INFLUENCE OF GROWTH CONDITIONS ON THE STRUCTURAL AND ELECTRICAL PROPERTIES OF GALLIUM ARSENIDE THIN FILMS

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Abstract

GaAs films were usually grown by MOCVD using AsH_3 and TMGa as precursors. In this study, TDMAAs and TMGa had been successfully used as As and Ga precursor, respectively. For these experiments, the growth temperature was allowed to range from 580 to 600^oC, the total reactor pressure was varied from 50 to 70 torr, and the flows of hydrogen and nitrogen were varied from 200 to 400 sccm. The TDMAAs/TMGa ratio was kept at 4.5. The structural and electrical properties are characterized using SEM method and standard van-der Pauw Hall measurement, respectively. The optimum growth condition occurred at growth temperature of 580 ^oC, reactor pressure of 50 torr, H_2/N_2 ratio of 1,and V/III ratio of 4.5. This film had grain size of 1.08 μm, growth rate of 0.94 μm/h, 395 cm^2/Vs mobility, and hole concentration of 3.44×10^{15} cm^{-3}.

Abstrak

Film tipis GaAs biasanya ditumbuhkan dengan metoda MOCVD dengan menggunakan precursor AsH_3 dan TMGa. Dalam studi ini, TDMAAs dan TMGa telah berhasil digunakan sebagai precursor As dan Ga. Dalam eksperimen ini , parameter penumbuhan diatur sebagai berikut: temperatur penumbuhan divariasikan dari 580 sampai 600 ^oC, tekanan total dalam reaktor divariasikan dari 50 sampai 70 torr, dan laju aliran H_2 dan N_2 divariasikan dari 200 sampai 400 sccm, sedangkan perbandingan TDMAAs /TMGa dijaga pada nilai 4,5. Sifat-sifat struktural dan listrik dikarakterisasi dengan menggunakan metoda SEM dan Hall-van der Pauw effect. Kondisi optimum penumbuhan GaAs terjadi pada temperatur penumbuhan 580 ^oC, tekanan reaktor 50 torr, perbandingan H_2/N_2 sama dengan 1, dan perbandingan V/III 4,5. Film tersebut memiliki ukuran butir kristal 1,08 μm, laju penumbuhan 0,94 μm/jam, mobilitas 395 cm^2/Vs, dan konsentrasi hole 3.44×10^{15} cm^{-3}.

I. INTRODUCTION

In the last few years the interest in Gallium Arsenide (GaAs) rapidly increased because of their unique electrical and optical properties and the resulting wide range of electronic applications [1-5]. GaAs-based optoelectronic for optical fiber communications is an interesting alternative for some important applications such as optical interconnections, fast switching systems, etc. Beside that, semi-insulating GaAs has received great deal attention because of its high performance as a substrate for advanced integrated circuits (ICs).

Therefore, the state of the art of GaAs growth allows one to obtain a semi-insulating material without intentional doping. Successful homoepitaxial growth of high purity, unintentionally doped GaAs layers using metal organic chemical vapor deposition (MOCVD) has traditionally involved the use of arsine (AsH_3) and trimethyl-gallium (TMGa) as precursors. Unfortunately, the high toxicity of AsH_3, which is caused by As-H bonds, and its inefficient reaction with TMGa [6], as well as the incorporation of carbon impurities from the TMGa into the layers, are inherent drawbacks to this system. To overcome those problems, trisdimethylamino-arsenic (TDMAAs) has been proposed as another alternative precursor with no As-H bonds and As-C bonds [7-9]. In this study, some phenomena will be reported. These are structural and electrical properties of GaAs films, which are influenced by growth conditions. The phenomenon is studied by scanning electron microscopy (SEM) method and the standard Hall-van der Pauw effect measurement.

