液滴エピタキシー法による InP(111) A 基板上 InAs 量子ドット成長過程 における濡れ層形成とその制御

Formation and control of wetting layer during the growth of InAs quantum dots on InP(111)A by droplet epitaxy

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Introduction On the GaAs and InP (111)A substrates, it is difficult to form InAs QDs using the conventional Stranski-Krastanov (SK) method [1.2]. Instead of island formation, InAs grows two-dimensionally owing to the strain relief by misfit dislocations at the initial stage of these heteroepitaxy systems. To achieve the InAs QDs that emit entangled photons at telecom wavelengths of 1.3 and 1.55 μ m, we successfully grew highly-symmetric InAs QDs on InP (111)A substrates by employing droplet epitaxy (DE) [3]. Unlike the strain-free GaAs QDs by DE, however, we found significant size and/or density changes of InAs QDs after a capless annealing, accompanied by a formation of strained two-dimensional wetting layer (WL). In this work, we report that the above-mentioned phenomena are dramatically prevented when a monolayer InAs is previously grown before the QDs formation by DE.

Experiments The samples were grown on InP(111)A by a solid source molecular beam epitaxy. We prepared two kinds of buffer structures for the InAs QDs formation. In sample A, 150 nm-In_{0.52}Al_{0.48}As grown at 470°C was used as a buffer, and in sample B a monolayer-thick InAs was additionally grown on the top of the In_{0.52}Al_{0.48}As. On these buffers, 0.4 ML In was supplied to form In droplets at 270°C without As flux. The In droplets were crystallized by a supply of As₄ flux of 3×10^{-5} Torr at 270°C, followed by annealing at 370°C for 5 minutes under As₄ supply. The surface morphology was characterized by an atomic force microscope in air.

<u>Results and discussion</u> Figures 1 (a) and (b) show the surface morphology after crystallization (before capless annealing) for samples A and B. In both cases, QDs were formed. The densities are (a) 3.6×10^{10} /cm² and (b) 1.7×10^{10} /cm². These changes might be caused by the difference in surface migration potential between the In_{0.52}Al_{0.48}As and InAs surfaces for In droplet formation After annealing the sample A at 370° C, most of the QDs disappeared and the density decreased drastically to 5.0×10^{8} /cm² (Fig.1 (c)). We attribute this disappearance of QDs to the growth of a strained two-dimensional WL caused by detaching

and diffusion of the constituent atoms from InAs QDs. In contrast, many QDs remain after annealing in sample B (Fig. 1 (d)). The density is 8.3×10^9 /cm². In addition, the averaged size of the QDs increases. During the capless annealing, diffusion of atoms from the QDs should occur. However, the surface was previously covered with strained InAs WL and further growth of WL may not occur preferably in order to prevent the strain accumulation. Instead, the diffusing atoms migrate toward another QD, which might result in the ripening effect. These results suggest that strain balance should be taken into account to control the size and density of DE-QDs in strained InAs/InP(111)A system.

References

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Fig. 1 AFM images of InAs QDs on (a) sample A and (b) sample B after crystallization. (c) and (d) AFM images after capless annealing.