Atomically smooth GaAs (110) surface fabricated by growth-interrupt annealing and cleaved-edge overgrowth

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MBE growth of GaAs on a cleaved (110) surface is becoming of increasing importance as a fabrication method for novel semiconductor nanostructures. The overgrowth on a cleaved (110) surface requires, however, a low substrate temperature range (470 - 510°C) and a very high As_4-vapor overpressure for GaAs, and overgrown film has rough surfaces. We have found that rough as-grown (110) surface turns to an atomically smooth surface if we perform growth-interrupt in-situ annealing at 600 °C for 10 min [1]. This annealing method enables us to realize quantum wires and wells with unprecedentedly high quality.

The purpose of this joint study is to understand formation mechanisms of the atomically flat (110) GaAs surface. For this purpose, we formed annealed (110) GaAs surface with fractional monolayer (ML) coverage, and performed AFM measurements on characteristic step-edges shapes of isolated pits and islands [1], and also performed statistical analysis on the size and shape distribution of 1-ML-deep pits [2].

Figure 1 shows a model for the atomic step-edges of the 1-ML-deep pit, which is based on the stability of atomic sites. Our model, namely Ga atom migration occurs from two-bond sites to three-bond sites having higher stability, well explained the driving force to form an atomically smooth surface and characteristic atomic step edges [2].

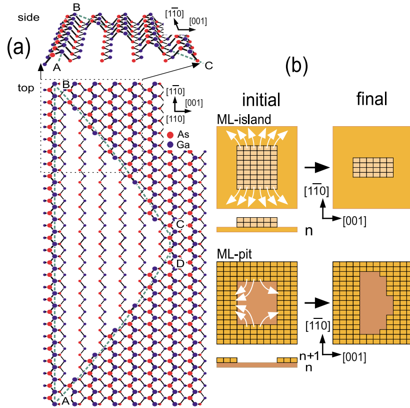

FIG. 1: (**a**) Top and side views of the atomic arrangement model of a 1-ML-deep pit observed on the annealed (110) surface. This model has the Ga-terminated three-bond step-edge (A-B), the As-terminated three-bond step-edge (C-D), and the two-bond step-edges (A-D and B-C). (**b**) Atomic step kinetics of the surface evolution during annealing. Proposed schematic drawings of the evolution for the island and pit structures from an assumed square initial shape.

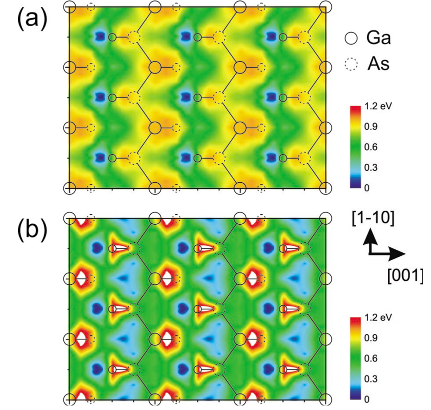

FIG. 2: Contour map of migration barrier energy for (a) Ga adatom and (b) As adatom on a GaAs (110) surface with the surface atomic configuration. The dotted and solid circles correspond to As and Ga, respectively.

We also performed the first-principles calculation on the migration barrier energy for Ga and As adatoms on a GaAs (110) surface [3]. The results show far smaller barrier energies than those on a (100) GaAs surface, which enable adatoms to migrate in a very long length and explain the formation of a very wide atomically smooth ((110) surface as stated above.

Figure 2 (a) and (b) show the calculated potential surfaces for the Ga and As adatoms on the GaAs (110) surface. Migration barrier energy surface of Ga adatoms is 1-D, while that of As adatoms is 2-D. For both Ga and As adatoms, the stable near As of the topmost layer are very stable, while those near Ga are unstable. This fact explains the asymmetric shapes of 1 ML deep pits shown in Fig. 1 (a).

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