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SUMMARY OF Ph.D. DISSERTATION

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Title

Visualization of local perturbation in semiconductor quantum dots by using a near-field scanning optical microscope

Abstract

Semiconductor quantum dots (QD) are nanostructures which exhibit intriguing quantum mechanical effects due to the three-dimensional confinement of carriers. QDs are also called artificial atoms because their energy level is discretized in the same way as those of an atom. Several applications for quantum information utilizing entanglement or superposition which cannot be realized in classical devices are proposed. For example, an electron spin state confined in QD is a candidate for a quantum two-level system as a building-block of quantum computer. In this case, detection of charged exciton emission is used for the readout of the electron spin state. Entangled photons for quantum cryptography can be formed via two different exciton states by cascade emission from biexciton. Quantum coherence, which can be disturbed by phonon scattering, an impurity or external field. It is important to investigate local perturbation to obtain an exact exciton state in QD.

Self-organized growth is a promising approach to grow uniform QDs at high density. However there remains inhomogeneous spectral broadening when QDs are observed using a far-field optical microscope. A near-field scanning optical microscope (NSOM) is one of the techniques to observe single QDs far beyond the diffraction limit of light. Moreover, aperture which is much smaller than the size of QD enables us to map out a wavefunction of exciton confined in a QD. In this thesis, local perturbations inside and surrounding a QD are visualized by the NSOM mapping of wavefunctions of the exciton and the exciton complex states confined in the QD.

This dissertation consists of seven chapters. Chapter 1 presents applications of QDs and the motivation for the study. In Chapter 2, basic theory of semiconductor quantum structures and near-field optics is explained. Chapter 3 describes the instrumentation and related measurement techniques. Chapter 4 shows the optical visualization of exciton localization due to a shallow potential formed in a QD. Chapter 5 shows the optical detection of surrounding environment of a QD: distortion of an exciton wavefunction due to the local electric field generated by a nearby trapped electron. Fluorescence correlation spectroscopy of the exciton emission to reveal switching behavior between a neutral and charged exciton states is also described. Chapter 6 shows evaluation of transmission coefficient of light through the near-field aperture probe in near-infrared region. Chapter 7 describes the conclusion and perspective.