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Preliminary results of GaAs single crystal growth under high gravity conditions *

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GaAs single crystals have been grown under high gravity conditions, up to $9g_0$, by a recrystallization method with decreasing temperature. The impurity striations in GaAs grown under high gravity become weak and indistinct with smaller striation spacings. The dislocation density of surcharge-grown GaAs increases with increase of centrifugal force. The cathodoluminescence results also show worse perfection in the GaAs grown at high gravity than at normal earth gravity.

1. Introduction

Comparing the results of some space-grown semiconductor crystals [1,2], one concludes that gravity driven convection plays a significant role in determining the doping inhomogeneity of the ground-grown crystals from the melt. According to the results of space growth of GaAs [3,4], we believe that convection affects the composition homogeneity. In order to comprehensively understand the effects of gravity on single crystal growth of GaAs, and compare with the results under microgravity, GaAs single crystals were grown by a recrystallization technique consisting of cooling the melt under high gravity, up to 14 times the earth gravity g_0. A Sn melt was used to simulate the temperature oscillation in the GaAs melt. This paper presents the results on the high gravity grown GaAs single crystals.

2. Experiments

GaAs single crystal growth was carried out at the extremity of the arm of a centrifuge. The latter is owned by the "Chinese Academy of Space Technology"; it has an arm length of 7 m and an available centrifugal acceleration up to $30g_0$. The scheme of the crystal growth apparatus

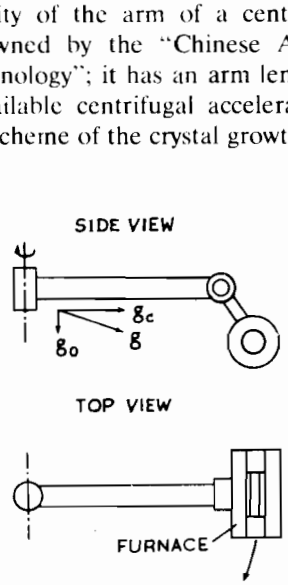

Fig. 1. Scheme of the crystal growth apparatus under high gravity conditions.

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under high gravity conditions is shown in fig. 1. The axis of the furnace was perpendicular to the arm of the centrifuge. A GaAs:Te single crystal grown under normal gravity conditions with electron concentration $(2-5)\times 10^{18}$ cm^{-3} was used as the starting material, placed in a sand-blasted quartz boat, finally sealed in a cleaned quartz tube with a proper amount of As.

Half of the starting GaAs ingot was melted, and then the furnace temperature was stabilized while the centrifuge was put into rotation. When the temperature was decreased at a cooling rate 0.2°C/min, at a fixed centrifugal acceleration, the single crystal grew, starting from the unmolten portion as a seed.

In order to find the relaminarization conditions for GaAs single crystal, the time-dependent temperature trace should be recorded. However, since direct temperature measurement of the GaAs melt is difficult, a Sn melt was used for simulated measurement of the temperature oscillations in the GaAs melt.

The high gravity grown single crystal of GaAs was cut along the {100} face, and then mechanically and chemically polished. The impurity striations were revealed by anode etching. Disloca-

