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Extremely Low Energy EBE-Epitaxy of GaAs on the Fluorides

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Heteroepitaxial growth of GaAs on the fluorides depending on electron beam energy during the surface modification of the fluorides was studied. At 40eV of electron beam energy, the adsorption of As on the CaF_2 surface was found to be independent of the substrate temperature, and the highest Hall mobility of GaAs overgrown on the CaF_2 films was obtained.

1. INTRODUCTION

Heteroepitaxial GaAs/fluorides/Si structures are very attractive for the future applications of OEIC, three-dimensional IC, and very high speed devices. This is because the alkaline earth fluorides such as CaF_2, SrF_2 are very promising candidates as epitaxial insulators. For heteroepitaxy of GaAs on the fluorides, the surface modification of the fluorides before the growth was found to be very useful, that is so called electron beam exposure(EBE)-epitaxy method[1]. An ideal condition of the surface modification is considered that the top layer of F-ions are replaced by group V elements by means of simultaneous electron beam exposure as shown in Figure 1[1]. But, the crystallinity of heteroepitaxial GaAs has not been enough satisfactory probably due to irradiation damage by electron beam near the CaF_2 surface. It was indicated that the damage could be reduced by using the electron energy of about 40eV[2] because of the least electron mean free path in the CaF_2 bulk.

In this paper, we investigated the electron beam energy during the surface modification to obtain the good crystallinity of GaAs layers on the CaF_2/Si(111) structure.

2. EXPERIMENTAL

Si(111) substrates were loaded into an MBE system after chemical cleaning. Then 50nm thick CaF_2 films for evaluation of the amounts of adsorbed As and 200nm thick films for the GaAs growth were grown at 600°C after thermal cleaning. After that, the CaF_2(111) surfaces were modified by impingement of As_4 molecular beam with simultaneous electron
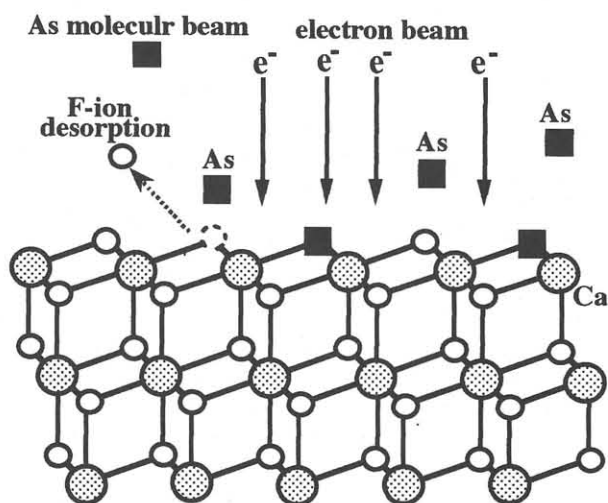

Figure 1. Schematic illustration of surface modification of CaF2(111) by simultaneous exposure of electron beam and As4 molecular beam.
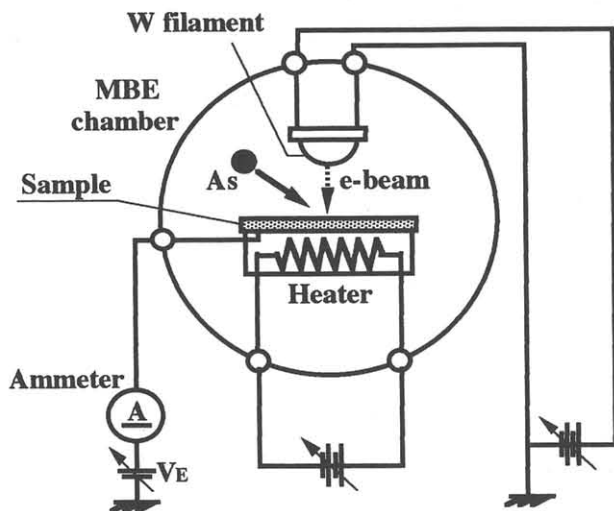
Figure 2. Schematic illustration of surface modification performed in the MBE chamber.

beam exposure, varying electron beam energy(V_E) and substrate temperature during the surface modification(T_{sub}) as shown in Figure 2. During the modification process, molecular beam flux of As_4 on the CaF_2 surface was speculated to be approximately order of 10^{-5} Torr, and electron beam current density was $5\sim6\mu C/cm^2$. After that, the amounts of adsorbed As were observed by Rutherford backscattering spectroscopy method by using a reference sample where 1ML As is adsorbed on Si(111) surface[3].

GaAs layers were grown on the surface modified CaF_2 where the modification was carried out at 300 ℃ with an electron dose of $6000\mu C/cm^2$. The GaAs films were grown by means of the 2-step growth method[4], where 20nm of GaAs layers were grown first at 500℃ and the following 1.5µm GaAs layers were grown at 570℃, where 0.5µm of surface layers were doped by Si with $3\sim4 \times 10^{17} cm^{-3}$. The crystallinity of GaAs films were evaluated by electron Hall mobility at 300K.

