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Ar Ion Laser-Assisted MOMBE and Selective Growth of InGaAs

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This reports the selective growth of InGaAs by Ar ion laser-assisted MOMBE. Laser irradiation increases the GaAs growth rate in InGaAs at substrate temperatures below 500°C, but decreases it above 500°C. No change is observed for the InAs growth rate in InGaAs due to laser irradiation. The cross-section profile of the laser-irradiated area at 580°C is nearly rectangular, which is quite different from the Gaussian profile at 460°C. A line pattern is formed by scanning a laser beam.

1. Introduction

Recently, there has been considerable interest in the selective area growth of III-V compound semiconductors. This growth method has potential for realizing deposition of patterned films without lithography. Many studies have reported the selective growth of GaAs, InP and AlGaAs by either metalorganic chemical vapor deposition (MOCVD) or metalorganic molecular beam epitaxy (MOMBE)[1-4]. However, none has dealt with the selective growth of InGaAs. So far, only growth rate enhancement due to laser irradiation at substrate temperatures below 500°C has been studied. Such low temperature growth is incapable of yielding films that are of sufficient high quality to fabricate electronic or optical devices. This letter reports the first selective growth of InGaAs by Ar ion laser-assisted MOMBE ; specifically, growth suppression due to laser irradiation above 500°C in contrast to growth rate enhancement below 500 °C.

2. Experimental

Experiments were performed in a modified MBE system equipped with gas lines for trimethylindium (TMI), triethylgallium (TEG), and arsine(AsH_3). TMI and TEG were introduced into the growth chamber without any carrier gas. AsH_3 was introduced through a low-pressure cell heated to 920°C. Electronic mass flow controllers were used for the precise flux control of TMI, TEG, and AsH_3. Iron-doped semi-insulating or Sn-doped n-type (100)-oriented InP substrates were used. The substrate temperature was monitored by an infrared pyrometer calibrated using the melting point for InSb, 525°C, as a reference, and was varied over a range of 400-600°C. A cw Ar ion laser beam (514.5 nm) was focused on a 400-μm spot and directed at the substrates at normal incidence. Laser power was 500-650 mW. The laser beam was scanned with a galvanometer-controlled turning mirror to form a line pattern. Typical InGaAs growth rate was 1.0 μm/h and the electron mobility was about 40000 cm^2/vs (at 77 K) at a substrate temperature of 555°C. The compositions of the InGaAs films were measured by Auger electron spectroscopy (AES). In AES analysis using a PERKIN ELMER SAM-660, the electron beam voltage was 3-5 keV. Auger electron emissions of In and Ga were detected from an area 20 μm in diameter.

3. Results and Discussion

Figure 1 shows the dependences of the InGaAs growth rates of the laser-irradiated and nonirradiated areas on the substrate temperature. The growth rates of the nonirradiated areas, shown as open circles, increase from 0.5 to 1.1 μm/h as the substrate temperature increases from 400 to 500°C. The growth rate is almost constant in the range 500-550°C, then falls off drastically at 600°C[5]. The growth rates of the laser-irradiated areas, shown as solid circles, are greater than those of the nonirradiated areas below 500°C, but smaller above 500°C. That is, laser irradiation increases the growth rate below 500°C, but decreases it above 500°C. At 580°C, the growth rate of the laser-irradiated area decreases to half that of the nonirradiated area. It is found for the first time that laser irradiation suppresses InGaAs growth rate. Figure 1 suggests that this suppression may be attributed to a local heating due to laser irradiation by about 20 degrees.

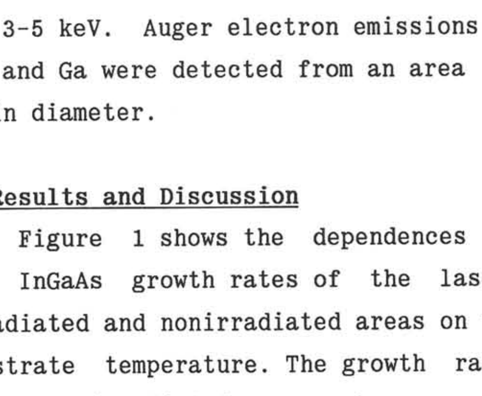

Fig.1. Comparison of substrate temperature dependence of the InGaAs growth rates of the laser-irradiated and the nonirradiated areas. Laser power : 500 mW.

Next, we studied the reason for the InGaAs growth rate variation due to laser irradiation. The substrate temperature dependences of GaAs and InAs growth rates in the InGaAs films are shown in Fig.2. InAs growth rates are determined from the growth rate of InGaAs and the InGaAs composition ascertained by AES analysis. Laser irradiation increases the GaAs

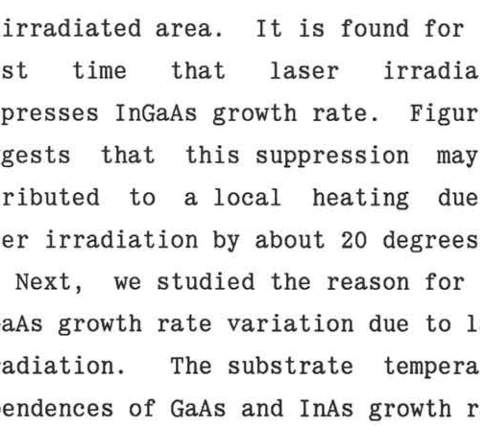

Fig.2. Comparison of substrate temperature dependence of the GaAs and InAs growth rates in InGaAs of the laser-irradiated and nonirradiated areas. Circles (○,●) indicate InGaAs growth rates. Triangles (△,▲) indicate InAs growth rates. Laser power: 500 mW.

growth rate below 500°C, but decreases it above 500°C. No change is observed for the InAs growth rate due to laser irradiation. Therefore, variations in the InGaAs growth rate by laser irradiation are attributed to those in GaAs growth rate in the InGaAs films.

