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Template method for nano-order positioning and dense packing of colloidal quantum dots

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Abstract

Semiconductor quantum dot (QD) is promising for various future optoelectronic devices. One important application is the quantum information device. It is necessary to set QDs at the desired position for the fabrication of the quantum circuit. The methods to form the epitaxial QDs on the processed surface of the substrate have been proposed, but the generation of the non-radiative defects is unavoidable at the surface. QD is also attractive to the solar cell application. If the QDs are packed densely with long periodicity, the intermediate band will be created due to the overlap of the electron wave function among QDs. This artificial energy band will expand the light absorption wavelength, and will raise the photoelectric conversion efficiency up to 70%. Such epitaxial growth of QDs is, however, not easy. In this paper, we propose the usage of the colloidal QDs (C-QDs) in these applications. The emission wavelength of the C-QDs covers from visible to infrared. The positioning of the PbS C-QD was achieved using nano-scale holes processed by the scanning probe microscope (SPM) lithography of Si substrate. The SPM oxidation lines were used as a negative etching mask to form the holes of the depth same as the C-QD diameter. We also report that the three-dimensional long-periodic ordering of the C-QDs is attainable by depositing C-QDs into the pyramidal holes processed by the anisotropic etching of Si substrate. Microscope observations and optical evaluations suggested the creation of the intermediate band after the slow sedimentation of C-QDs into the holes.

Biography

Kohki Mukai received ph.D. in Electronics Engineering from Kyoto University, Japan. He is the Professor of Graduate School of Engineering, Yokohama National University. In 1994 he invented the method to grow self-assembled InGaAs quantum dots (QDs) which emit at the optical telecommunication wavelength of 1.3 and 1.55 µm. In 1999 he realized the first 1.3-µm CW lasing of QDs at room temperature. His achievements led to the world's first establishment of QD's photonic device provider, QD Laser, Inc..