CHAPTER V

CONCLUSIONS

In series of thin-capping-and-regrowth MBE process for QDM formation, it is found that nanohole shape, i.e. size and depth, formed after the capping stage directly impacts the shape of QDM. The as-grown InAs QDs capped by a thin GaAs layer at low temperature are changed to nanohole. After the deposition of the GaAs capping layer on the as-grown InAs QDs, the deposited Ga atoms prefer to migrate from the top of the dot, due to the lattice mismatch between GaAs and InAs at the top of QDs is higher than that between GaAs and InAs at the wetting layer. The material transport away from the island surface during GaAs cap layer growth is a consequence of the surface chemical potential resulting in the directional migration of adatoms on the surface. The strain profile modifies the chemical potential of Ga induces net Ga migration away from the dot and reduces the growth rate of GaAs at the top of QD. The GaAs would cover the sides of the InAs QDs, yet some InAs QDs remains are left on the surface. After capping, QD is collapsed due to the In atom diffused out from dot resulting in the reduction of QD size. When the GaAs capping layer is thicker, more In atoms are pulled out from the dots, leading to the increase nanoholes depth.

Subsequent regrowth of InAs on nanoholes results in nano-propeller QDs with alignment along the $[1\bar{1}0]$ crystallographic directions. When the QD of nano-propellers are not saturated, the deeper nanoholes give smaller dots due to the smaller remained InAs islands at the center of nanoholes. The variation of capping thickness defines also the length of nano-propeller blades. At the thinner capping layer, the In content at the base side is higher due to the lower Ga atoms at the surface resulting in In atoms accumulate because of the lower mismatch between InAs and $In_xGa_{1-x}As$. The more In atoms are accumulated, the larger blade are formed.

When the amount of InAs regrowth layer increases, QDMs with different shapes are created. We observed that if the blade size of nano-propeller is large and long, the number of satellite dots is likely to be high. However, when the amount of InAs is greater than a critical regrowth thickness, the high dot density is obtained resulting in less uniform QDM.

When the GaAs capping thickness increases, the center dot height increases, as the satellite dot decreases. Therefore, the height difference between center dot and satellite dot tend to increase when the GaAs capping thickness become thicker.

The PL results of QDMs with different capping thicknesses and different regrowth thicknesses are studied. The ground state peak emission of center dot at low excitation power in each case would appear first. And then, if the excitation energy increase, the

first excited state of center dot and ground state and the higher excited states exhibit.

However, the observed results are in contrast with spectra observed from as-grown quantum dots. These results are explained by state filling in the presence of extended electron states formed due to lateral electronic coupling of the QDs within the QDMs. The asymmetric broadening together with the shift of the PL peak towards higher energies are first indications for the formation of extended states in the QDMs due to tunnel coupling. Tunnel coupling of the QD ground states creates extended states with a distinct energy separation determined by the coupling strength.

Our PL results from some case of different QDMs also exhibit the shift of the PL peaks toward higher energies. We believe that the coupling between center dot and satellite dots lead to the extending in band structures.