II. EXPERIMENT

GaAs films were grown in vertical MOCVD reactor on semi-insulating (100) GaAs substrate, using TMGa and TDMAAs as Ga and As precursors, respectively. The TMGA and TDMAAs were introduced to the reactor by carrier gas H_2 which is purified in hydrogen purifier (Palladium diffuser RSI-10). It was assumed that the carrier gas is fully saturated and the precursor exerted its equilibrium vapor pressure. Thus, the flow rate of the precursor could be accurately controlled by mass flow controller (MFC) upstream from the bubbler. For these experiments, the growth temperature was allowed to range from 580 to $600^{o}C$, the total reactor pressures were varied from 50 to 70 torr, and the flow of hydrogen and nitrogen (N_2) were varied from 200 to 400 sccm. The TDMAAs/TMGa ratio was kept at 4.5 due to the optimum growth condition, which has been reported in our previous paper [10]. Growth conditions of GaAs films are presented in table 1. The shadow part shows the variety of growth conditions.

Table 1. Growth conditions and grain size of GaAs films

V/III	Tg (^oC)	H_2/N_2	Pg (torr)	Grain Size (μm)
4	580	1	50	1.67
4.5	580	1	50	1.08
5	580	1	50	0.78
4.5	580	1	50	1.08
4.5	590	1	50	3.20
4.5	600	1	50	1.84
4.5	580	0.5	50	1.8
4.5	580	1	50	1.08
4.5	580	2	50	0.75
4.5	580	1	50	1.08
4.5	580	1	60	2.50
4.5	580	1	70	1.00

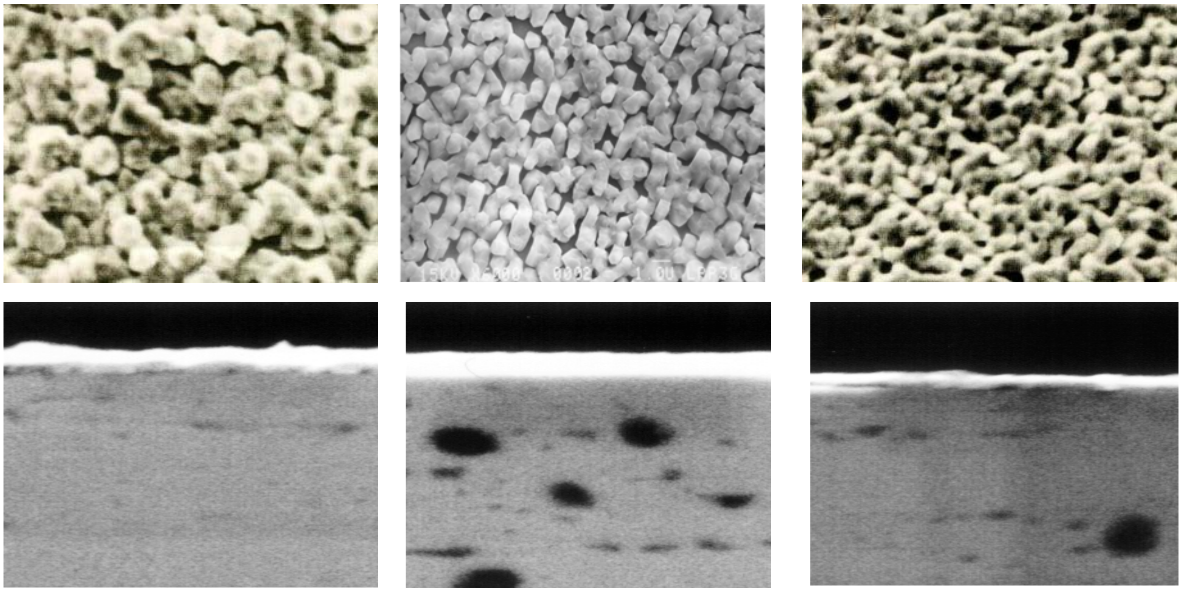
All GaAs films were characterized structurally by SEM method to study the GaAs surface morphology. The electrical properties of GaAs films were characterized by the standard Hall-van der Pauw effect measurement at room temperature. Au was deposited on the GaAs films by evaporation method acting as an Ohmic contact [11-12].

