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CRYSTAL GROWTH OF COMPOUND SEMICONDUCTORS IN A LOW-GRAVITY ENVIRONMENT (InGaAs CRYSTALS)

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Outline

Compound semiconductor crystals, such as galium arsenide and indium phosphide crystals, have many interesting properties that silicon crystals lack, and they are expected to be used as materials for optic and/or electro-optic integrated devices. Generally speaking, alloy semiconductors, which consist of more than three elements, demonstrate new functions. For example, values of important parameters, such as lattice constant and emission wavelength, can be chosen independently. However, as it is easy for macroscopic and/or microscopic fluctuations of composition to occur in alloy semiconductor crystals, it is difficult to obtain crystals having homogeneous properties.

Macroscopic change of composition in a crystal is caused by the segregation phenomenon. This phenomenon is due to a continuous change in the concentration of constituent elements at the solid-liquid interface during solidification. On Earth, attempts have been made to obtain a crystal with homogeneous composition by maintaining a constant melt composition near the solid-liquid interface, through suppression of the convection flow of the melt by applying a magnetic field. However, the attempt has not been completely successful. Convective flow does not occur in microgravity because the gravity in space is from four to six orders of magnitude less than that on Earth. In such a case, mass transfer in the melt is dominated by the diffusion phenomenon. So, if crystal growth is carried out at a rate that is higher than the rate of mass transfer due to this phenomenon, it is expected that crystals having a homogeneous composition will be obtained. In addition, it is also possible that microscopic composition fluctuations (striation) may disappear because microscopic fluctuations diminish in the absence of convection.

We are going to grow a bulk-indium galium arsenide (InGaAs) crystal using the gradient heating furnace (GHF) in the first material processing test (FMPT). The structure of the sample is shown in Figure 1 where InGaAs polycrystals in a crucible are doubly sealed in two quartz tubes for safety. As shown in Figure 2, the GHF consists of two zones, namely, high temperature and low temperature zones, which results in a large temperature gradient at the interface. Crystal growth is performed by moving the furnace (i.e. the temperature profile) from the left to right at a definite rate. Thus, we will grow crystals both on Earth and in space under the same conditions. As previously described, it is possible to obtain good quality crystals which are homogeneous in composition both macroscopically and microscopically due to the lack of convection in space. We are planning to study effects of convection on crystal growth from a melt by comparing and characterizing the properties of crystals grown on Earth with those grown in space.

Expected Results

It is important to control convection during crystal growth, especially from a melt. However, the effects of convection in a melt during crystal growth are not clear. In order to control convection in melt on Earth, various methods have been attempted, for example, imposing a magnetic field in a melt and adding forced convection by rotation, but the effects of these methods are also not clear.

Because the magnitude of gravity is small enough in space it is possible to completely suppress convection resulting from gravity. Accordingly, we can control convection in microgravity and study the effects. In the FMPT we are planning to study the effects of convection on crystal growth from a melt by comparing the properties of crystals grown on Earth and in space under the same conditions. The results will help to control convection in melts and to grow crystals on Earth. If a high quality crystal with uniform composition is obtained, InGaAs will be even more important as a material for optic devices for optical communication using quartz fiber. This experiment in the FMPT will also provide information for obtaining good crystals on Earth.

If we can control convection in a melt, we can grow big compound semiconductor crystals of any composition, and even crystals having few defects. Such crystals would not only lower production costs greatly but allow easy fabrication of many kinds of light emitting diodes, laser diodes, and electron devices for rapid calculation. Also, the realization of optical integrated circuits and optical computers would be possible.

