**Precise control of the fabrication in InAs quantum dots**

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Precise control of fabrication of quantum wells (QWs) and quantum dots (QDs) are necessary in order to apply these structures to the mutual control of optical and electronic wave packets. QDs without dislocations have been formed by using a self-assembly growth technique [1]. Because we want to be able to control the shape of QDs and improve their uniformity, in the present work we observed in detail the shape of self-assembled QDs at various temperatures. And because the horizontal and vertical distances between QDs should be controlled appropriately for coupling the energy levels in coupled QDs, we also made layers of closely spaced QDs and stacked the layers.

We used molecular beam epitaxy to grow InAs QDs on GaAs substrates at various temperatures ranging from 500°C to 550°C. Figure 1 is scatter plot of QD height as a function of QD diameter. At temperatures over 510°C, large QDs more than 9 nm high are formed and at 550°C all of the QDs formed are large and about same size. The two lines in Fig. 1 indicate that the smaller QDs and larger QDs have different aspect ratios [2]. Both the height and diameter of the high-aspect-ratio QDs were within ±4% of their mean values. And as shown in Fig. 2, photoluminescence spectra measured at room temperature revealed that the spectrum of the high-aspect-ratio QDs had two peaks, corresponding to discrete energy levels, and that the FWHM of the ground-state-level peak was only 22 meV.

The area density of the uniform high-aspect QDs grown at 550°C was only $5.0\times10^{9}$ $cm^{-2}$, so to obtain a higher density we grew the InAs at a temperature of only 490°C. To improve uniformity and to prevent incoherent islands from forming at this relatively low growth temperature, we deposited In and As alternately because alternate deposition enhances the migration of In atoms, which has the same effect of high-temperature growth. The high-aspect QDs formed in this way were packed uniformly and closely ($5.7\times10^{10}$ $cm^{-2}$) without coalescence. After capping the QD layers with 55-nm-thick GaAs, we stacked them. The cross-sectional transmission electron microscope picture of stacked QD layers revealed that all the layers had similar area density of QDs, but that the positions of the QDs in the overlayer were not related to those of the QDs in the underlayer. We expect to be able to align QDs vertically by reducing the thickness of the capping layer.

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[2] H. Saito, K. Nishi, and S. Sugou, Appl. Phys. Lett. 74, 1226 (1999).

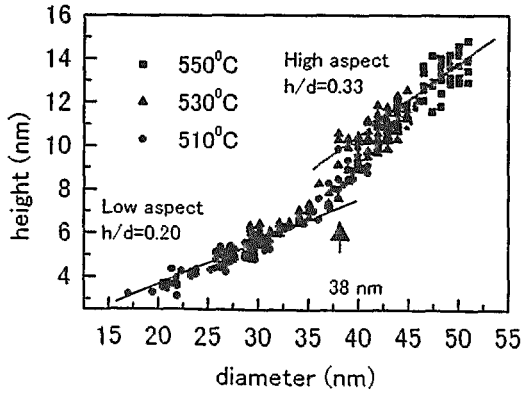


Fig. 1.

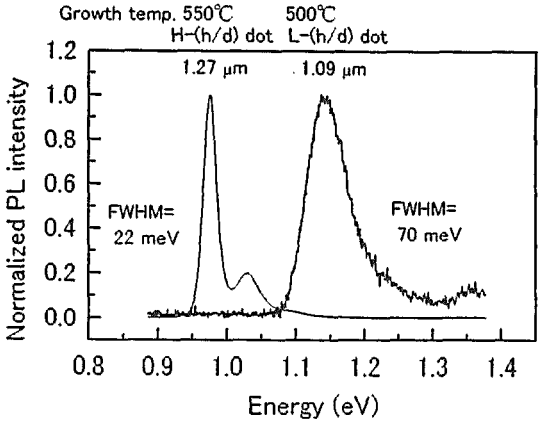


Fig. 2.

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3) A.V. Uskov, A. -P. Jauho, B. Tromborg, J. Mork, and R. Lang, "Dephasing Times in Quantum Dots due to Elastic LO Phonon-Carrier Collisions", Phys. Rev. Lett. 85, 1516 (2000).

(2) Presentations

1) Kazuhiko Misawa, "Wave packet engineering: From molecules to semiconductor nanostructures", US-Japan Workshop, Hawaii (Dec. 11-14, 1999)

2) 三沢和彦「光電子波束エンジニアリング」物質研シンポジウム、1999年11月16日

3) 三沢和彦「フェムト秒チャープパルスを用いた分子振動波束の時間発展」ワークショップ「化学反応ダイナミクスの量子制御」、2000年3月

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5) 三沢和彦、覧具博義「フェムト秒チャープパルスを用いた電子波束のコヒーレント量子制御」電子情報通信学会LQE研究会、2000年5月

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9) 平田賢治、伊藤弘明、覧具博義「量子ドットレーザーにおける空間的なホールバーニングの解析」応用物理学会、2000年9月

10) 三沢和彦、松田功、覧具博義「全固体フェムト秒位相制御レーザー開発の試み」電子情報通信学会LQE研究会、2000年10月

(3) Patent　no application