Endowed Research Section
– Nano-Interface Photonics –
(SEI Group CSR Foundation)

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

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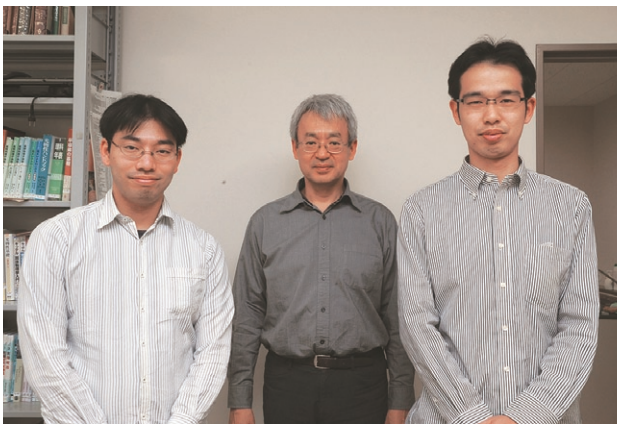
Scope of Research

Nanostructured materials are one class of the most promising candidates for future device materials because of their unique electronic and optical properties beyond the bulk crystals. Our research aim is to open up new research fields of nanomaterials science, by focusing on nano-interface as a platform to develop novel optical functionalities. We study optical properties of semiconductor nanomaterials by means of time- and space-resolved spectroscopy, leading to new solar energy conversion technologies. The main subjects are (1) photocarrier dynamics and photovoltaic effects in transition metal oxides and (2) ultrafast carrier dynamics and unique optical properties of one-dimensional materials.

KEYWORDS

Nano-interface
Photovoltaic Science
Nanocarbon Materials
Laser Spectroscopy
Solar Energy Conversion



Selected Publications

Yamada, Y.; Kanemitsu, Y., Photoluminescence Spectra of Perovskite Oxide Semiconductors, *J. Lumin.*, **133,** 30-34 (2013).

Yamada, Y.; Kanemitsu, Y., Determination of Electron and Hole Lifetimes of Rutile and Anatase TiO_2 Single Crystals, *Appl. Phys. Lett.*, **101,** [133907-1]-[133907-4] (2012).

Okano, M.; Kanemitsu, Y.; Chen, S.; Mochizuki, T.; Yoshita, M.; Akiyama, H.; Pfeiffer, L. N.; West, K. W., Observation of High Rydberg States of One-dimensional Excitons in GaAs Quantum Wires by Magneto-photoluminescence Excitation Spectroscopy, *Phys. Rev. B*, **86,** [085312-1]-[085312-5] (2012).

Yamada, Y.; Kanemitsu, Y., Band-edge Luminescence from $SrTiO_3$: No Polaron Effect, *Thin Solid Films*, **520,** 3843-3846 (2012).

Okano, M.; Matsunaga, R.; Matsuda, K.; Masubuchi, S.; Machida, T.; Kanemitsu, Y., Raman Study on the Interlayer Interactions and the Band Structure of Bilayer Graphene Synthesized by Alcohol Chemical Vapor Deposition, *Appl. Phys. Lett.*, **99,** [151916-1]-[151916-3] (2011).

Nanointerface as a Platform to Develop Novel Optical Functionalities

Solar energy conversion is a key technology to solve the world-wide and emergent energy problems, such as fossil fuel exhaustion and global warming. However, the conversion efficiency of practically used solar cell is still less than 30%, and thus there is a compelling need for the development of highly-efficient and cost-effective solar cells.

Nanostructured materials, such as nanoparticles, nanotubes, and nanowires, are the most promising candidates for the next-generation solar cells because of their unique electronic and optical properties beyond the bulk crystals. For example, plasmon resonance in metal nanoparticles enhances the light absorption efficiency, and carrier multiplication due to strong carrier confinement and Coulomb interactions in the semiconductor nanoparticles can improve the light conversion efficiencies.

To take more advantages of nanomaterials, it is significant to understand the role of their surface and interface. Nanomaterials have large surface-to-volume ratios, and thus their optoelectronic properties are strongly affected by the surrounding materials and interface states. This indicates that the novel optoelectronic properties can be developed by controlling the nano-interface. Moreover, in the practical nanomaterial-based devices, the energy and carrier transport processes are dominated by the characteristics of the interface between nanomaterials.

In our research group, we focus on such nano-interface as a platform to develop novel optical functionalities. Using advanced time- and space-resolved spectroscopy, we study the optical properties of unique nanomaterials and their nanocomposites. Through the studies on the nano-interface photonics, we aim to open up new research fields of nanomaterials science, leading to new solar energy conversion technology.

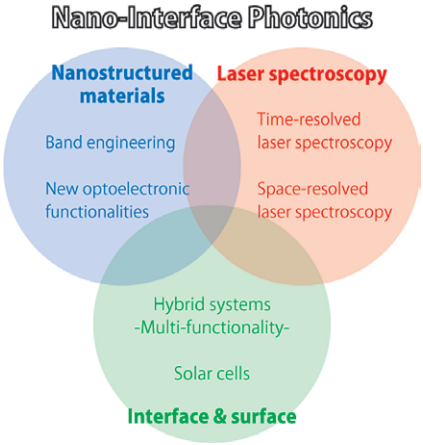


Figure 1.

Observation of High Rydberg States of One-dimensional Excitons in GaAs Quantum Wires by Magnetophotoluminescence Excitation Spectroscopy

We have studied the higher Rydberg states of the ground exciton in T-shaped GaAs quantum wires using magneto-photoluminescence excitation spectroscopy at low temperatures. Under strong magnetic field, a new peak appears at the onset of the one-dimensional (1D) continuum edge. The peak is assigned to the second even-parity Rydberg state on the basis of the polarization dependence measurements. By comparison with the ground exciton, it shows significantly low zero-field oscillator strength and a large diamagnetic shift. These characteristic features are attributed to the weakly bound wave function of the second Rydberg state intrinsic to 1D excitons.

Determination of Electron and Hole Lifetimes of Rutile and Anatase TiO_2 Single Crystals

TiO_2 is one of the most important oxide semiconductors in terms of energy and environmental applications, such as dye-sensitized solar cells and photocatalysts. We investigated the photocarrier decay dynamics of rutile and anatase TiO_2 single crystals by combining the advantages of time-resolved photoluminescence, transient absorption, and photoconductivity spectroscopy analyses. Electrons and holes in rutile show exponential decays with the lifetime of a few tens of nanoseconds, while non-exponential decays are observed in anatase, indicating the presence of multiple carrier trapping processes. We revealed the generic features of the carrier recombination processes in rutile and anatase TiO_2.

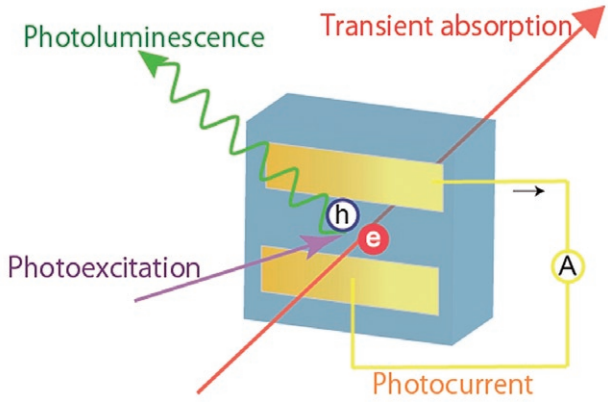


Figure 2.