-0.2 micrometer. Ultrasonic vibrations introduced into the melt by an ultrasonic vibrator. Vibrations of the vibrator through the graphite rod were introduced into the bottom portion of the crucible melt.

The resulting ingots 80-100 mm in diameter and 120-150 mm length was cut into 1.5 mm thick substrates in (001) direction perpendicular and (100) parallel to the growth direction. The substrates weredeveloped in the full cycle of chemical-mechanical polishing. The etching in molten KOH and DSL – etching were used for monitoring of dislocation structure. Fig. 1 shows the results of photo-etched around the crystal of gallium arsenide grown under ultrasonic vibration.

It is clear that in the upper part of the image contrast can be seen easing impurity growth bands. It can be associated with an increase in the homogeneity of the impurity distribution in volume of crystal.

The rate of nucleation of the critical size in this case can be described by the expression:

Fig. 1 – The results of longitudinal slice photoetchingof single crystal of gallium arsenide grown without ultrasonic vibration and in the presence of ultrasonic vibrations

$$J = J_0 \exp(-u/kT) \exp(-\Delta G/kT) \qquad (1)$$

where J_0 – the coefficient of the order of magnitude close to the number of atoms in the volume under consideration, u – activation energy of atoms of transition from the liquid to the complex, ΔG – change in free energy of the system during the formation of the critical size of the nucleus.

Introduction of mechanical vibrations increase the energy of the system and change the rate of nucleation of a new phase:

$$J_1 = J_0 \exp(-u/kT) \exp(-\Delta G/kT) \exp(-<\Delta\varepsilon>/kT) \qquad (2)$$

From this relation, taking into account (1) we determine the ratio of the rate of nucleation of critical size in the absence and in the duration of the ultrasonic wave:

$$\ln(J/J_0) = 2\pi^2 \cdot \rho \cdot \Delta V \cdot \nu^2 \cdot A^2 / kT \qquad (3)$$

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Equation (3) shows that the nucleation rate related to the amplitude and frequency of the ultrasonic vibration acting on the melt. It can be assumed that the additional energy introduced into the melt with ultrasonic vibrations will reduce the magnitude of the temperature fluctuations at the front of crystal growth. Destruction of temperature fluctuations at the crystallization front is possible if we introduce such additional (non- thermal) energy to the nucleation rate does not react to temperature fluctuations (according to our measurements, the amplitude of temperature fluctuations near the crystallization front can reach 5-10 degrees, i.e. δT = 5-10 K, $<\Delta\varepsilon> \cong k\ \delta T$, or , with regard to the expression (3) we obtain :

$$\nu = (k_b \cdot \delta T / 2\pi^2 \cdot A^2 \cdot \rho \cdot \Delta V)^{1/2} \qquad (4)$$

From the expressions (3) and (4) we can conclude that the melt by ultrasonic vibration will effectively suppress the temperature fluctuation at the solidification front at a certain ratio of frequency and amplitude of ultrasonic oscillations. Evaluating the effectiveness of this action, made the case for growing single crystals of gallium arsenide showed that in the frequency range of 0.8-1.2 MHz oscillation amplitude should be close to 1 micrometer. Reducing frequency of the ultrasonic vibration is required to achieve a similar effect a significant increase in the oscillation amplitude.

3. CONCLUSIONS

Ultrasonic transducers are commercially available generally provide mechanical oscillation amplitude of the order of 1 micron, so this process is necessary to use vibrations of a frequency more than 800 kHz.

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