International Research Center for Elements Science
- Photonic Elements Science -

http://www.scl.kyoto-u.ac.jp/˜opt-nano/index-e.html

Prof
KANEMITSU, Yoshihiko
(D Eng)

Assoc Prof
MATSUDA, Kazunari
(D Eng)

Assist Prof
TAYAGAKI, Takeshi
(D Sc)

Assist Prof (SER)
YAMAMOTO, Shinpei
(D Eng)

PD
ITO, Hisashi
(D Sc)

SPD (JSPS)
MIYAUCHI, Yuhei
(D Eng)

PD
YAMADA, Yasuhiro
(D Sc)

Students

HIRANO, Daisuke (D2)
MATSUNAGA, Ryusuke (D1)
TAGUCHI, Seiji (M2)
YOSHIKAWA, Kohei (M2)
UEDA, Akihiro (M2)
SAKASHITA, Takerou (M1)
YAMAMOTO, Hidenobu (M1)

Visitor

ANTONIN, Fejfar — Institute of Physics, Academy of Sciencies of the Czech Republic, Czech Republic, 1 October 2007–31 March 2008

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 nano-structures 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 optical microscope, (2) Development of nanoparticle assemblies with new optical functionalities, and (3) Ultrafast optical spectroscopy of excited states in semiconductor nanostructures.

Research Activities (Year 2008)

Publications

Matsunaga R, Matsuda K, Kanemitsu Y: Evidence for Dark Excitons in a Single Carbon Nanotube due to the Aharonov-Bohm Effect, *Phys. Rev. Lett.*, **101**, [147404-1]-[147404-4] (2008).

Hosoki K, Tayagaki T, Yamamoto S, Matsuda K, Kanemitsu Y: Direct and Stepwise Energy Transfer from Excitons to Plasmons in Close-packed Metal and Semiconductor Nanoparticle Monolayer Films, *Phys. Rev. Lett.*, **100**, [207404-1]-[207404-4] (2008).

Yasuda H, Kanemitsu Y: Dynamics of Nonlinear Blue Photoluminescence and Auger Recombination in $SrTiO_3$, *Phys. Rev. B*, **77**, [193202-1]-[193202-4] (2008).

Hirano D, Tayagaki T, Yamada Y, Kanemitsu Y: Dynamics of Biexciton Localization in $Al_xGa_{1-x}N$ Mixed Crystals under Exciton Resonant Excitation, *Phys. Rev. B*, **77**, [193203-1]-[193203-4] (2008).

Ueda A, Matsuda K, Tayagaki T, Kanemitsu Y: Carrier Multiplication in Carbon Nanotubes Studied by Femtosecond Pump-probe Spectroscopy, *Appl. Phys. Lett.*, **92**, [233105-1]-[233105-3] (2008).

Presentations

Mechanism of Carrier Multiplication in Carbon Nanotubes Studied by Ultrafast Pump-Probe Spectroscopy, Ueda A, Matsuda K, Tayagaki T, Kanemitsu Y, 8th International Conference on Excitonic Processes in Condensed Matter (EXCON08), 22–27 June 2008, Kyoto, Japan.

Excitonic Properties of Carbon Nanotubes Studied by Advanced Optical Spectroscopy, Matsuda K, The 5th Japan-Korea Symposium on Carbon Nanotube, 8–12 November 2008, Busan, Korea (Invited).

Topics

Direct Observations for Dark Excitons in Carbon Nanotubes due to the Aharonov-Bohm Effect

Electronic properties of single-walled carbon nanotubes (SWNTs) have attracted much attention from the fundamental physics viewpoint. The enhanced Coulomb interaction leads to the formation of stable 1-dimensional excitons in SWNTs. We studied exciton structures and the Aharonov-Bohm effect in a single carbon nanotube using micro-photoluminescence (PL) spectroscopy under magnetic field at low temperatures. A single sharp PL peak from the bright exciton state of a single carbon nanotube was observed under zero magnetic field, and the additional PL of dark exciton state appeared below the bright exciton peak under high magnetic fields as shown in Figure 1. It was found that the split between the bright and dark exciton states is several meV at zero field. The tube diameter dependence of the splitting arises from the intervalley short-range Coulomb interaction.

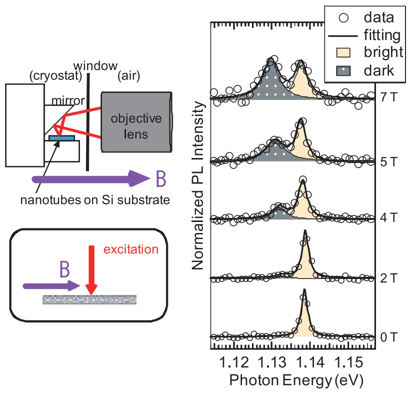

Figure 1. Schematic of experimental setup of a single nanotube spectroscopy under a magnetic field. PL spectra of a single carbon nanotube under magnetic fields.

Carrier Multiplication in Carbon Nanotubes

Carbon nanotubes are one of the excellent materials for studying the many-body effects of excitons, because of their unique band structures and large exciton binding energies. We studied exciton population dynamics in single-walled carbon nanotubes using pump-probe transient absorption spectroscopy. The temporal profiles of the transient absorption signals depend on the excitation intensity and excitation photon energy. We observed carrier multiplication in carbon nanotubes at room temperature, when the excitation photon energy exceeds the third subband exciton energy. We demonstrated that carbon nanotubes show unique optical responses because of their strong electron-electron interactions.

Direct and Stepwise Energy Transfer in Close-packed Metal and Semiconductor Nanoparticle Monolayer Films

Semiconductor and metal nanoparticles (NPs) serve as nanoscale building blocks for tailored materials with fascinating multifunctional properties beyond those of bulk crystals. Recently, we prepared macroscopically ordered NP supra-solids and close-packed NP solids have been prepared, allowing the study of quantum and cooperative phenomena. One of the central issues in ordered or close-packed NP solids is the understanding of energy and charge transfer processes on a nanoscale. We studied the dynamics of PL and energy transfer in close-packed monolayer films of CdSe and Au NPs assembled using the Langmuir–Blodgett technique. The PL intensity and dynamics depend on the ratio of CdSe to Au NPs in the mixed films in Figure 2. The PL quenching of CdSe NPs occurs through rapid energy transfer from excitons in CdSe NPs to plasmons in Au NPs. The PL decay curves of the mixed NPs monolayers are determined by three decay processes: the direct energy transfer between the nearest-neighbor CdSe and Au NPs (CdSe→Au), the stepwise energy transfer from CdSe to CdSe to Au NPs (CdSe→CdSe →Au), and the radiative recombination in CdSe NPs.

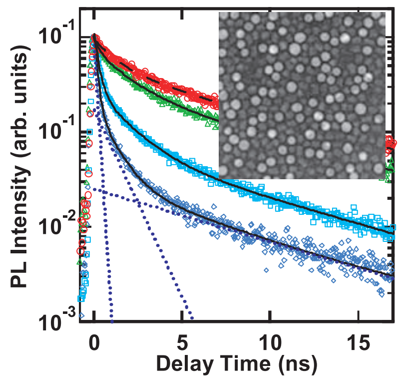

Figure 2. PL dynamics in CdSe and Au NPs monolayer films in various mixing ratios. Inset shows the TEM image of the CdSe and Au NPs mixed monolayer film.

Grants

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, Optical Quantum State Manipulation of Carbon Nanotubes, Grant-in-Aid for Scientific Research (B), 1 April 2008–31 March 2011.