

Surface Analysis of Compound Semiconductor Nano-structures by AFM and STM

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We investigate the formation of self-organized GaAs and InGaAs quantum wires (QWRs) on coherent multiautomic-stepped AlGaAs/GaAs on (001) GaAs vicinal substrates by using atomic force microscopy (AFM). In the initial stages of GaAs growth, Ga atoms preferentially attach to the bottom edges of the multiautomic steps to form QWRs. We also investigate surface reconstruction on coherent multiautomic-stepped GaAs on (001) GaAs vicinal surface by using ultra-high vacuum scanning tunneling microscope (UHV-STM). From these results we discuss the growth mechanisms.

1. Introduction

Low dimensional electron confinement systems, such as quantum wires and dots, have been attracting much attention because of their novel electrical and optical properties. We reported on the direct fabrication methods of GaAs/Al_xGa_{1-x}As quantum wire (QWR) structures by crystal growth on vicinal surface using self-organization techniques, and describe the structural and optical properties of those low-dimensional electron systems whose active regions are buried two dimensionally in cladding materials[1]. We used metalorganic vapor phase epitaxy (MOVPE) to grow the structures. The advantages of this method are that the size and shape of the wires and dots are controlled by the substrate pattern and/or crystal growth conditions, and that damage-free and contamination-free interfaces are formed. Characterization methods are also very important for the formation of uniform quantum nano-structures. We used atomic force microscopy (AFM) for the study of surface morphology and ultra-high vacuum scanning tunneling microscopy (UHV-STM) for the study of reconstructed GaAs stepped surface. From these results, we discuss detail of QWR formation mechanisms.

2. Experiments

First we report on formation of coherent multiautomic steps on GaAs vicinal surfaces. Coherent multiautomic steps with extremely straight edges were widely formed by MOVPE under various growth conditions. The average spacing of the multiautomic steps depends on the growth temperature, growth rate and AsH₃ partial pressure, and is 30-100nm [2]. Figure 1(a) shows typical AFM image of the GaAs grown layer surface. Uniformity and periodicity are easily observed by AFM.

For discussion of the multiautomic step formation mechanisms, more detail information on surface atomic structures is needed. We observed the surface reconstruction structures at the atomic step area as well as on the terrace by UHV-STM. We observed c4x4 reconstruction which includes As dimers on the terrace of MOVPE grown (001) surface. At the multiautomic step areas, 4x reconstruction was also observed. This indicates that 4x reconstruction is most stable atomic structure even at the multiautomic step areas. From STM line scan profile, average tilted angle is close to 9-10 degree, which corresponds to (119) surface. We will discuss the formation mechanism using Schwoebel barrier model[3].

Self-organizing QWR structures were

also grown on GaAs layer with coherent multiatomic steps as schematically shown in Fig. 1(b). PL peak energies of the QWRs on vicinal substrates measured at 20 K were smaller than those of the QWs formed on (001) exactly oriented GaAs substrates. The peak energy shift indicates that locally thick quantum wire like structures were successfully formed at the edge of multiatomic steps as illustrated in Fig. 1(b).

References

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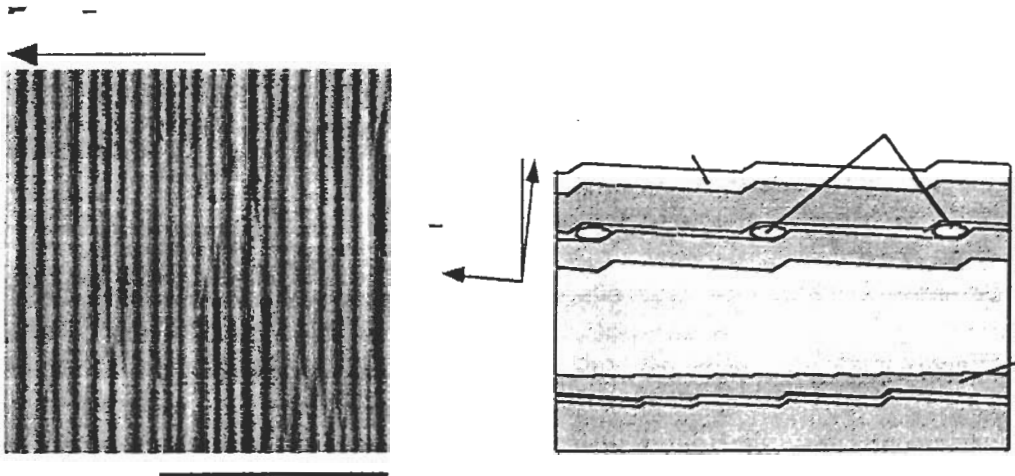


Fig.1. (a) AFM image of multiatomic steps formed on GaAs vicinal surface. (b) Schematic view of GaAs QWRs formed on GaAs (001) vicinal surface.