III. RESULT AND DISCUSSION

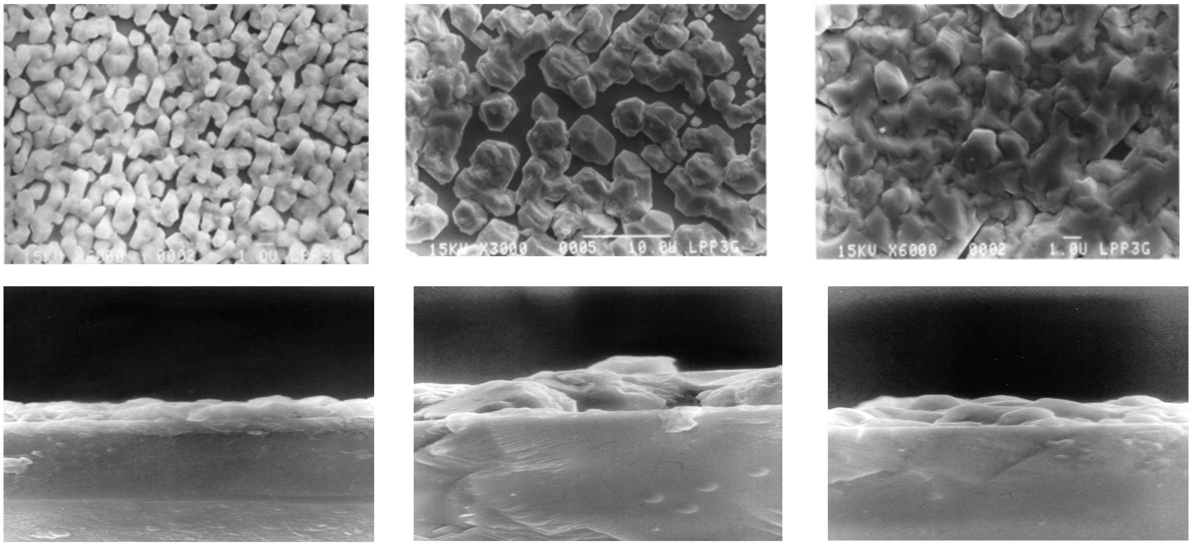
The surface morphology of GaAs films, grown at different growth conditions was presented in fig. 1. It can be seen that the quality of films are influenced by the V/III ratio, the growth temperature, the H_2/N_2 ratio, and the reactor pressure. (a) GaAs films with 4.5 V/III ratio has homogeneous surface morphology, and it has migration between its grain. It also revealed that the higher V/III ratio, the small the grain size of GaAs . (b) Due to the goal obtained from (a), GaAs films grown at different growth temperature. It is found that the GaAs are grown at temperatures of 590 and 600^oC have grain size larger than 580^oC. But those GaAs have no migration between its grains. So, we can not get information that of grown at these conditions. (c) We set growth condition by varying total reactor pressure. GaAs film grown at reactor pressure of 70 torr, has grain that more dense but inhomogeneous, whereas GaAs film grown at pressure reactor of 60 torr, has no migration between its grain. (d) GaAs films grown at varying H_2/N_2 ratio. It is found that the optimum condition for obtaining GaAs film with good morphology is by using H_2/N_2 ratio of 1. That film has grain size bigger than the other and more homogeneous (d). The effect of growth conditions on the grain size is presented in table 1.

The growth rates of all films vary from 0.4 to 1.25 μm/h. The fastest growth rate is obtained for GaAs film grown at V/III ratio of 4.5, growth temperature of 590^oC, reactor pressure of 50 torr, and H_2/N_2 ratio of 1. However, from the fig. 1, it can be seen that, this film has no migration between its grain. For this condition, cohesive energy between atoms of films is stronger than cohesive energy between atoms of films and atoms of substrate, so island growth is formed [13].

