EFFECTS OF NANOINDENTATION ON PHOTOLUMINESCENCE OF InGaAs/GaAs QUANTUM DOTS

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Self-assembled quantum dots (QDs), owing to its three dimensional confinement and the promising applications in optoelectronics, are presently the subject of intense interest [1]. Recently, many methods of simulating the quantum dot heterostructures have been developed to analyze the strain effects on optical and electronical properties of QDs [2].

In the present paper, we used low-temperature near field photoluminescence (PL) spectroscopy to study emission properties of self-organized InGaAs/GaAs QDs under nanoindentation by an optical fiber probe. The significant energy band shifts as high as 100meV of QD emission induced by nanoindentation were observed. Then, a three-dimension FE model was developed to analyze the strain distribution of the QDs due to lattice mismatch and nanoindentation, respectively. The lattice mismatch is incorporated through a thermo-mechanical model and was applied in multiple time increments. The thermal expansion coefficient of the QD and the substrate were set to the value of lattice mismatch strain and 0 respectively, and raising the temperature by 1K. To simulate the indentation force, the uniform pressure was applied within the contact region between nanoprobe and capping layer in another step.

Based on a six-band strain-dependent $k \cdot p$ Hamiltonian, the influence of strain on energy band shifts was examined [3]. The linear relationship between the energy-band shifts and the increment of indentation force was predicted. The nonlinear relationship induced through the six-band Hamiltonian was shown. We ascribe this nonlinearity to the exchange of the top valence band between light hole and heavy hole. According to our results, the originally degenerate valence-band edge at k=0 is split by the existence of strain and the heavy hole band can be above or below the light hole band depending on the variation of the strain components. The simulation results are qualitatively and quantitatively in agreement with experimental results shows that the FE method of determination of the QDs PL characteristics is valid. It would be an efficient auxiliary way to tune quantum dot emission in further research.

References

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