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Regular Array Formation of Self-Assembled InAs Dots Grown on Patterned (111)B GaAs Substrate by MBE

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Self-organized growth of InAs dots on GaAs by Stranski-Krastanow growth mode [1-5] is drawing much attention for future device application. For such applications, control of the dot distribution is essential as well as the control of the dot size. However formation of periodic InAs dots on (100) GaAs has not so far been reported. In this paper, InAs dots on patterned (111)B GaAs substrates were investigated for the realization of regular array formation.

(111)B GaAs substrates were patterned by using conventional optical lithography process and wet-chemical etching. Self-assembled InAs dot growth was investigated on both inverted tetrahedral-shaped pattern formed by anisotropic etching and trapezoidal grooves formed by using the line and space pattern.

Molecular beam epitaxial (MBE) growth of InAs dots were perfomed at substrate temperature ranged from 510℃ to 540℃. During the growth of InAs dots, the arsenic beam equivalent pressure of 7.5×10^{-6} Torr and the InAs growth rate of 0.05 ML/s were used. In order to enhance the migration of In atoms on the surface, multiple sequences of 2 seconds of the InAs growth followed by 4 seconds or 10 seconds of arsenic exposure were used. Prior to the InAs dot growth, 50Å of GaAs layer was grown on the patterned substrate.

Firstly, InAs growth on tetrahedral etch-pit pattern was investigated. Figures 1 (a), (b) and (c) show SEM images of inverted tetrahedral shaped surfaces after the InAs growth at substrate temperature (T_S) of 510℃, 530℃ and 540℃, respectively. The total amount of InAs deposition was 2.5ML. The multiple sequence of 2 seconds of the InAs growth followed by 10 seconds of arsenic exposure was used. InAs dots were selectively grown on the bottom of the tetrahedral etch-pit when the growth condition of T_S = 530℃ was chosen as shown in Fig.1 (b). On the other hand, the InAs dots grown were formed on the etched wall as shown in Fig.1 (a) when the growth condition of T_S = 510℃ was used. This difference indicates that the migration of In atoms were enhanced by raising of the temperature from 510℃ to 530℃. Furthermore, InAs dots could not be observed on the surface of the sample grown at 540℃ as shown in Fig.1 (c). This result indicates that the growth temperature of 540℃ does not allow the formation of InAs dots because of the high evaporation rate of In atoms on the surface. Figure 2 shows SEM image of inverted tetrahedral shaped surface after the InAs growth at temperature of 530℃ using the multiple sequence of 2 seconds of the InAs growth followed by 4 seconds of arsenic exposure. The best yield for T_S = 530℃ was obtained so far 70%.

InAs growth on trapezoidal grooves was also investigated. Figures 3 (a) and (b) show SEM images of InAs dots grown on trapezoidal grooves. The InAs dots shown in Fig.3 (a) and (b) were grown on the groove pattern along the direction of $[2\bar{1}\bar{1}]$ and $[0\bar{1}1]$, respectively. Total amount of InAs growth of 2.5ML and 2.0ML, and the sequence of the duration without the In pressure of 10 seconds and 4 seconds were used for Fig.3 (a) and (b), respectively. Most of the InAs dots were found on the middle of the slope ((331) facet) as shown in Fig.3 (a). Furthermore, the periodicity of the InAs dot position along the line direction was reasonably good. There is a possibility that the position of the InAs dots are determined by the "periodic" inhomogeneous lattice strain observed at the slope in the initial stage of the strained layer growth [6]. On the other hand, the InAs dots shown in Fig.3 (b) were formed along the top and the bottom surface. Thus, by controlling the growth condition and line direction, the InAs dot arrays can be selectively formed on the trapezoidal grooves.

These experimental results of InAs dots grown both on inverted tetrahedral pattern and on trapezoidal grooves show a possibility of arrayed InAs dot formation by using the suitable growth condition. Further experiments and analyses are needed to determine precise growth conditions and to clarify the physical mechanism of the natural array formation.