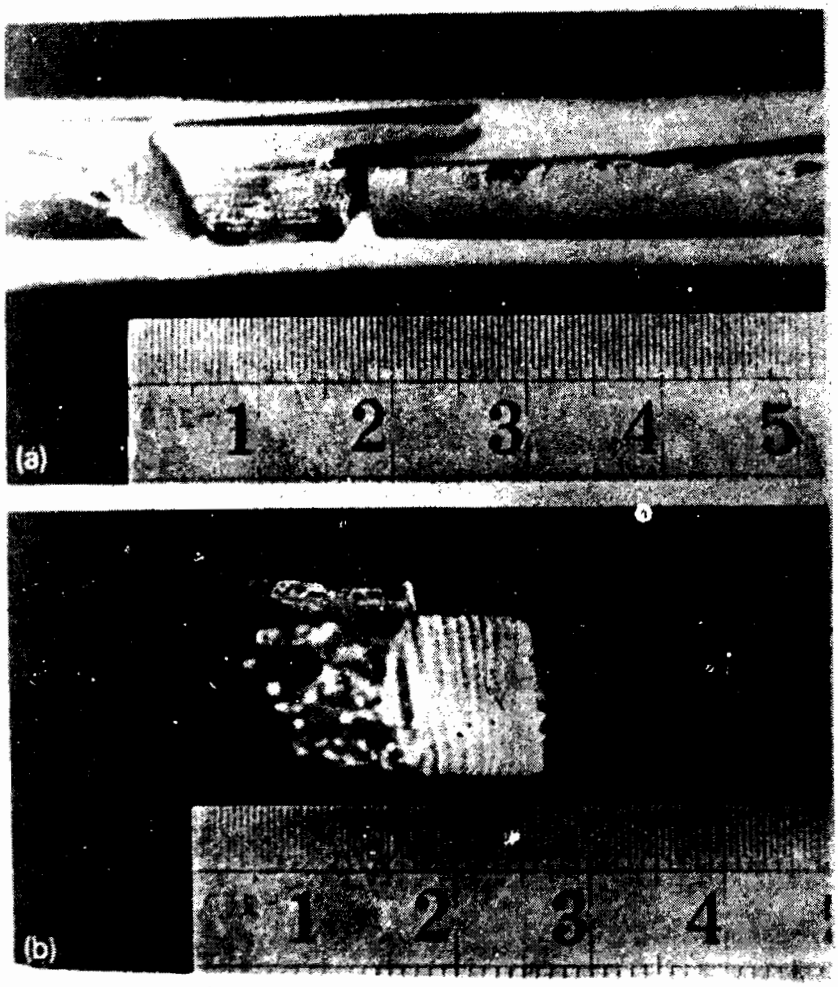

Fig. 2. Melting of seed affected by Coriolis force at $14g_0$: (a) side view; (b) bottom view of the unmolten part.

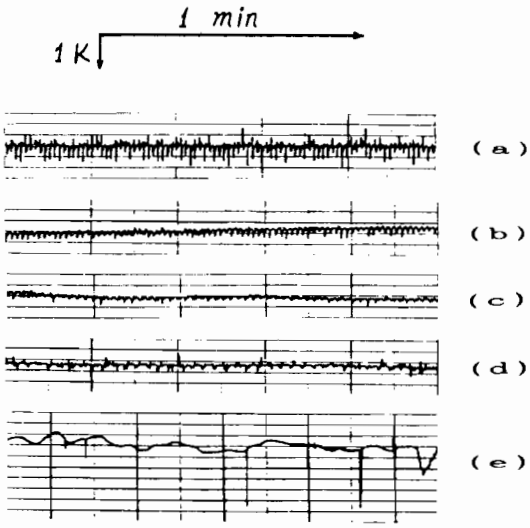

Fig. 3. Time-dependent temperature traces at: (a) $22g_0$; (b) $16g_0$; (c) $8g_0$; (d) $4g_0$; (e) $1g_0$.

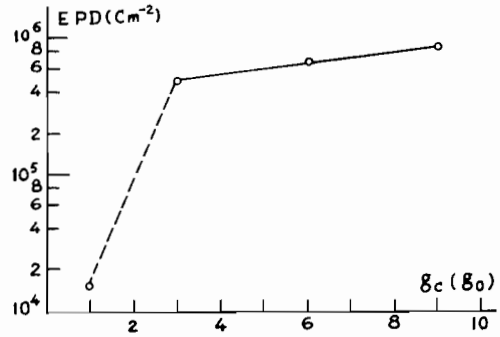

Fig. 5. Dislocation density of GaAs single crystals grown at various gravity levels.

tions were revealed by the molten KOH method. The structure was also investigated by cathodoluminescence topography.

3. Results and discussion

The melting of GaAs seed caused by Coriolis force was observed at high surcharge, when the upper surface of the seed crystal is higher than that of the melt. The lower part of the seed, located in the position where the temperature of the furnace profile is lower than the melting point, is molten at $14g_0$ in the direction of the Coriolis force, leaving the upper part of the seed unmolten. A very interesting result is shown in fig. 2, where fig. 2a is the side view and fig. 2b is the bottom view of the unmolten part. The wavy molten trace on the unmolten seed indicates temperature fluctuations in the melt. Therefore, in order to normally grow a single crystal, the seed should be placed in a proper orientation at high centrifugal force.