The result obtained from electrical measurement of GaAs films, are summarized in fig.3. All of films have p-type conductivity. The room temperature mobility and the hole concentration exhibit growth temperature and V/III ratio dependency [14]. GaAs films with 4 and 5 V/III ratios and 590 and 600 ^oC growth temperatures have low mobility. It is caused by the absence of migration between its grain, as can be seen from fig. 1. Mobility for GaAs film with 4.5 V/III ratio and 580 ^oC growth temperature has high mobility, i.e. 395 cm^2/Vs. These results are comparable to those obtained by Dong [9].

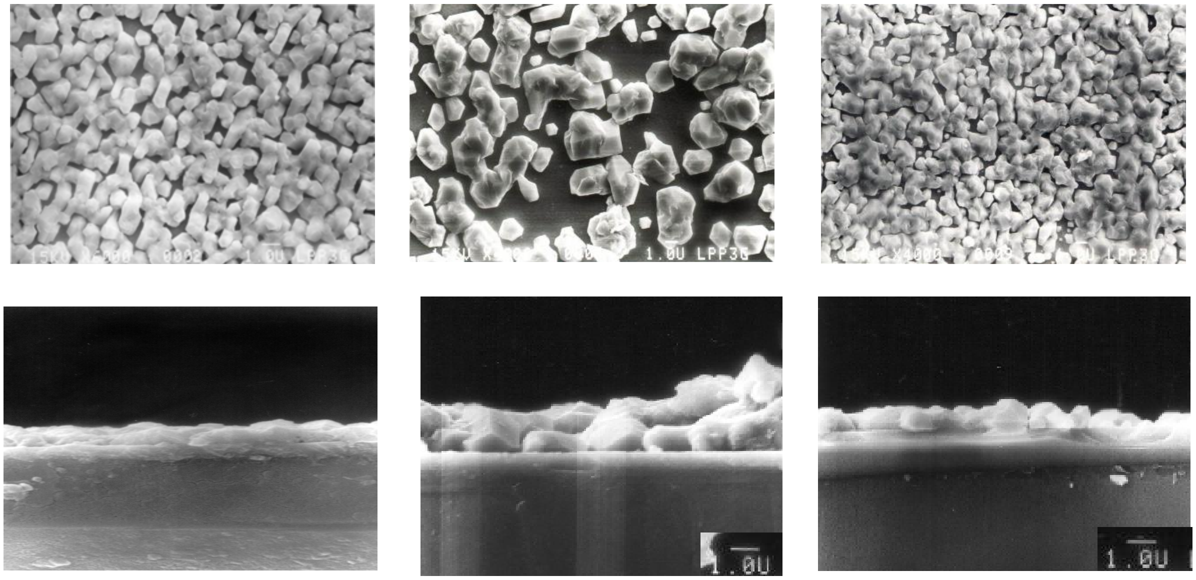


(a) V/III=4 V/III=4.5 V/III=5

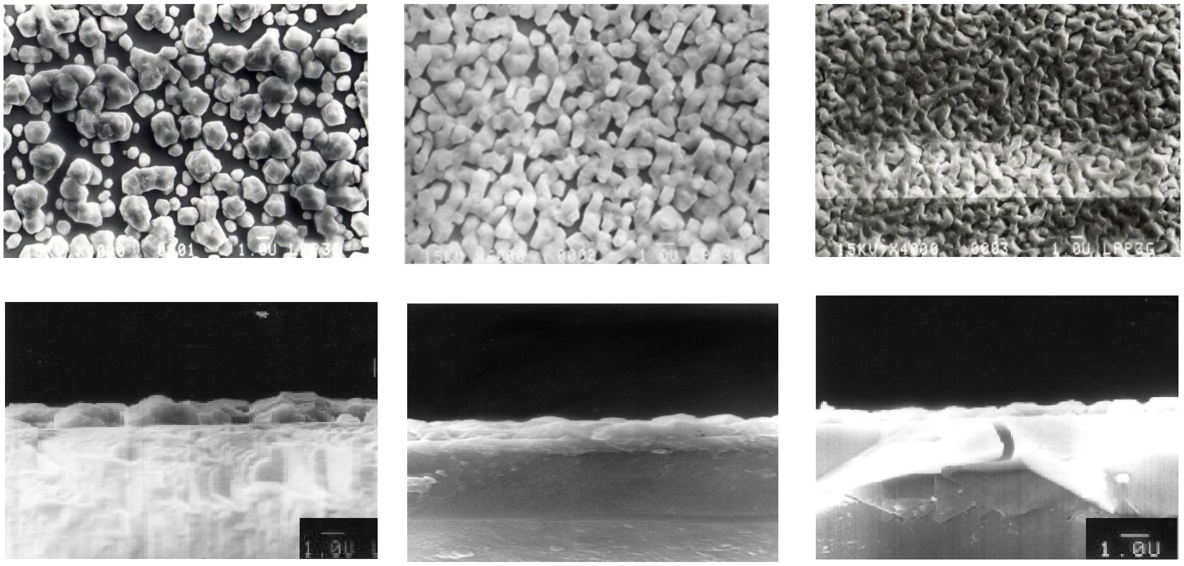


(b) Tg=580^{o}C Tg=590^{o}C Tg=600^{o}C

Fig.1a &b. Surface morphology and cross section of GaAs films grown at different growth condition (a)Tg=580^{o}C, Pg=50 torr, N_2,H_2=300 sccm. (b) V/III=4.5, Pg=50 torr, N_2,H_2=300 sccm



(c) Pg=50 torr Pg=60 torr Pg=70 torr



(d) $H_2/N_2=0.5$ $H_2/N_2=1$ $H_2/N_2=2$

