International Research Center for Elements Science
- Photonic Elements Science -

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Scope of Research

Our research interest is to understand optical and quantum properties of nanometer-scale materials and to develop opto-nanoscience for creation of innovative functional materials. Optical responses of semiconductor quantum nanostructures and low-dimensional strongly correlated electron systems are studied by means of space- and time-resolved laser spectroscopy. The main subjects are as follows: (1) Development of high-resolution scanning near-field optical microscope and optical properties of single nanostructures, (2) Ultrafast optical spectroscopy of excited states of semiconductor nanostructures, and (3) Development of nanoparticles with new optical functions.

Research Activities (Year 2004)

Presentations

Luminescence from Single Nanoparticle Phosphors (Special Lecture), Kanemitsu Y, The 71st Meeting of The Electrochemical Society of Japan, 24 - 26 March, Yokohama, Japan.

Luminescence Properties of Single Semiconductor Nanoparticles Embedded in Transparent Films (invited), Kanemitsu Y, 2004 International Symposium on Organic and Inorganic Electronic Materials and Related Nanotechnologies, 7 - 10 June, Niigata, Japan.

Optical Properties of Wide Band-Gap Semiconductors (invited), Kanemitsu Y, The 65th Autumn Meeting, The Japan Society of Applied Physics, 1 - 4 September, Sendai, Japan.

Photoluminescence Dynamics of Highly Excited GaN (invited), Nagai T and Kanemitsu Y, The 65th Autumn Meeting, The Japan Society of Applied Physics, 1 - 4 September, Sendai, Japan.

Advanced Nano-scale Optical Spectroscopy of Semiconductor Quantum Structures (invited), Matsuda K, The 1st International Symposium on Synchrotron Radiation Nanomaterials Science and Technology, 15 - 17 March, Tokyo, Japan.

Near-field Optical Mapping of Exciton and Biexciton Wavefunctions Confined in a Semiconductor Quantum Dot (invited), Matsuda K, The Conference on Lasers and Electro-Optics/International Quantum Electronics Conference, 16 - 21 May, San Francisco, USA.

Real-space Mapping of Exciton Wave Function in a GaAs Quantum Dot by Near-field Imaging Spectroscopy (invited), Matsuda K, 6th International Conference on Excitonic Processes in Condensed Matter, 6 - 9 July, Cracow, Poland.

Imaging Spectroscopy of Semiconductor Quantum Structures by Near-field Scanning Optical Microscope with a High Spatial Resolution (invited), Matsuda K, 2004 Autumn Meeting, The Physical Society of Japan, 12 - 15 September, Aomori, Japan.

Nano-imaging Spectroscopy of Semiconductor Quantum Structures (invited), Matsuda K, The 4th NSF-MEXT Joint Symposium on Nano-photonics, 27 - 29 October, Tokyo, Japan.

Grants

Kanemitsu Y, Fabrication of Impurity-doped Semiconductor Nanoparticles and Optical Responses of Single Semiconductor Nanoparticles, Grant-in-Aid for Scientific Research (B)(2), 1 April 2002 - 31 March 2005.

Matsuda K, Wavefunction Imaging and Control in Semiconductor Nano-structure by Ultimate Optical Nanoprobe, Precursory Research for Embryonic Science and Technology, Japan Science and Technology Agency, 1 November 2002 - 31 October 2005.

Inouye H, Luminescence Dynamics of Nanoparticles in a Photonic Crystal and Study for Realizing High Luminescence Efficiency, Grant-in-Aid for Young Scientists (B), 1 April 2003 - 31 March 2005.

Single Nanoparticle Spectroscopy

Semiconductor nanoparticles of sizes comparable to or smaller than the exciton Bohr radius in bulk materials have attracted much attention, because they exhibit a wealth of quantum phenomena. We have prepared semiconductor nanoparticles embedded in dielectric matrices by many different techniques and discussed luminescence properties of single semiconductor nanoparticles studied by selective excitation spectroscopy and scanning near-field optical microscopy at low temperatures. The free-exciton and shallow-impurity luminescence show very narrow line widths. The deep impurity luminescence is broad even in single nanoparticles. We discussed the mechanism of the exciton-phonon coupling in semiconductor nanoparticles.

Femtosecond Laser Spectroscopy of Wide Band-Gap Semiconductors

Recently, there has been great interest in the optical processes in wide-gap semiconductors. The developments of wavelength-tunable femtosecond laser systems and remarkable progress in semiconductor crystal growth have enabled us to study intrinsic optical processes and dynamics. Because of the large exciton binding energy, GaN and related materials provide us an excellent stage for the study of the excitonic many-body effects in semiconductors. We have clarified the luminescence processes in highly excited GaN and InGaN semiconductors by means of optical Kerr-gate time-resolved photoluminescence measurements (Fig. 1).

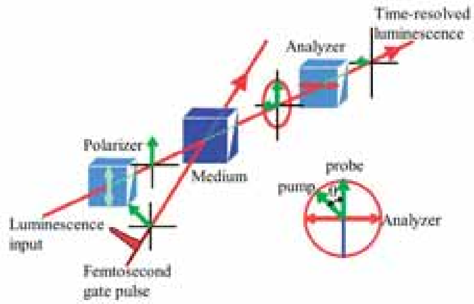

Figure 1. Schematic of optical Kerr-gate time-resolved photoluminescence measurements using femtosecond laser pulses.

Optical Near-field Spectroscopy of Semiconductor Quantum Structures

Scanning near-field optical microscope with a spatial resolution of 100-150 nm ($\lambda/7$-$\lambda/5$, λ: wavelength of light) has contributed to explorer novel electronic and optical properties of semiconductor quantum structures. Recently, the spatial resolution as high as 30 nm ($\lambda/30$) has been achieved by employing a specially designed fiber probe with a small and clear aperture in photoluminescence measurements of the semiconductor quantum structures. With using this advanced tool, we have demonstrated that the local optical probe directly maps out the center-of-mass wave function of an exciton confined in a GaAs quantum dot (Fig. 2). The photoluminescence image in a biexciton (bounded two-excitons due to Coulomb interactions) state differs from that in an exciton state due to different distributions of the polarization field for the exciton and biexciton recombinations.

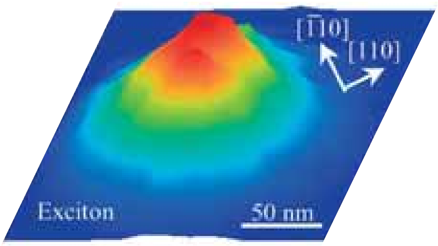

Figure 2. Exciton wave function image in a GaAs quantum dot by near-field photoluminescence mapping.

Awards

Kanemitsu Y, Phosphor Award, Pioneering Contributions for Semiconductor Nanoparticles, Phosphor Research Society, The Electrochemical Society of Japan, 26 November 2004.

Matsuda K, Research Award, Near-field Optical Mapping of Exciton Wave Function in a GaAs Quantum Dot, Research Foundation for Opto-Science and Technology, 16 March 2004.

Inouye H, Best Young Presenter Award, Ultrafast Response of a Self-organized Closely-packed Metal Nanoparticles System, Society of Nano Science and Technology, 10 May 2004.