Figure 3 shows cross-section profiles of the laser-irradiated areas of the InGaAs films grown at 460°C (a) and 580°C (b). The former is a Gaussian-like profile and, is similar to the profile obtained in the case of GaAs selective growth.[1)] In contrast, the latter is nearly rectangular, which has yet to be obtained by any other laser-assisted selective growth methods. The film quality of the nonirradiated area at 580°C (electron mobility was 401400cm^{2}/vs at 77K) is much higher than that at 460°C (7500cm^{2}/vs at 77K). Therefore, selective growth above 500°C is feasible for the fabrication of electronic or optical devices.

Laser beam scanning is applied to form a line pattern. A photograph of the patterned film is shown in Fig.4. Laser power was 650mW. The line pattern is 2 mm long and 280 µm wide. The cross-section profile is similar to that shown in Figure 3 (b). The result indicates that laser beam scanning can be applied to the formation of various patterns.

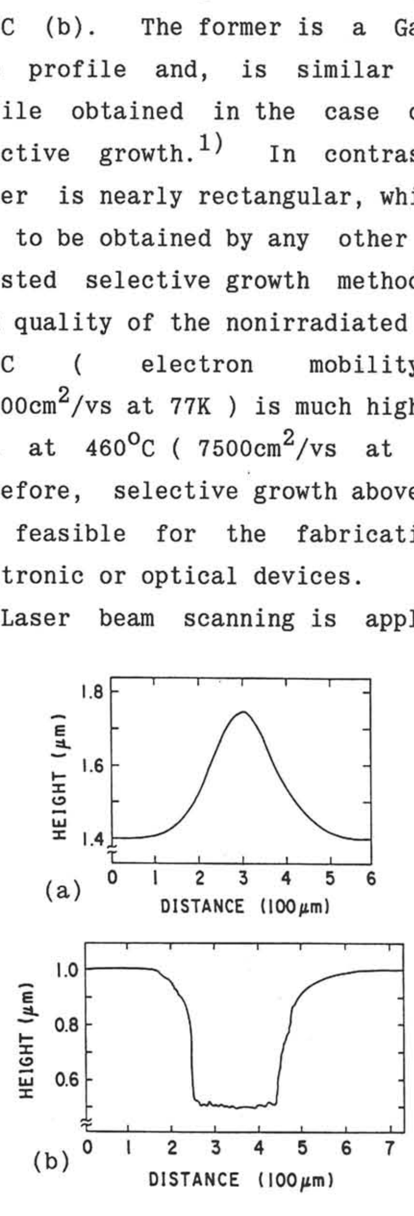

Fig.3. Cross-section profiles of the laser-irradiated area of the films grown at 460°C (a) and 580°C (b).

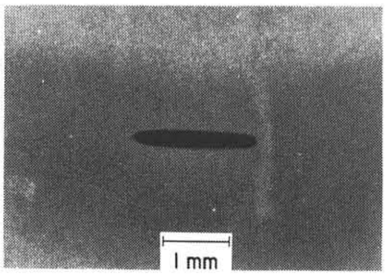

Fig.4. Photograph of a line-patterned film grown by laser scanning. Laser power :650mW.

Here, we briefly describe the mechanism of growth rate suppression. Laser irradiation heats the irradiated area by 20 degrees, which coincides with that derived theoretically[6)]. The temperature rise enhances desorption of As atoms from the surface, resulting in an increase in the re-evaporation of TEG on the substrate surface.

4. Conclusion

We have achieved the first selective growth of InGaAs by Ar ion laser-assisted metalorganic molecular beam epitaxy. Laser irradiation increases the GaAs growth rate in InGaAs below 500°C, but decreases it above 500°C. No change is observed for the InAs growth rate in InGaAs due to laser irradiation. The cross-section profile where the growth rate suppression occurs is nearly rectangular. In addition, line patterns are formed by laser beam scanning.

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References

1)H.Sugiura, R.Iga and T.Yamada; Appl. Phys. Lett. 54(1989)335.
2)V.M.Donnely, C.W.Tu, J.C.Beggy, V.R.McCrary, M.G.Lamont, T.D.Harris, F.A.Baiocchi and R.C.Farrow; Appl. Phys. Lett. 52(1988)1065.
3)A.Doi, S.Iwai, T.Meguro and S.Nanba; Jpn. J. Appl. Phys. 27(1988)795.
4)R.Iga, H.Sugiura and T.Yamada; Appl. Phys. Lett. 51(1989)451.
5)G.J.Davies, and D.A.Andrews; CHEMITRONICS, 3(1988)3.
6)Y.I.Nissim, A.Lietoila, R.B.Gold, and J.K.Gibbons ; J. Appl. Phys. 51(1980)274.