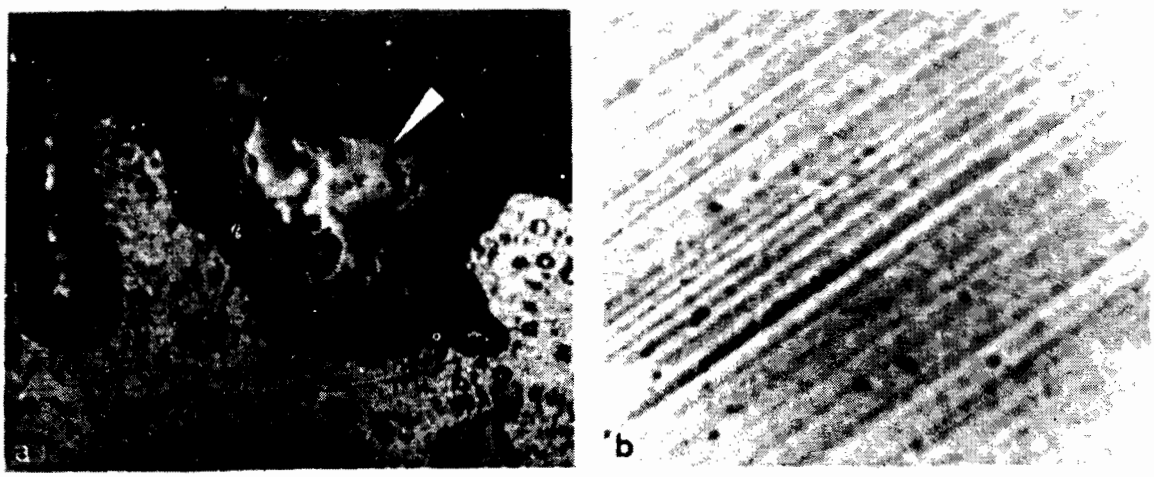

Fig. 4. Impurity striations in GaAs single crystals grown at various gravity levels: (a) $3g_0$; (b) $1g_0$.

The time-dependent temperature traces were recorded in the range of $1g_0$ to $22g_0$; they are shown in fig. 3. The temperature pulsation retards when the centrifugal force is in the range of $8g_0$ to $12g_0$. The steady state (relaminarization) is not reached yet.

GaAs single crystals have been obtained at $3g_0$, $6g_0$ and $9g_0$ centrifugal acceleration. The impurity striations of GaAs single crystals grown under high gravity are shown in fig. 4. While the impurity striations obtained under normal gravity are clear, the ones of the crystal grown at $3g_0$ are weak, less distinct and have a smaller spacing. The striations for the cases $6g_0$ and $9g_0$ are visible by the naked eye, but too weak and indistinct to be recorded by photography. This means

