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Trimodal Redshift Due to Carrier Tunneling in Chained InGaAs/GaAs Quantum Dots

<u>Sang Jun Lee</u>[1], Jun Oh Kim[1], Sam Kyu Noh[1], Tae Won Kang[2] and Jung Woo Choe[3]

[1]Division of Advanced Technology, Korea Research Institute Standards and Science
[2]Quantum-functional Semiconductor Research Center, Dongguk Univeristy
[3]Department of Electrical Engineering and Computer Science, Kyung Hee University

Unusual redshift behavior of the temperature dependence of photoluminescence (PL) emission spectra is one of ambiguous issues associated with self-assembled quantum-dot (QD) structures, which has to be settled for not only academic understanding but also realization of room-temperature operating QD-based devices. In this presentation, we report some experimental results on redshifts of emission energies observed in self-assembled InGaAs/GaAs trimodal QD structures formed via atomic-layer epitaxy (ALE) mode. As nominal InGaAs coverage increases, isolated QDs are apt to become more closely coupled and spontaneously aligned to one-dimensional chain-like structure. This results in extremely asymmetric photoluminescence (PL) spectra that contributions by three QD modes with different coupling extents are superposed. The temperature dependence of PL peaks with higher energies associated with isolated or coupled QDs digresses from the empirical equation ($E_g(T) = E_g(0) - aT^2/(T+b)$) and approaches to the lower energy curves attributed to coupled or chained QDs. The redshift behavior found in the trimodal InGaAs/GaAs QD structure prepared for this study may arise from the sublevel lowering by carrier tunneling among adjacent QDs, rather than thermal carrier emission or carrier transfer through the wetting layer that has introduced for explanation of redshift behaviors appearing in QD structures with a pair of sublevels.