Fig.1c & d. Surface morphology and cross section of GaAs films grown at different growth condition (c) $Tg=580^oC$, $V/III=4.5$, $N_2,H_2=300$ sccm, (d) $Tg=580^oC$, $Pg=50$ torr, $V/III=4.5$.

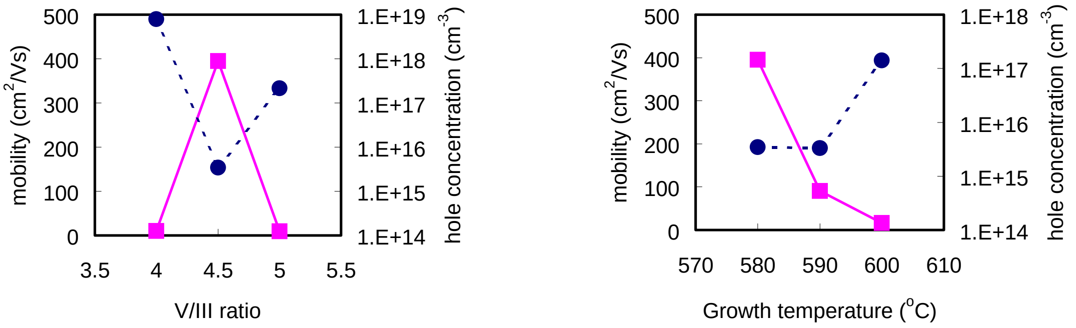


Fig. 2. Hole concentration (dash line) and mobility (thick line) of GaAs films

The carrier concentration is in the range between 10^{15} to 10^{17} cm^{-3}. From fig. 2, we can see that the higher mobility the lower hole concentration.

IV. CONCLUSION

GaAs films have been successfully grown by MOCVD using TDMAAs and TMGa precursors. The structural and electrical properties are characterized using SEM method and standard van-der Pauw Hall measurement, respectively. All the grown films show p-type conductivity. The optimum growth condition occurs at V/III ratio of 4.5, growth temperature of 580 ^{o}C, H_2/N_2 ratio of 1 and pressure of reactor of 50 torr. This film has grain size of 1.08 μm, growth rate of 0.94 μm/h, 395 cm^2/Vs mobility, and hole concentration of 3.44 x 10^{15} cm^{-3}.

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