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Optical Characteristics of Near-monolayer InAs Quantum Dots

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It is known that semiconductor quantum-dot (QD) heterostructures have superior zero-dimensional quantum confinement, and they have been successfully applied to semiconductor laser diodes (QDLDs) for optical communication and infrared photodetectors (QDIPs) for thermal images [1]. The self-assembled QDs are normally formed at Stranski-Krastanov (S-K) growth mode utilizing the accumulated strain due to lattice-mismatch existing at heterointerfaces between QDs and cap layers. In order to increase the areal density and the number of stacks of QDs, recently, sub-monolayer (SML)-thick QDs (SQDs) with reduced strain were tried by equivalent thicknesses thinner than a wetting layer (WL) existing in conventional QDs (CQDs) by S-K mode. Despite that it is very different from CQDs with a well-defined WL, the SQD structure has been successfully applied to QDIP[2]. In this study, optical characteristics are investigated by using photoluminescence (PL) spectra taken from self-assembled InAs/GaAs QDs whose coverage are changing from submonolayer to a few monolayers. The QD structures were grown by using molecular beam epitaxy (MBE) on semi-insulating GaAs (100) substrates, and formed at a substrate temperature of 480^{o}C followed by covering GaAs cap layer at 590^{o}C. We prepared six 10-period-stacked QD samples with different InAs coverages and thicknesses of GaAs spacer layers. In the QD coverage below WL thickness (～1.7 ML), the majority of SQDs with no WL coexisted with a small amount of CQDs with a WL, and multi-peak spectra changed to a single peak profile. A transition from SQDs to CQDs was found before and after a WL formation, and the sublevel of SQDs peaking at (1.32±0.1) eV was much closer to the GaAs bandedge than that of CQDs (～1.2 eV). These revealed that QDs with no WL could be formed by near-ML coverage in InAs/GaAs system, and single-mode SQDs could be achieved by 1.5 ML just below WL that a strain field was entirely uniform.

Keywords: InAs; Sub-monolayer, Quantum dot; Solar cell

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