International Research Center for Elements Science – Photonic Elements Science –

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

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

KEYWORDS

Femtosecond Laser Spectroscopy
Carbon Nanotube
Semiconductor Nanoparticles
Transition Metal Oxides
Semiconductor Nanostructures

Selected Publications

Yamada Y, Yasuda H, Tayagaki T, Kanemitsu Y: Temperature Dependence of Photoluminescence Spectra of Undoped and Electron-doped $SrTiO_3$: Crossover from Auger Recombination to Single-carrier Trapping, *Phys. Rev. Lett.*, **102,** [247401-1]-[247401-4] (2009).

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).

Ito Y, Matsuda K, Kanemitsu Y: Mechanism of Photoluminescence Enhancement in Single Semiconductor Nanocrystals on Metal Surfaces, *Phys. Rev. B*, **75,** [033309-1]-[033309-4] (2007).

Hirori H, Matsuda K, Miyauchi Y, Maruyama S, Kanemitsu Y: Exciton Localization of Single-walled Carbon Nanotubes Revealed by Femtosecond Excitation Correlation Spectroscopy, *Phys. Rev. Lett.*, **97,** [257401-1]-[257401-4] (2006).

Band-to-band Photoluminescence in $SrTiO_3$

Transition metal oxides have attracted a great deal of attention as new device materials due to their wide variety of fascinating and multifunctional properties. $SrTiO_3$ is one of the most important oxide materials. We observed band-edge photoluminescence (PL) in highly photoexcited $SrTiO_3$ and electron-doped $SrTiO_3$ at low temperatures. Two band-edge PL peaks coincide with the low- and high-temperature onsets of optical absorption. This clearly shows that band-edge PL peaks correspond to indirect band-to-band radiative recombination involving phonon emission and absorption processes and allows a determination of the band gap.

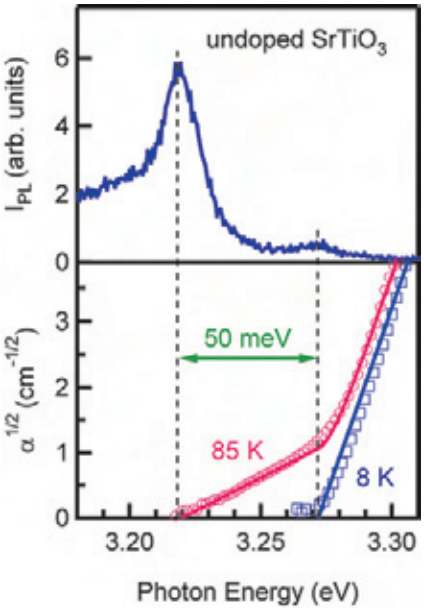

Figure 1. Time-gated (0–8 ns) PL spectrum of $SrTiO_3$ at 8 K (upper) and the square root of the absorption coefficient at 8 and 85 K (lower).

Multicarrier Recombination and Energy Transfer in Mn-Doped CdS Nanocrystals Studied by Femtosecond Pump-Probe Spectroscopy

Fabrication and characterization of semiconductor nanocrystals (NCs) doped with functional impurities have been extensively studied due to interest both in the fundamental physics and potential applications in optoelectronic devices. We studied the photocarrier decay dynamics of Mn-doped CdS NCs coated with a ZnS shell layer by femtosecond pump–probe transient absorption spectroscopy. At low excitation intensities, the decay dynamics of photocarriers is determined by energy transfer from electron–hole pairs in CdS NCs to Mn ions. At high excitation intensities, the photocarrier decay curves of Mn-doped CdS NCs are very similar to those of undoped CdS NCs, and they are determined by the fast Auger recombination of photocarriers. These density-dependent photocarrier behaviors in CdS NCs are confirmed by Mn^{2+} luminescence spectroscopy.

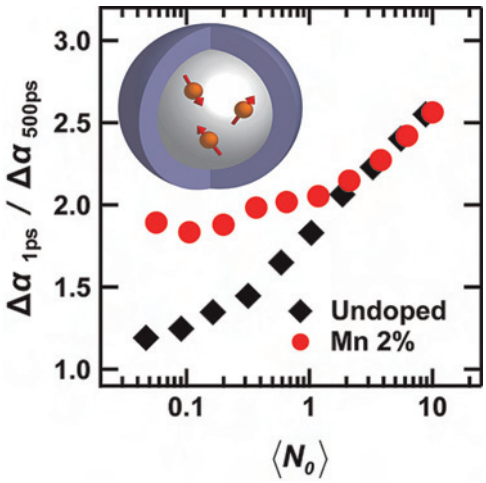

Figure 2. Intensity ratio of the transient absorption signal at 1 ps to that at 500 ps as a function of the average number of initially photocreated e–h pairs.

Plasmon-assisted Photoluminescence Enhancement of Single-Walled Carbon Nanotubes on Metal Surfaces

Carbon nanotubes are one of the excellent materials for studying the optical properties of excitons, because of their unique band structures and large exciton binding energies. We demonstrated PL enhancement in single carbon nanotubes using localized surface plasmons. Single nanotube spectroscopy revealed triple the PL intensity enhancement for carbon nanotubes on rough Au surfaces as on fused silica surfaces. The PL enhancement depends on the excitation wavelength and distance between the carbon nanotubes and the Au surface. The degree of PL enhancement is determined by the electric field enhancement from the localized surface plasmon and the energy transfer from the carbon nanotube to the metal surface.

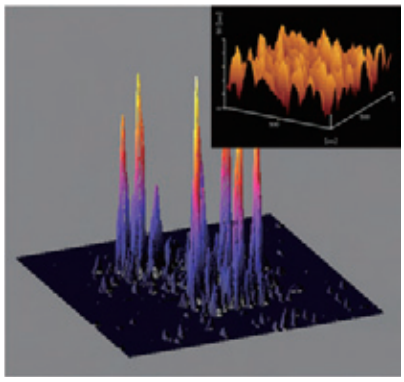

Figure 3. PL images of single carbon nanotubes on the rough Au surfaces. The image size is 40×40 μm^2. Inset: Topographic images of rough and flat Au surfaces measured using atomic force microscopy with a vertical scale of ±25 nm and area of 1×1 μm^2.