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-structured materials and to establish opto-nanoscience for creation of innovative functional materials. Optical properties of semiconductor quantum nanostructures and strongly-correlated electron systems in low-dimensional materials are studied by means of space- and time-resolved laser spectroscopy. The main subjects are as follows: (1) Investigation of optical properties of single nanostructures through the development of high-resolution scanning near-field optical microscope, (2) Development of nanoparticle assembly with new optical functionalities, and (3) Ultrafast optical spectroscopy of excited states of semiconductor nanostructures.

Research Activities (Year 2006)

Presentations

Nanoimaging Spectroscopy and Its Application Using Near-Field Scanning Optical Microscope (Invited), Matsuda K, The General Meeting of Kansai Branch of the Japanese Society of Microscopy, 22 July 2006, Kyoto, Japan.

Exciton Luminescence of Single-walled Carbon Nanotubes Investigated by Single Nanotube Spectroscopy, Inoue T, Matsuda K, Murakami Y, Maruyama S, Kanemitsu Y, 28th International Conference on Physics of Semiconductor (ICPS28), 24–28 July 2006, Vienna, Austria.

Mechanism of Surface-Enhanced Light Emission from Single CdSe Nanoparticles on Metal Substrates, Ito Y, Matsuda K, Kanemitsu Y, 28th International Conference on Physics of Semiconductor (ICPS28), 24–28 July 2006, Vienna, Austria.

Photoluminescence Dynamics in Highly Excited GaN-based Ternary Alloys, Hirano D, Inouye H, Kanemitsu Y, 28th International Conference on Physics of Semiconductor (ICPS28), 24–28 July 2006, Vienna, Austria.

Grants

Kanemitsu Y, Basic Research for Development of Near-Field Optical Microscope for Elemental Analysis and Mass Spectrometry, Grant-in-Aid for Exploratory Research, 1 April 2005–31 March 2007.

Kanemitsu Y, Study of Highly Excited State in Semiconductor Nanostructures by Means of Time and Spatially Resolved Spectroscopy, Grant-in-Aid for Scientific Research (B), 1 April 2006–31 March 2008.

Matsuda K, Explorer of Optical Properties and Application of Quantum Optical Devices in an Individual Carbon Nanotube by Optical Nanoprobing, Grant-in-Aid for Young Scientists (A), 1 April 2005–31 March 2008.

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 March 2006.

Matsuda K, Explorer of Properties and Application of Quantum Devices in Carbon Nanotubes by Optical Nanoprobing, Foundation for C&C Promotion, Research Grant for Young Scientists, 1 April 2005–31 March 2006.

Matsuda K, Development of Near-Field Scanning Optical Microscope with Nanometer-Level Spatial Resolution, Research Foundation for Opt-Science and Technology, Research Grant, 1 April 2005–31 March 2007.

Inouye H, Luminescence Dynamics of Self-Assemble Nanocrystal Composite Film and Study for Realizing

Topics

Mechanism of Photoluminescence Enhancement in a Single CdSe Semiconductor Nanocrystal/Metal Interface

Colloidal semiconductor nanocrystals with high photoluminescence (PL) quantum efficiencies have been extensively studied both from the viewpoint of fundamental physics and with consideration for the potential applications to electronics and biotechnology. The interfaces between metals and nanocrystals play complex and essential roles in the optical responses of semiconductor nanocrystals on metals. The detailed understanding interactions between nanocrystals and metal surface are very important to enhance the PL intensity of nanocrystals in conjunction with the improvement of the PL efficiency of nanocrystals. We have studied the mechanism of the PL enhancement and quenching of single CdSe/ZnS core/shell nanocrystals on Au surfaces by means of single nanocrystal spectroscopy. The *on-off* PL blinking observed on the glass surface (upper panel of Figure 1) is drastically suppressed on Au surfaces (lower panel of Figure 1), because of the fast energy transfer between Au surfaces and nanocrystals. The PL enhancement of single CdSe/ZnS nanocrystals occurs on rough Au surfaces, but PL quenching occurs on flat Au surfaces, compared to the case of the glass surface. Single nanocrystal spectroscopy reveals that the PL enhancement on rough Au surfaces is caused by the suppression of PL blinking and the electric field enhancement due to localized plasmon excitation.

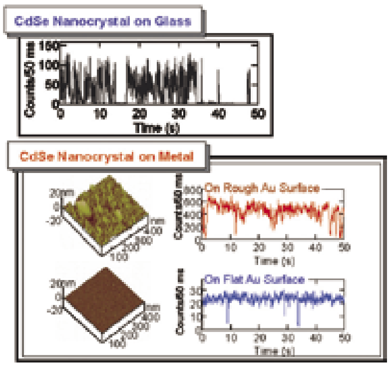

Figure 1. PL time-traces of a single CdSe/ZnS nanocrystal on glass and metal substrate.

Exciton-phonon Interaction in Individual Single-Walled Carbon Nanotubes Studied by Micro-Photoluminescence Spectroscopy

Electronic and optical properties of single-walled carbon nanotubes (SWNTs) have attracted much attention both from the fundamental physics viewpoint and due to the potential applications to opto-electronic devices. The recent discovery of efficient photoluminescence (PL) from isolated semiconducting SWNTs has stimulated considerable efforts in understanding optical properties of SWNTs. However, the SWNTs samples are usually inhomogeneous systems in the sense that many different species of nanotubes exist: the inhomogeneous broadening and the spectral overlapping of PL peaks cause the complicated spectra. It is therefore needed to perform PL measurements on single SWNTs for clarifying the optical properties of each SWNT species. Single nanotube spectroscopy provides us essential information such as exciton-phonon interaction. We have investigated the diameter dependence of the exciton luminescence linewidth in individual SWNTs by means of micro-photoluminescence (μ-PL) spectroscopy. The lineshapes of μ-PL spectra for single SWNTs suspended on a patterned Si substrate at room temperature can be fitted by single Lorentzian functions. The PL linewidth becomes broad in small diameter SWNTs. Our observation suggests that the exciton-phonon interaction becomes stronger with a decrease of the diameter, i.e., with an increase of the surface curvature. From the temperature dependence of the PL linewidth, it was found that the very low energy phonon mode has the dominant contribution to the diameter dependence of the linewidth broadening.

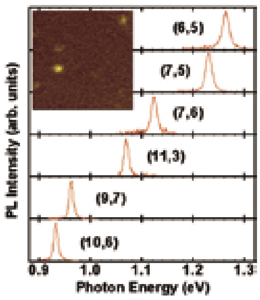

Figure 2. μ-PL spectra of single SWNTs with different chiral indices. Inset shows the PL image [7.6 μm × 7.6 μm].

High Luminescence Efficiency, Grant-in-Aid for Young Scientists (B), 1 April 2005–31 September 2006.

Awards

Kanemitsu Y, Pioneering and Outstanding Contributions to Nano-silicon Optoscience, Inoue Prize for Science, Inoue Foundation for Science, 3 February 2006.

Kanemitsu Y, Outstanding Contributions to Semiconductor Nanoparticle Optoscience, Yazaki Memorial Foundation Award, Yazaki Foundation, 9 March 2006.

Matsuda K, Nanoimaging Spectroscopy of Semiconductor Quantum Structures in the Research Field of Nano-optics, Young Scientist's Prize, the Commendation for Science and Technology, Ministry of Education, Culture, Sports, Science and Technology, 11 April 2006.