CHAPTER VI

CONCLUSION

The following are the main results presented in this thesis:

By using Schrödinger equation implemented using the finite difference method, the degree of linear polarization was subsequently calculated. For calculations, the dimensions of the QDs were approximated from the AFM images. The QDs investigated in this thesis were assumed to be flat in the [001] growth direction and had extended sizes in the $[1\bar{1}0]$ and the [110] directions. Two-dimensional Schrödinger equation was thus used for the calculation. It was found that, the polarization degree strongly depends on the wavefunction overlapping between adjacent quantum dots. For single, isotropic quantum dots, a certain degree of polarization is obtained when the dot is elongated in one direction. For binary quantum dots and aligned quantum dots, the polarization degree strongly depends on spacing (thickness) between the adjacent quantum dots. When the interdot spacing is smallest (thinnest barrier between adjacent dots), the largest polarization degree is obtained. Dot size also affects the polarization degree. Smaller quantum dots, when closely aligned, show a larger degree of coupling, and as a result, emit luminescence with a larger degree of linear polarization. For larger isotropic quantum dots in the alignment, the wavefunction is confined in the dot region and hence a small extent of wavefunction overlapping among adjacent dots. In summary, to get a larger polarization degree from aligned quantum dots, a smaller dot size, a smaller interdot spacing and a longer alignment of dots are preferred.

However, there were several difficulties in the calculations. First, the Matlab® program was used in the simplest form for this work. Secondly, since the finite difference method was used to numerically solve the Schrödinger equation and the nature of this method is based on mesh or grid points, the number of accuracy of the calculation results depends on the number and size of grid points used. Matlab® has limitation when running too large matrix. In order to get the better results and to extend the size of the problems as we want, we should use other scientific programs like C++ or FORTRAN. Using the Finite Element Method (FEM) can reduce the size of the grid compared with the Finite Difference Method (FDM).

For the experimental results, excitation-power-dependent, temperature-dependent and polarization-resolved photoluminescence spectroscopy were used to optically characterize the laterally aligned quantum dots samples, specifically binary-QDs, one-dimensional linearly aligned quantum dots and two-dimensional alignment of QDs on a cross-hatch pattern. Optical measurements reveal interesting behavior of those laterally aligned quantum dots which could be due to size anisotropy, effect of coupling between QDs, and lateral alignment of quantum dots, as well as strong PL emission at room temperature and temperature-insensitive linewidths.

An interesting property of aligned quantum dots is the polarization property. The degree of this property depends on length of alignment of the QDs. If the chain of the QDs is longer, the one-dimensional quantum-wire-like aligned quantum dots show a higher degree of polarization property. If the interdot spacing between QDs is small, the coupling effect between aligned QDs may occur and manifest in temperature-dependent measurements. According to the nature of the thin-capping-and-regrowth process, the uncontrollable shape and size sometimes occur on the top-most layer, and so the overall degree of polarization of aligned quantum dots may depend on three intrinsic properties: shape, size, and spacing of the dots.

A binary-QD sample and two linearly aligned quantum dot samples showed that the temperature-dependent PD originates from coupling between the QDs. It was found out that the sample with long alignment and small spacing between QDs showed a higher degree of polarization.

Two-dimensionally aligned QDs on the cross-hatch pattern might be expected to have a higher degree of polarization because of their long-range ordering, but the two-dimensional alignment character may result in cancellation of the perpendicular linear polarizations. In other words, this kind of sample would exhibit zero degree of linear polarization if the density of QDs in $[1\bar{1}0]$ and [110] directions is the same (so that the polarization in each direction may completely cancel). On the other hand, if strain in the $[1\bar{1}0]$ and the [110] directions are different, or the dot density in each direction are not the same, a high degree of polarization might be obtained. For this sample, around 10 % to 20% of polarization degree was observed. QDs on the cross-hatch pattern did not show temperature-dependent PD. The PD of this sample comes from the shape anisotropy of QDs. AFM images for QDs on a cross-hatch pattern show long alignment of QDs but distance between adjacent dots is not close enough to get wavefunction overlapping, and so the observed PD did not come from coupling but from shape anisotropy.

Originally, there was hope to investigate effect of electric field on laterally aligned InAs quantum dots and study the resonant tunneling of electrons and holes. Studying electric field effect on aligned quantum dot sample was not successful because in the past of this work, there were too many unknowns in the properties of our quantum dots and there was some problem with experimental set up. Those quantum dot parameters are better known, thus this work is worth attempting.