High Mobility HEMT Growth with Water-cooling MBE System

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High mobility GaAs / AlGaAs HEMT structures were grown by using a water-cooling
molecular beam epitaxy (MBE) system. Irrespective of no use of liquid nitrogen shroud, mobilities of more than 1x106cm2/Vs samples were successfully grown.

Introduction

Since the technique of molecular beam epitaxy was employed, the use of liquid nitrogen shroud has been thought to be essential to suppress the pressure of the impurity gases for the high quality crystal growth [1]. However, the pressure of typical impurity gasses in the growth condition in MBE chamber are normally very low even without using liquid nitrogen shroud. For examples, N_2, CO and CO_2 have more than 1 Torr of thermal equilibrium pressure which is 1010 times larger than that in the growth chambers. Recently, small water-cooling MBE machines became commercially available which are designed to be efficient to get rid of impurity gasses using effective baking system from inside of the chamber. Using the water-cooling MBE machine, we tried to grow GaAs / AlGaAs HEMT structures.

System description

We used Eiko Engineering EW-100 water-cooling MBE system which has eight K-cell ports and substrate holder of 2 inches wafers. As shown in figure 1, the main chamber of this MBE machine has a double wall structure between these two walls, cooling water is flowing. Cooling water is maintained at 5℃ with a small circulator. Because of there double walls, baking from outside of the chamber is not efficient, so this system employs lamp heaters which radiate the inner surface of the chamber wall. Baking heaters were controlled to maintain the inner wall temperature at 200℃. The main chamber was pumped using turbo molecular pump, Ion pump and titanium sublimation pump through the baking procedure. After the initial baking of 3 days with room temperature K-cells and of 3 days with hot K-cells, pressure of the main chamber becomes about 1x1010 Torr. In figure 2, we show

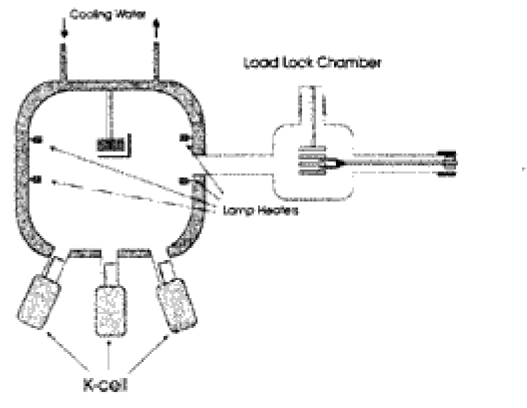

Fig.1 Structure of water-cooling MBE system used for HEMT growth.

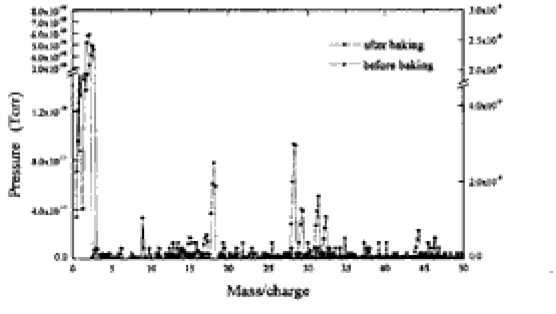

Fig.2 Partial pressure as a function of Mass/charge measured before and after initial baking.

an example of mass spectra measured before and this initial baking. It is clear that H2O, CO, CO2, N2, and O2 signals were not observed with our detector. After this initial baking, no baking of the chamber was performed through more than 10 months.

In figure 3, we show typical conduction band structure of the HEMT grow with the water-cooling MBE. Growth rate of the GaAs is about 1000Å/hour. Main difference of the water-cooling system from the system with liquid nitrogen shroud exist in that As4 gas pressure is not easily lowered by closing the K-cell shutter. So the technique such as atomic layer epitaxy can not be used practically in this system. However, in the usual growth of GaAs / AlGaAs hetero-structures, we have no difficulty in the growth procedure.

