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Observation of Large Quantum Size Effect in GaInAs/GaInAsP Strained Quantum-Box Structure

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We report large energy shift observed in the compressive-strained quantum-box (QB) structures, which is 3-4 times larger than the unstrained QB at the same size. To our knowledge, this is the first measurement showing the difference between unstrained and strained QB structures.

Schematic structure of the fabricated QB sample is shown in Fig.1. $Ga_{1-x}In_xAs$ QBs with $x = 0.33$ (tensile), 0.53 (unstrain), and 0.70 (compressive) are embedded in GaInAsP (bandgap wavelength 1.1μm) layer lattice-matched to InP substrate. The pitch of quantume-box array is 100nm. These high density QB samples were fabricated by the organo-metalic vaper-phase epitaxy (OMVPE), electron-beam (EB) lithography, wet chemical etching, and OMVPE overgrowth process. The size of the boxes was controlled by changing the EB line dose, and measured by SEM to be 17^2(nm^2)-45^2(nm^2). Figure 2 shows one of the fabricated boxes before the overgrowth.

Photoluminescence spectra of these samples were measured at liquid helium temperature excited with Ar laser. Examples of measured spectra are shown in Fig.3 for compressive-strained and unstrain QB structures at nearly the same area. Emission peak of compressive-strained sample is shifted by 63meV from that of quantum film sample due to 0-dimensional quantum-size effect, which is much larger than unstrain sample (16meV).

Figure 4 shows measured energy shift with respect to the quantum-film for different box size, comparing between unstrain, tensile-, and conpressive-strained samples. As seen, energy shift obtained for compressive-strained samples (45-63meV) are much larger than tensile-strained (19-23meV) and unstrain (9-19meV) samples at the same box size by a factor of 1.5 and 3-4 times, respectively. This is because of the reduction of the hole effective mass in compressive-strained case. The measured results agree well with the theoretical calculations including the size fluctuation shown by the hatched region in Fig. 3.

From these results, compressive-strained quantum-box is expected to be more advantageous for low threshold lasers. Moreover, due to the possibility of large size, the laser properties are less-dependent on size fluctuation.

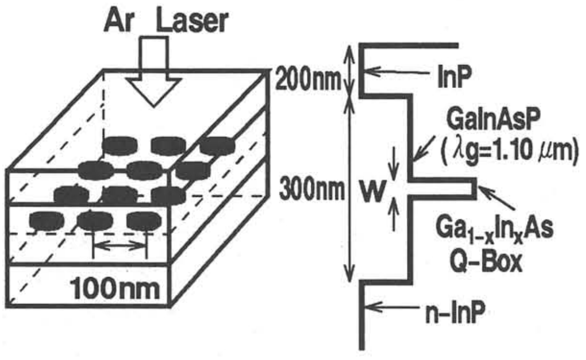

Fig.1 Schematic structure of fabricated quantum-box samples.

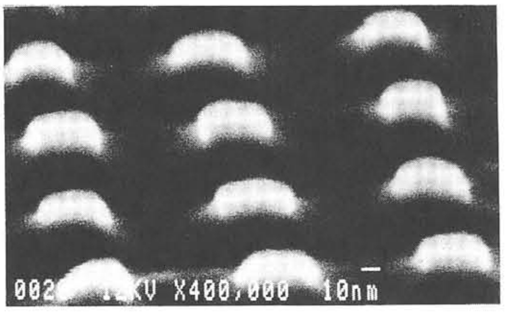

Fig.2 SEM image of an example of the fabricated quantum box.

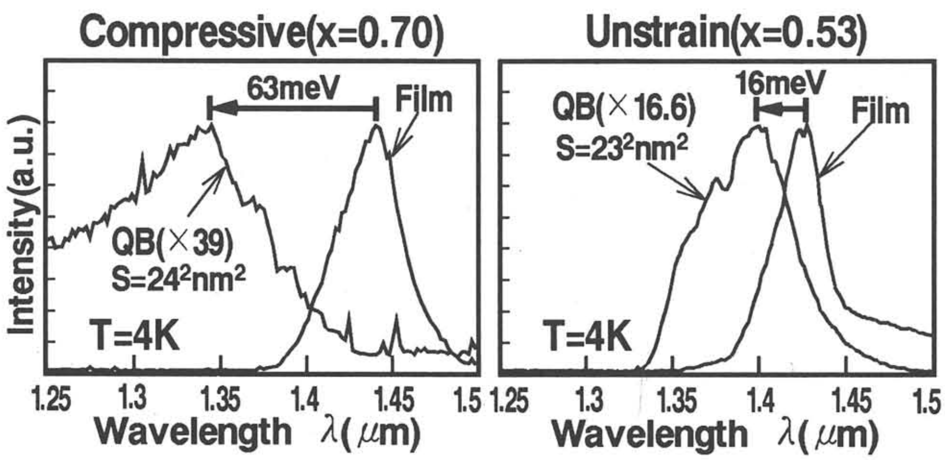

Fig.3 Example of photoluminescence spectra for compressive-strained and unstrain quantum-box samples at nearly the same area. Large shift is observed in compressive case.

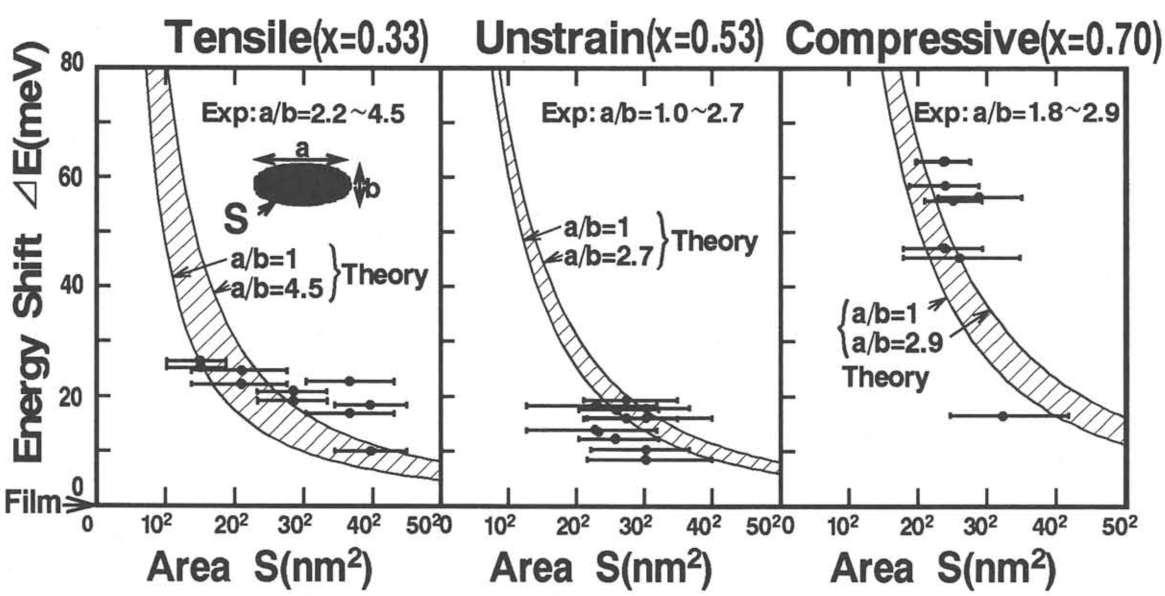

Fig.4 Comparison of measured energy shift with respect to the quantum-film for different size of unstrain, tensile-, compressive-strained quantum-box structures.