Extended Abstracts of the 18th (1986 International) Conference on Solid State Devices and Materials, Tokyo, 1986, pp. 739-740

Stepwise Monolayer Growth of GaAs by Switched Laser Metal Organic Vapor Phase Epitaxy

Atsutoshi Doi, Yoshinobu Aoyagi, Sohachi Iwai, and Susumu Namba

The Institute of Physical and Chemical Research
Wako-shi, Saitama, 351-01, Japan

Introduction

There is growing interest in stepwise single atomic layer epitaxy of the GaAs/GaAlAs system since this technique seems to be a promising candidate for producing thin epitaxial layers and abrupt interfaces. In order to realize stepwise monolayer epitaxy (SME), a means of arresting deposition at 100 % surface coverage is an essential part of the growth mechanism. Conventional growth techniques involve continuouse growth, therefore SME may not be achieved by these methods. In this paper we demonstrate the SME of GaAs using the Switched Laser MOVPE (SL-MOVPE)[1)] technique. Using this method the ideal growth rate of one monoatomiclayer/cycle is realised.

Experiment

Epitaxial layers of GaAs were grown on Si doped (100)$\pm$0.5° oriented n-GaAs substrates in a low pressure reactor. The growth system is shown in Fig.1. The flows of trimethylgallium (TMG) or triethylgallium (TEG) and AsH_3 (20% in H_2) were switched on and off alternately, each lasting for one second. In the interval between the flow of source gases, the growth chamber was purged with H_2 for 1s in order to minimize gas mixing. A cw Ar ion laser was also switched, with irradiation occuring at the same time as the flow of TMG/TEG in order to decompose the TMG/TEG and minimize the local temperature increase by the irradiation.

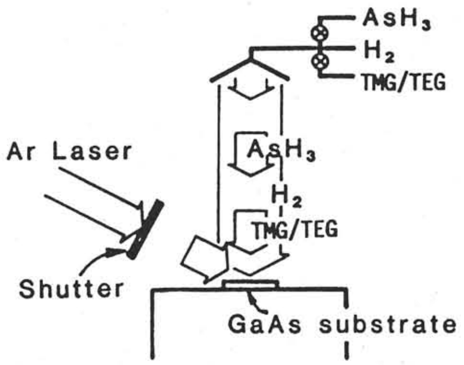

Fig. 1. Growth system of Switched Laser MOVPE.

Results and Discussion

The growth rate for TMG as a function of reciprocal growth temperature is shown in Fig.2. The growth rate is independent of the growth temperature between 365-430 °C, remaining constant at one monolayer/cycle. This result suggests that SME of GaAs is achieved in this temperature region. We believe that for SME to occur by SL-MOVPE, the growth mechanism must involve a surface photocatalytic reaction[2)]. The growth rate is dependent on the growth temperature above 430 ℃. Above the temperature of 430 °C, photocatalytic reaction is likely to be masked by pyrolytic reaction caused by local temperature increase during laser irradiation. In the absence of laser irradiation, SME of GaAs may not be obtained, as shown in Fig. 2. It is seen from this figure that the pyrolytic decomposition of TMG at surface Ga

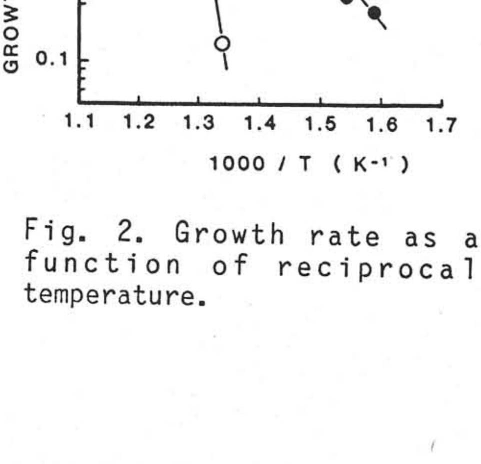

Fig. 2. Growth rate as a function of reciprocal temperature.