3. RESULTS AND DISCUSSION

Figure 3 shows the amounts of adsorbed As on the CaF_2 as a function of T_{sub}. The V_E were 300eV and 40eV, and the electron beam dose was $1800\mu C/cm^2$. In the case of V_E=300eV, the amounts

of adsorbed As increased drastically at T_{sub} of 500℃ and 700℃, whereas such increase could not be observed for 40eV. The previous works[2,5,6] pointed out the generation of irradiation damage or defects in the CaF_2 when V_E of 300eV or so was used. So, it can be considered that the adsorbed behavior at 300eV
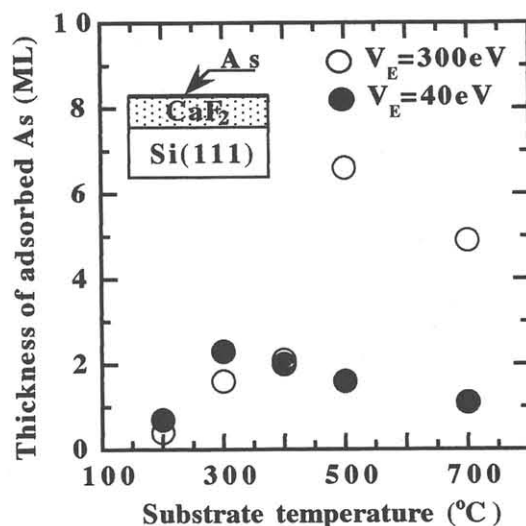

Figure 3. Adsorbed amount of As measured by Rutherford backscattering spectroscopy method depending on T_{sub} at electron dose of $1800\mu C/cm^2$ and V_E of 300eV(○) and 40eV(●).

is strongly related to the diffusion of As into the damaged region. However, at 40eV, it was found that the amounts of adsorbed As were almost independent of T_{sub}. This result indicates less damage generation due to low V_E. At 200℃, the amounts of adsorbed As were less then 1ML both for 300eV and 40eV because the surface modification was not fully occurred. And higher than 400℃, the amounts of adsorbed As were gradually decreased at 40eV. This is considered to be the desorption of adsorbed As on the CaF_2 surface. From this results, 300℃ of T_{sub} was used for the heteroepitaxy of GaAs on the CaF_2 films.

In order to clarify the effect of V_E on the crystallinity of GaAs on the CaF_2, electron Hall mobilities of the GaAs films as a function of V_E were observed as shown in Figure 4. The electron Hall mobility was found to depend on V_E strongly. At 40eV, the highest Hall mobility about 1960cm²/V-s
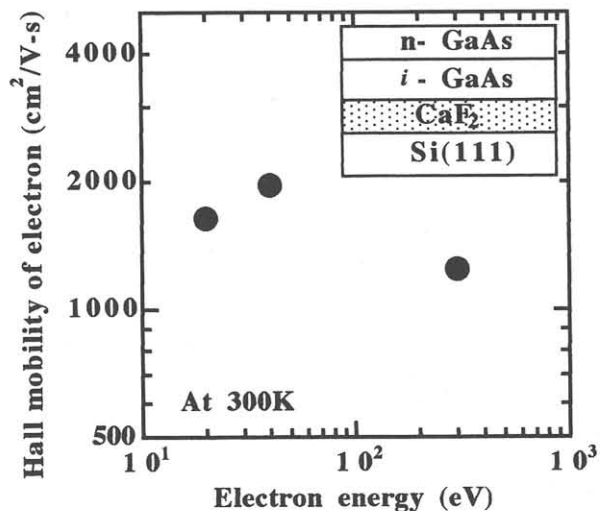
Figure 4. Dependence of electron Hall mobility at 300K in the $3\sim4\times10^{17}cm^{-3}$ Si doped GaAs film on V_E at 300°C of T_{sub} with electron dose of $6000\mu C/cm^2$.

with $3.5\times10^{17}cm^3$ of electron concentration was obtained. From this results, it can be said that 40eV is optimum energy, as far as this experiment, which is consistent with the result of the As adsorption behavior.

The optimization of process parameters for the heteroepitaxy of GaAs on the fluorides such as electron dose and substrate temperature is now under way.

4. SUMMARY

The adsorption of As on the CaF_2 surface was independent of T_{sub} at 40eV, whereas strong T_{sub} dependence was found at 300eV. Electron Hall mobility of GaAs on the CaF_2 films showed that V_E of 40eV was optimum. The crystallinity of GaAs on the CaF_2 films and adsorption behavior of As strongly depended on the V_E during the surface modification. This is considered to be related to the electron beam induced damage in the CaF_2.

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