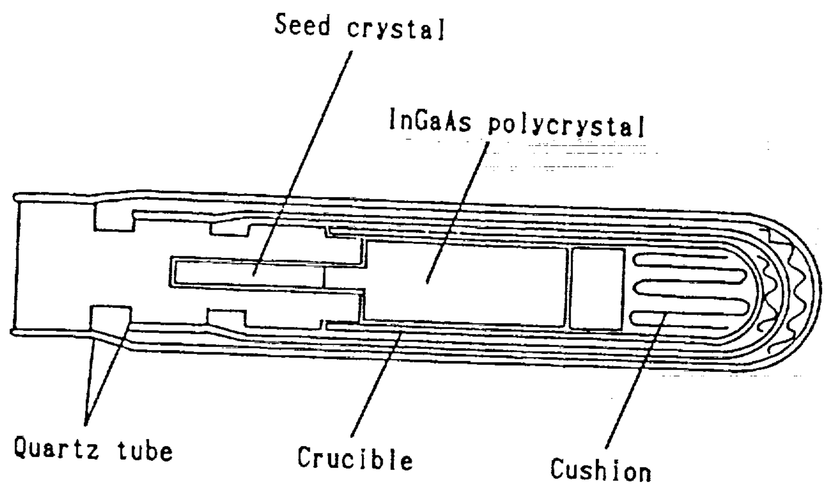

Figure 1. Sample structure.

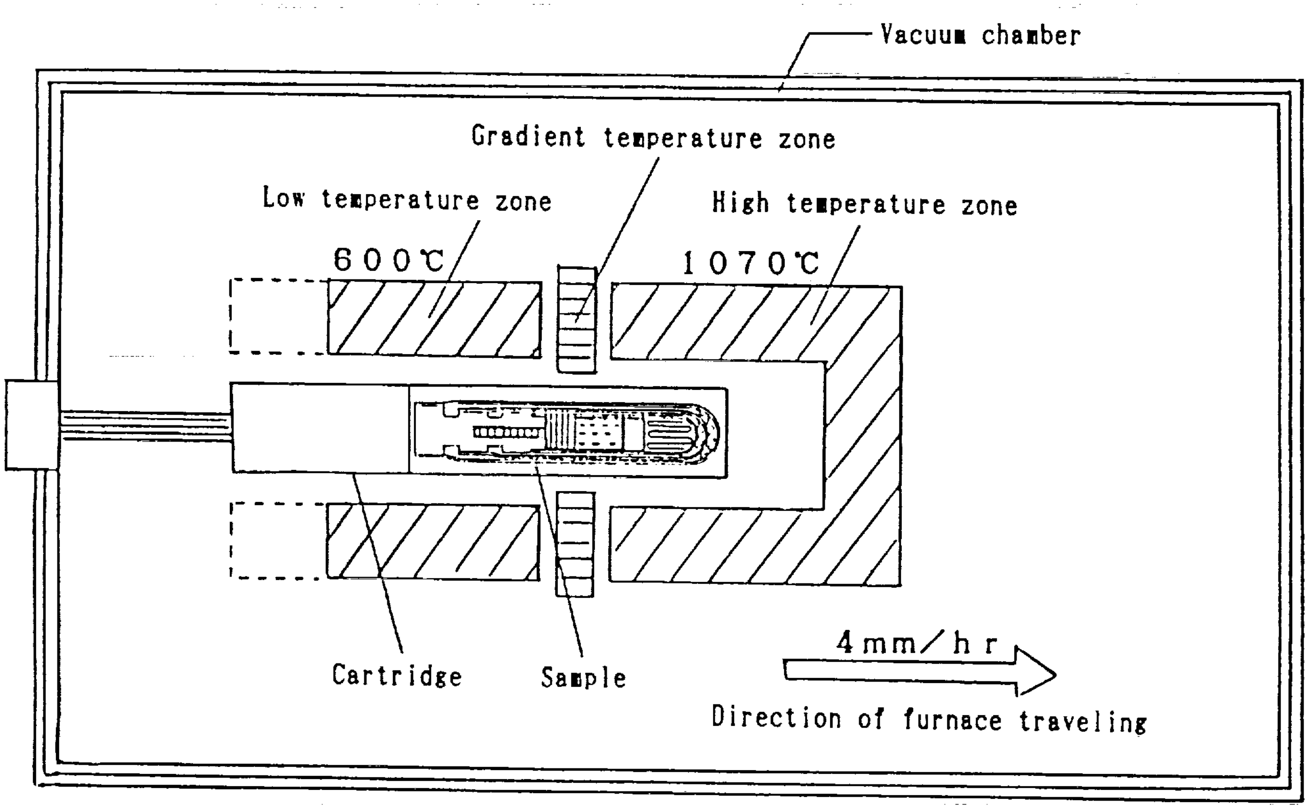

Figure 2. Crystal growth by the GHF.