atoms arises at a growth temperature of 487 ℃ without laser irradiation and at 426 ℃ with irradiation. The temperature difference is possibly caused by a local temperature rise of 61 C during laser irradiation at 160 W/cm^2. The growth rate as a function of the laser power is shown in Fig. 3. The growth rate is constant at a value of 1 monolayer/cycle when the laser power is between 150 W/cm^2 and 230 W/cm^2. Increase of the growth rate above 230 W/cm^2 may be attributed to a local temperature rise due to the laser irradiation. An estimated temperature increase of 88 ℃ at 230 W/cm^2 leads to a local substrate temperature as high as 488 ℃. This temperature is nearly equal to the critical temperature of 487 ℃ at which decomposition of TMG occurs at surface Ga atoms. When the source gas of TMG was used, lower laser power was sufficient to achieve the SME of GaAs. The growth rate of GaAs as a function of the quantity of TMG introduced is shown in Fig. 4. Above a TMG flux of 1×10^{-7} mol/cycle, the growth rate is independent of the TMG flux and remains constant at 1 monolayer/cycle up to the highest TMG flux examined in our experiments. Below a TMG flux of 1×10^{-7} mol/cycle, the growth rate decreases non linearly with decreasing TMG flux. The non linear dependence of the growth rate on the TMG flux can be explained by assuming that the photocatalytic decomposition of TMG/TEG takes place only at surface As atoms and does not occur at surface Ga atoms. This simple model shown in Fig. 5 satisfies the requrement for SME. According to this model, the growth rate of (100)-GaAs is given by,

$$R(nm/cycle)=0.283(1-\exp(-ANt/N_{so})), \quad (1)$$

where N_{so}(cm^{-2}) is the surface density of lattice sites, N(cm^{-2}) the arrival rate of TMG or TEG, and A a constant. The calculated curve obtained by fitting a parameter is shown in Fig. 4 by a broken line. Good agreement between experimental and calculated values attests to the validity of the model.

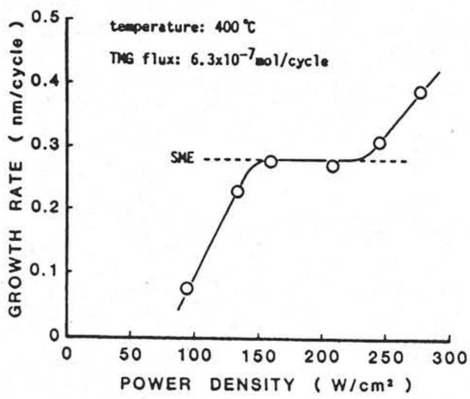

Fig. 3. Growth rate as a function of laser power density.

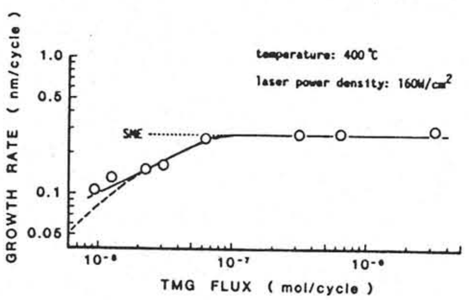

Fig. 4. Growth rate of GaAs as a function of TMG flux.

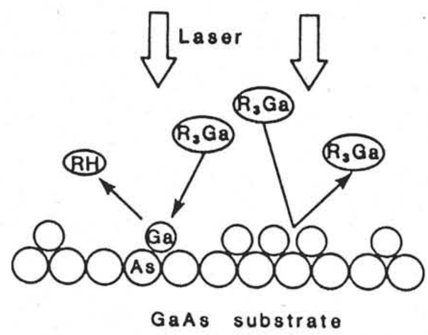

Fig. 5. Growth model for stepwise monolayer epitaxy.

In conclusion, SME of GaAs has been demonstrated using the SL-MOVPE. A growth model for SME has been proposed, which suggests that photocatalytic decomposition of TMG/TEG occurrs only at surface As atoms and not at Ga atoms.

Acknowledgement

This work was suported in part by the Scientific Research Grant-in-Aid No.60222037 from the Ministry of Education, Science and Culture of Japan.

References

1) A. Doi, Y. Aoyagi, and S. Namba, Appl. Phys. Lett., 48, 1787 (1986).

2) A. Doi, Y. Aoyagi, and S. Namba, in 12th Int. Symp. on GaAs and Related Compounds, Karuizawa, 1985, p. 331.