변조도핑된 InAs/GaAs 양자점의 동력학 연구

Dynamics of modulation-doped InAs/GaAs quantum dots

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We have investigated the many-body effects of InAs/GaAs modulation-doped quantum dots (MDQD's) by using the steady-state and time-resolved photoluminescence (PL) measurements. As the modulation doping concentration of GaAs barrier increases, the peak positions of the MDQD's PL spectra shift to low energy. A relation between the renormalization energy (ΔE_g) and the electron density (N) occupying MDQD's is given by $\Delta E_g \propto N^{1.9}$. The larger exponent value for MDQD's than that (0.32) for quantum wells[1] is attributable to the disappearance of exchange interaction of electrons within a single state. We also obtained from the time-resolved PL measurement that the lifetimes of three MDQD's are longer than that of undoped QD's, and increases with the excitation intensities (Table 1). These results show that the interaction between the electrons inside the QD's is screened by the electrons at the GaAs-doped layer as well as the photogenerated 2D carriers. It is apparent that the screening effect due to the carriers at GaAs matrix play an important role in determining the radiative recombination rate of the MDQD's spectra. On the other hand, as the modulation-doping concentration increases, the lifetime becomes shorter slightly. It is supposed that the interaction of photogenerated carriers in the QD's with remote ionized impuruties invokes the nonradiative process to induce a shorter lifetime.

Table 1. The lifetimes of the MDQD's spectra.

Sample	Doping concentration (cm^{-3})	Excitation intensity (%)	Lifetime (ps)
A	Undoped	100	700
B	$1x10^{17}$	100	990
		20	910
		8	850
		2	770
C	$5x10^{17}$	100	930
D	$1x10^{18}$	100	820

1. D. A. Kleinman, and R. C. Miller, Phys. Rev. B 32, 2266 (1985)