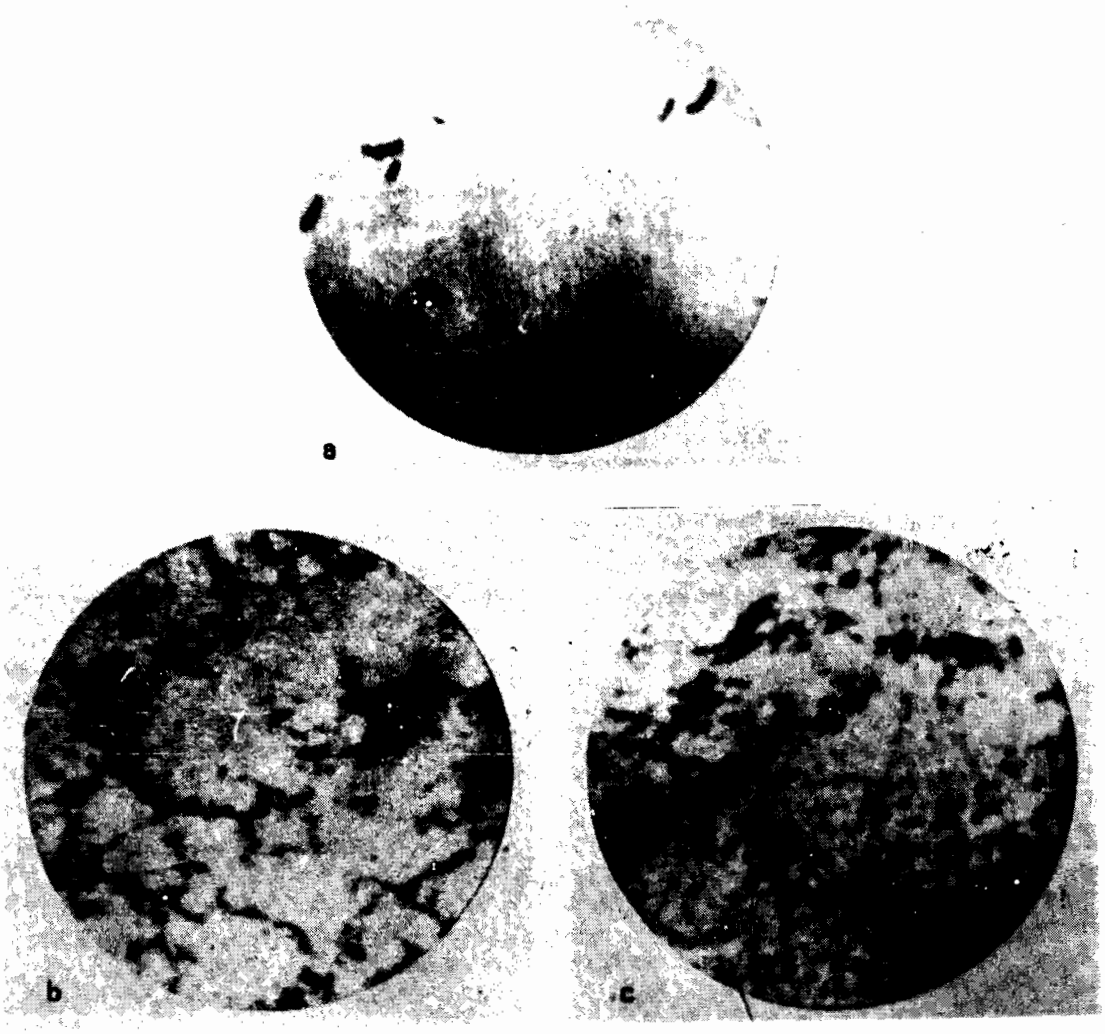

Fig. 6. Cathodoluminescence (CL) topography for GaAs single crystal grown at various gravity levels: (a) μg_0; (b) $3g_0$; (c) $9g_0$.

that the homogeneity of impurity distribution is improved. This is an advantage of the growth of GaAs under a surcharge.

It is well known that the gravity driven convection introduces temperature fluctuations at the solid–liquid interface. However, the results of the recorded temperature traces indicate that the frequency of the temperature oscillations at high gravity is higher than at normal gravity, and the amplitude of the oscillation decreases to a minimum value around $8g_0$ to $12g_0$ with increasing gravity. On the other hand, the convection is efficient for mass transport and mixing of the solutes and dopants. The two mechanisms mentioned above both contribute to homogenizing the chemical composition of the melt, leading to weakening of the impurity striations and decreasing the striation spacings at high gravity.

The dislocation density of GaAs single crystals grown at different gravity levels is shown in fig. 5. The dislocation density of surcharge-grown GaAs increases with increase of the centrifugal force.

The cathodoluminescence (CL) topography for GaAs single crystal grown at different gravity conditions is shown in fig. 6. The CL topography results are in agreement with the dislocation data, sine they show worse perfection with increasing gravity.

It seems to us that introduction of imperfections is the disadvantage of the surcharge growth. One can imagine that a high centrifugal force can introduce greater stress into growing single crystals of GaAs than the normal earth gravity.

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