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Methods of controlling colloidal quantum dots for future optoelectronics

Semiconductor quantum dot (QD) is promising for various kinds of future optoelectronic devices. We are aiming to realize ultrahigh-efficiency solar cells and quantum information processing devices using colloidal QD. A solar cell with QD superlattice, in which highly uniform QDs are three-dimensionally arranged, is expected to have energy conversion efficiency of 70% or more due to the formation of intermediate energy bands. Realization of superlattice using epitaxial QDs has been studied eagerly, but the conversion efficiency still remains at 20% or less. The principle of epitaxial QD growth is crystal strain energy, and the strain changes constantly on the growth surface. So, it is very difficult to realize uniform superlattice structure. On the other hand, it is known that chemically synthesized colloidal QDs self-form a densely-packed structure in narrow electron microscope area when deposited on a substrate in a solvent. However, since QDs can freely move on a substrate, the long-period packed structure cannot be realized. We have proposed a method to realize a large area superlattice structure by limiting the free motion of QD using a template fabricated by wet etching. We recently reported the effect of using faceted QDs and short-chain ligands with the template. QDs having facets bring the same facet into contact during the deposition in a solvent, and the number of intermediate bands can be increased by enhancing hybridization of quantum states using short-chain ligands. Meanwhile, colloidal QD is also important as a single photon source used for quantum information processing. The position of QD can be precisely controlled using a template fabricated by scanning probe microscope lithography. We have combined one QD with one metamaterial element to realize high-speed, high-efficiency, and high-directivity photon emission with controlled polarization based on Purcell effect.

Biography

Kohki Mukai received PhD in Electronics Engineering from Kyoto University, Japan. He is a Professor of Graduate School of Engineering, Yokohama National University. In 1999 he realized the first room-temperature continuous-wave lasing of quantum dot (QD) lasers at the optical telecommunication wavelength. His achievements led to the world's earliest establishment of QD's photonic device provider 'QD Laser, Inc.'. Afterward, he has engaged in research on quantum information technology and high-efficiency solar cells using QDs. He is a winner of many awards such as 'Award of The Field of Technology (research section)' presented by Minister of MEXT Japan.

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