Discussion

In figure 4, we show Schbnikov de-Hass oscillation measured with sample T-61 which has 300Å well width and 3x1011cm-2 carrier density. From the lower field dependence of the pxx and pxv, this sample has more than 1x106cm2 /Vs mobility. More than 10 samples grown with different well widths and dopings show between 5x105 cm2 /Vs and 1.2x106 cm2 /Vs, suggesting that our system has ability to grown high mobility samples constantly. To our knowledge [2], this mobility is highest of samples grown with water-cooling MBE and not so low in such a small chamber systems even with liquid nitrogen shroud. Here, we should consider advantage and disadvantage of the water-cooling MBE system. Main purpose of liquid nitrogen shroud is to lower the gas pressure of impurity in the growth chamber, which is supplied from the chamber wall surface and source materials. For the latter case, the liquid nitrogen shroud may be effective when the shroud is fully cooled. However this is effective mainly to the H2O as stated in the introduction and we do not think large amount of water contained in the source in heated K-cell. For the former case of impurity from the chamber wall, liquid nitrogen shroud may be not effective. Because, after the liquid nitrogen becomes empty, all the impurity trapped on the shroud surface comes out to the main chamber and there is not enough time to pump out these impurities in the interval of growth. So, the large amount of impurity stay in the growth chamber for long time. Contrary to the liquid nitrogen system, the water-cooling system has no effect to trap water vapor on the shroud surface. However, water vapor is constantly pumped out from the growth chamber, resulting in the small water partial pressure after the long pumping. In addition, the lamp heaters raise the surface temperature very efficiently

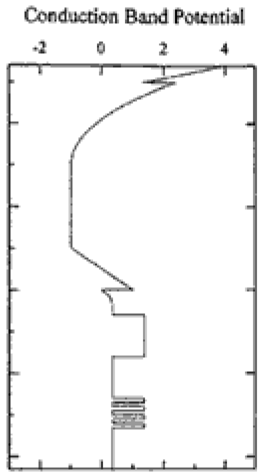

Fig.3 Conduction band structure of grown GaAs/AlGaAs sample.

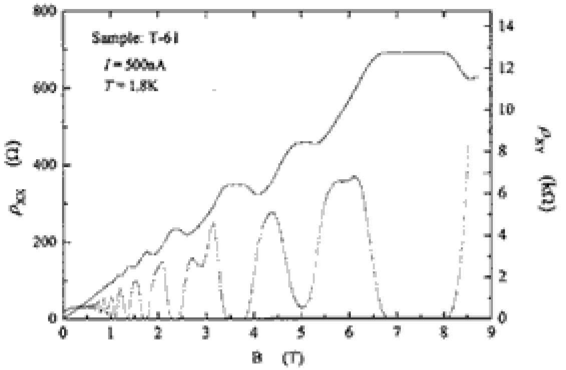

Fig.4 Shubnikov de-Hass oscillation of sample T-61 measured at T=1.8K.

compared with baking from the outside in the liquid nitrogen system.
Of course our system has disadvantage that the trapping speed of the surplus source gas is rather slow. It may be result in the slow change of the pressure especially for the As_4 gas. However, the surface temperature of water-cooling chamber is thought to be enough low for the source gas trap, the additional design to more effective trapping should be considered.

Summary

In summary, we have succeeded to grow high mobility HEMT of GaAs / AlGaAs using water-cooling MBE system. Conventionally performed technique with liquid nitrogen shroud is clarified to be unnecessary for the normal HEMT structure growth. Moreover, we pointed out the water-cooling system has even advantage to purify the chamber. Considering the reduction of man power and the cost together with the advantage, the water-cooling MBE has enough ability to grow high mobility devices.

References

[1] J.R.Arthur and T.R.Brown, J.Vac.Sci. Technol., 12 (1975) 200.
[2] T.Hayashi, S.Tokuda, K.Suekane, Y.Moriguchi and W.Susaki, J.Vac.Soc.Jpn.42 (1999) 4.