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Growth of truncated pyramidal InSb nanostructures on GaAs substrate

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ABSTRACT

Growth and structural characterization of InSb nanostructures formed on GaAs is presented. Saturated InSb nanostructure have a truncated pyramidal shape with rectangular base. In addition, some InSb nanostructures have twin truncated pyramidal configurations. The twin truncated pyramids align in parallel with each other and along [110] direction. We attribute the formation of rectangular base to the growth of highly mismatched InSb/GaAs system while the formation of twin configuration due to the nucleation of InSb islands on top of two-dimensional InSb plateau. The latter is suggested by an observation on the initial state of InSb nanostructure formation.

1. Introduction

Until now, growth techniques to realize semiconductor nanostructures especially quantum dot (QD) and QD molecule are still of interest [1]. Among them, self-assembled growth in non-planar growth modes is a popular method. Several techniques such as growth on patterned substrate [2], droplet epitaxy [3] and growth with *in situ* etching [4,5] have been utilized to demonstrate the realization of QD and QD molecules. Some of them have been spectroscopically checked for controlling the electronic coupling [6]. Concerning the material systems, InSb possesses the lowest semiconductor bandgap and high electron mobility. It is utilized in many optoelectronic applications such as infrared photodetectors [7–9]. Many previous studies have shown that one can realize InSb QD nanostructures in different matrices and the obtained nanostructures depend strongly on the growth conditions [10–14]. For InSb/GaAs, only a few studies have been reported [12–14]. Different growth techniques have been applied. For example, Bennett et al. [13] adopt migration-enhanced epitaxy to successfully grow InSb QD. Here we present our investigation on the growth of InSb QD nanostructures, which are formed into truncated pyramidal shape with rectangular base. With our applied growth conditions for growing InSb QDs, we have obtained distinct different QD morphology from other works. In addition, we found that some InSb nanostructures are formed into twin dot configuration, which can be explained by spatially different nucleation of InSb islands on the two-dimensional InSb plateau. Based on the experimentally observed results, growth scenario is depicted. This system might be usable for realizing self-assembled InSb QD molecules.

2. Experimental details

Self-assembled InSb nanostructures are grown on semi-insulating GaAs substrate by a solid-source molecular beam epitaxy with Sb valved cracker cell. First, the substrate is annealed at ~600 °C in As_4 rich atmosphere for removing native oxide surface. The 500-nm-thick GaAs layer is grown on the substrate at 580 °C as a buffer layer. Reflection high energy electron diffraction (RHEED) is monitored during growth and it shows typically streaky (2×4) surface reconstruction. After the buffer layer growth is completed, the substrate and the As_4 cell temperatures are cooled down to 260 °C and 180 °C, respectively. We then wait until the chamber background pressure is lower than 5×10^{-9} Torr. When the suitable background pressure is achieved, the GaAs surface is exposed to Sb_4 beam flux for 60 s. The exchange reaction between Sb and As atoms occurs [15]. After that, indium cell shutter is opened to deposit nominally 3.0 monolayer (ML) InSb layer at the growth rate of 0.01 ML/s and V/III ratio (Sb_4 to In beam flux) of

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