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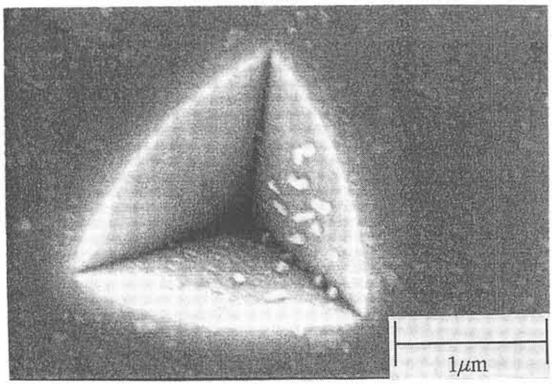
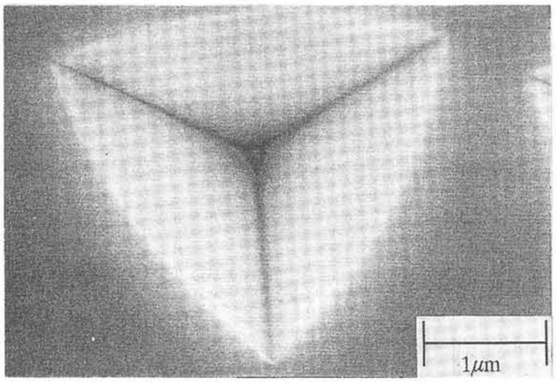


(a)



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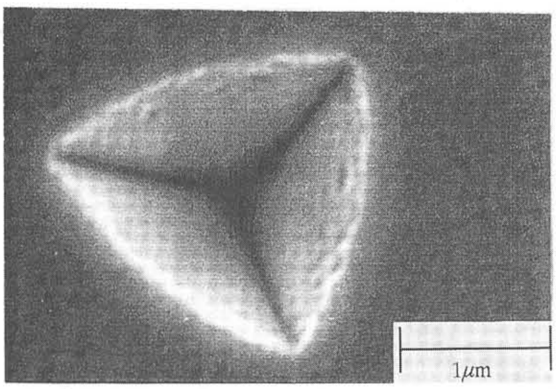


(c)

Fig.1 SEM image of inverted tetrahedral shaped surfaces after the InAs growth at temperature of (a)510℃, (b)530℃ and (c)540℃, respectively.

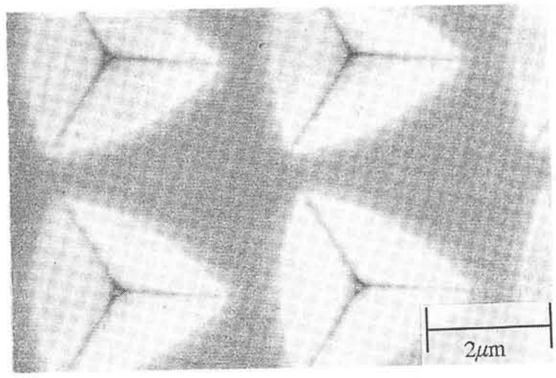
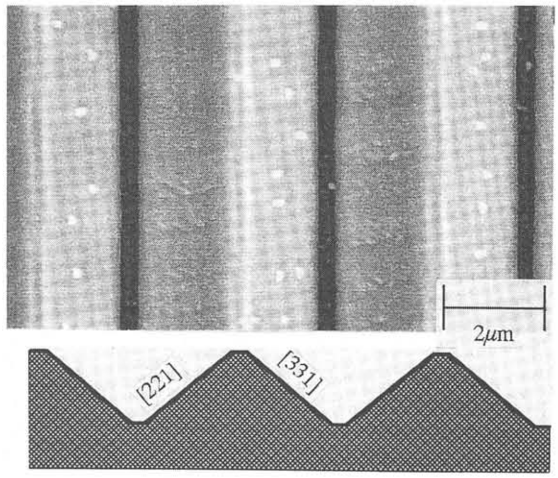
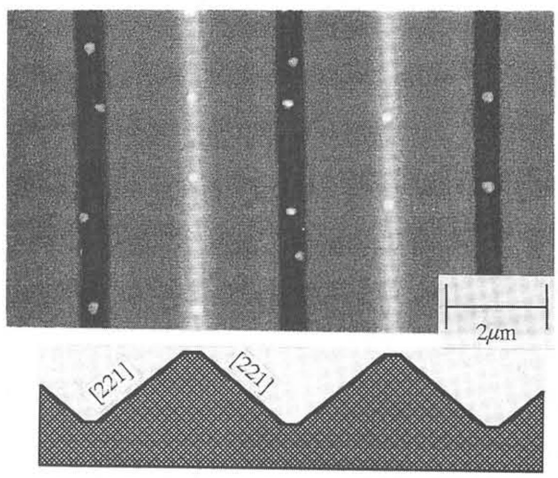


Fig.2 SEM image of inverted tetrahedral shaped surface after the InAs growth at temperature of 530℃ using the multiple sequence of 2 seconds of the InAs growth followed by 4 seconds of arsenic exposure.



(a)



(b)

Fig.3 SEM image of InAs dots grown on the groove pattern along the direction of (a) [2$\bar{1}\bar{1}$] and (b) [0$\bar{1}$1].