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Field-Induced Optical Effects in Two Non-Square Quantum Well Structures

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Inverse parabolic, two-step as well as square quantum well structures were grown by molecular beam epitaxy. The parabolic well was specially fabricated using a digital growth technique. Photoluminescence measurements of the inverse parabolic and two-step quntum wells under applied bias showed much larger Stark shifts than the conventional square well.

Quantum-confined Stark effect (QCSE) in a semiconductor quantum well (QW) has been extensively studied and utilized in optical devices, such as high-speed optical modulators, bistable devices, and photodetectors. For good performance of the devices, it is desirable to have QW structures with a large Stark shift. Most studies of the QCSE to date have focused on square quantum wells. Recent investigations on non-square wells revealed interesting features[1-6]. Thus modification of the well shape is a new freedom to optimize electro-optical properties.

We designed two $Al_xGa_{1-x}As$ QW structures, called inverse parabolic (IP) and two-step (TS) QWs, as shown in the insets of Fig. 2. By carefully adjusting the calculated QW parameters for the two structures, the electron ground level (1e) was localized just above the shallow barrier in the conduction band well and the heavy hole level (1hh) well below the shallow barrier in the valence band well. The former has almost a uniformly distributed wavefunction (global state) over the entire well and the latter has a wavefunction localized at two sides of the well (local state). This kind of local-to-global transition (1e-1hh) showed a large Stark shift in our calculations.

To compare the QCSE for these wells with the conventional square one in experiment, samples were grown by molecular beam epitaxy in a Varian GEN II system. The same well thickness (130 Å) and maximum depth were chosen for these three wells. Also the same layer sequence on n^+-GaAs (100) substrate was used for the three samples. The whole structure is composed of a 0.1-μm Si-doped GaAs buffer layer followed by 0.1-μm AlGaAs, five repeats of 130-Å well layer separated by 250-Å AlGaAs barriers, a 0.1-μm AlGaAs layer, and finally 100-Å GaAs cladding layer. The TSQW was fabricated by varying the Al-composition x of $Al_xGa_{1-x}As$ in different regions. The IPQW was specially grown by a digital growth technique[7], i.e. using a variable superlattice for an Al-compositional grading. The superlattice consists of $Al_{0.36}Ga_{0.64}As$/GaAs and has a period of 10 Å. On top of the samples, a semitransparent Au Schottky contact was made to apply an electric field perpendicular to the layers. The built-in voltage was estimated to be 0.7 V for all the three samples.

Photoluminescence (PL) measurements were made to see the QCSE in the three QW structures. The luminescence was excited by a He-Ne laser and measured by standard lock-in technique, with the use of a SPEX 1704 monochromator and an S-1 photomultiplier

