Growth of triangular shaped InGaAs/GaAs quantum wire structures

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In the future, semiconductor device technology will be developed based on nanometer sized ultra fine quantum structures. Recently, low dimensional structures such as quantum wires (one dimensional system) and quantum dots (zero dimensional system) have been actively investigated in many research laboratories [1–4]. It has been predicted that optical transitions and electrical transport properties should be significantly modified in low dimensional structures.

To fabricate low dimensional quantum structures, the control of the confined region is very important. Thus several approaches have been proposed to fabricate such low dimensional structures. Selective area epitaxy [3–6] by metalorganic chemical vapor deposition (MOCVD) is one of the most attractive techniques for providing direct control of the confined region in low dimensional structures.

In this work, we report on highly selective $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}/\text{GaAs}$ quantum wire structures grown by

low pressure MOCVD. The cleaved surface and top surface morphology of the grown structures were analyzed by using scanning electron microscopy (SEM).

The MOCVD growth was carried out in a horizontal, IR heated reactor at a pressure of 76 torr. As source materials, trimethylgallium, trimethylaluminum, trimethylindium, 100% arsine and 500 ppm SiH_4 diluted in H_2 were used. The growth temperature was 600 °C and V/III ratio was 100.

For the growth of GaAs/AlGaAs multilayer and InGaAs quantum wire structures, the first step is deposition of SiO_2 by plasma enhanced chemical vapor deposition (PECVD) and coating of photoresist (PR) on the substrate. Then the substrates are patterned with orientations along the [110] or $[1\bar{1}0]$, using conventional optical lithography. PR and SiO_2 layer can be removed by developer and buffered HF solution, respectively. The final step is MOCVD growth for InGaAs quantum wire structures.

(a)

Figure 1 SEM images of $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}/\text{GaAs}$ quantum wire structures. Stripes are aligned with [110] direction with (a) 2 μm , (b) 3 μm . (Continued)

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(b)

Figure 1 (Continued).

(a)

(b)

Figure 2 A magnified SEM image of $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}/\text{GaAs}$ structure grown at 600°C with opening windows of (a) $2\ \mu\text{m}$, (b) $6\ \mu\text{m}$.

Figure 3 A SEM image of the grown triangular shaped quantum wire structure where heights are depended on the width of opening windows.

When the growth rate was above $1.0 \mu\text{m/h}$, the surface of the grown GaAs/ $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ multilayer structure for test was not good. The surface morphology of $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ was more sensitive to the growth rate than GaAs. This is due to the slower surface migration velocity of Al adatoms than of Ga [4, 5]. So we have reduced the growth rate of $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ to $0.52 \mu\text{m/h}$ and of GaAs to $0.7 \mu\text{m/h}$.

InGaAs/GaAs quantum wire structures were grown by selective area epitaxy. Two samples were grown in the same reactor at the same time. Fig. 1 shows the SEM images of $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}/\text{GaAs}$ quantum wire structures grown on SiO_2 masked GaAs substrate. Stripes are aligned with [110] direction with separation of (a) $2 \mu\text{m}$, (b) $3 \mu\text{m}$. In the case of sample (b), the growth time was not enough to form the triangular structure. So for obtaining the completely grown triangular structure, a little longer growth time is needed.

Fig. 2 shows the magnified SEM images of $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}/\text{GaAs}$ quantum wire structures of Fig. 1a. In Fig. 2a, the detailed structure is GaAs (40 nm)/Si-delta doped layer/GaAs (7 nm)/InGaAs (5 nm)/GaAs buffer layer. No polycrystals were observed on the masked area at a growth temperature of 600°C . The facets of grown structure correspond to {111} B plane, and shows nearly perfect mirror surface. The smooth surface for the (111) B facet may be due to the higher migration velocity of adatoms at the (111) B facet than that of (100) facet [5]. Quantum wires are formed on top regions of the triangular structures. Fig. 2b shows the SEM images of InGaAs/GaAs quantum wire structures with stripe width of $6 \mu\text{m}$, and the opening stripes are aligned to [110] direction. Even though the opening width is different, we can obtain similar triangular shaped structure.

Fig. 3 shows the dependence on the opening width of the height of the grown triangular shaped quantum wire structures. Even though the opening width is different, it is possible to obtain similar triangular shaped structure. But the height of the triangular structure is

different, so the thickness of the quantum wire would be different. If we use this kind of different sized quantum confined structure, it would be possible to grow quantum wire structures with various thickness. So uniquely integrated optical devices, which include light emitting sources of multiple wavelength, could be fabricated.

In this work, we have grown $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}/\text{GaAs}$ quantum wire structures. Good quality of triangular shaped quantum structures with sharp tips and smooth side walls were grown on SiO_2 masked GaAs substrate by low pressure MOCVD. Even though the opening width is different, it was possible to obtain similar triangular shaped structure. If we use this kind of different sized quantum confined structure, it would be possible to grow quantum wire structures with various thickness and light emitting sources of multiple wavelength.

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