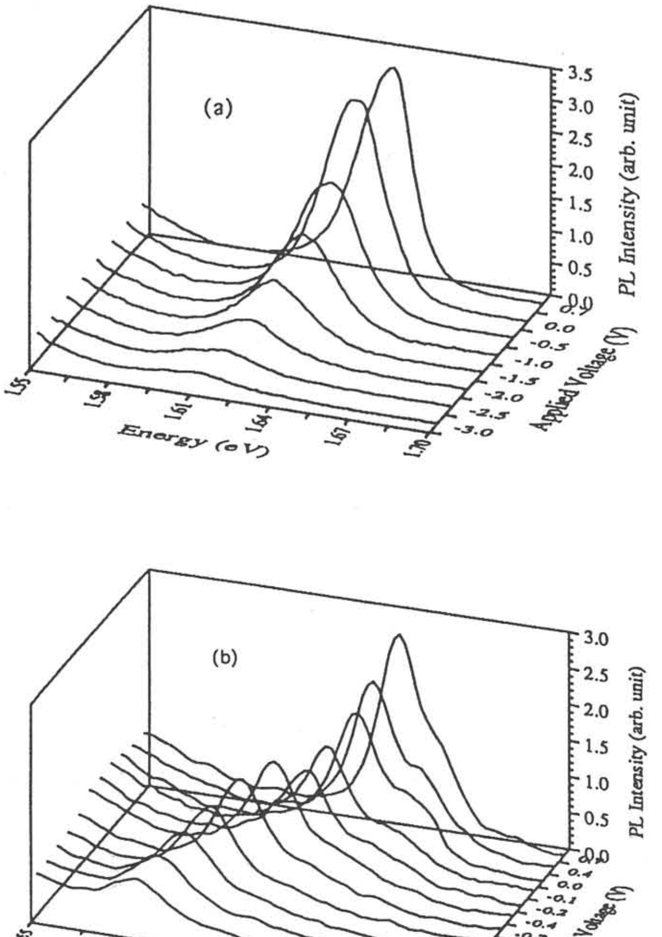

Fig. 1 Photoluminescence spectra measured at 77 K under different bias for (a) the inverse parabolic quantum well and (b) the two-step quantum well. The built-in voltage was estimated to be 0.7 V for both structures.

detector. Figure 1 (a) and (b) display the PL spectra measured at 77 K under different bias for the IPQW and TSQW, respectively. Several features can be seen. The main peak from the 1e-1hh exciton transition substantially shifts to lower energy, its intensity is reduced and the peak width broadens with the field. Particularly for the TSQW, the PL intensity for the 1e-1hh peak does not decrease monotonically with the field, instead a hump appeared at about -0.4 V. This is probably induced by impurity trapping centers that may exist at the interfaces. In addition, the 1e-1lh (involving the ground states of electrons and light holes) peak at the right shoulder of the 1e-1hh peak was also found shifted, but it became unresolved with increasing field. Comparisons were made in Fig. 2, which shows the measured and calculated Stark shift of the 1e-1hh transition for the three structures.

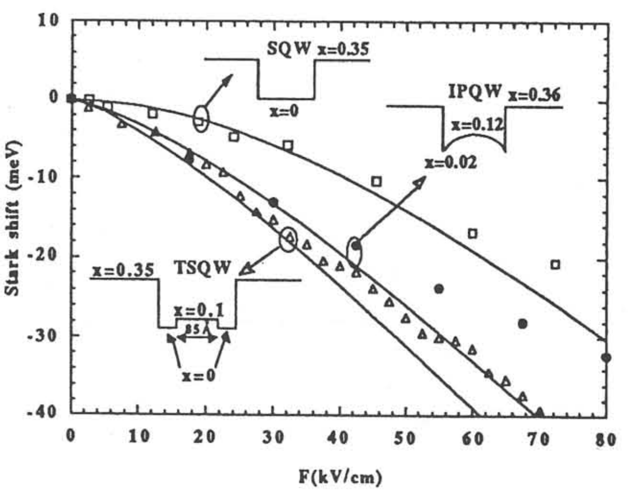

Fig. 2 Stark shifts obtained from the PL measurements (symbols) and calculations (solid curves) for the square QW, IPQW and TSQW. The well thickness is 130 Å for all the three structures. Al-composition x of $Al_xGa_{1-x}As$ is indicated in the insets.

A large Stark shift was achieved for the IPQW and TSQW; much greater than the square QW, in agreement with our calculations. Especially for the TSQW, the Stark shift is two times larger than that for the square QW. These favourable characteristics are expected to provide better performance of the QCSE-based devices than the conventional square well.

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References

1). T. Ishikawa, S. Nishimura, and K. Tada, Jpn. J. Appl. Phys. **29**, (1990) 1466.

2). M. Morita, K. Goto and T. Suzuki, Jpn. J. Appl. Phys. **29**, (1990) L1663.

3). G. D. Sanders and K. K. Bajaj, J. Appl. Phys. **68**, (1990) 5348.

4). T. Ishikawa and K. Tada, Jpn. J. Appl. Phys. **28**, (1989) L1982.

5). W. Q. Chen and T. G. Andersson, Semicond. Sci. Technol. **7**, (1992) 828.

6). P. W. Yu, D. C. Reynolds, G. D. Sanders, K. K. Bajaj, C. E. Stutz, and K.R. Evans, Phys. Rev. B **43**, (1991) 4344.

7). R. C. Miller, A. C. Gossard, D. A. Kleinman, and O. Munteau, Phys. Rev. B **29**, (1984) 3740.