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UNIAXIAL IN-PLANE STRESS DEPENDENCE OF OPTICAL TRANSITIONS IN GaAs-GaAlAs QUANTUM WELLS

G. PLATERO* and M. ALTARELLI**

Max-Planck-Institut für Festkörperforschung, Hochfeld-Magnetlabor, 166X, F-38042 Grenoble Cedex, France
**Instituto de Cienca de Materiales (CSIC), Universidad Autonoma, Cantoblanco, E-Madrid 28049, Spain*
***European Synchrotron Radiation Facility, BP 220, F-38043 Grenoble Cedex, France*

L'énergie des transitions optiques dans des puits quantiques de GaAs-GaAlAs sous contrainte uniaxiale est calculée par la méthode de la fonction enveloppe. Les résultats sont en bon accord avec des expériences récentes de photoluminescence.

Optical transition energies in GaAs-GaAlAs quantum wells under uniaxial stress are computed in the envelope-function approximation. Results are in good agreement with recent photoluminescence experiments.

The application of an external stress to semiconductor quantum wells and superlattices was shown to be a good spectroscopic tool to analyze the electronic structure of these systems. The different behaviour of heavy-hole and light-hole valence subbands under stress, combined to confinement effects, produces interesting and characteristic shifts in their electronic transitions.

Photoluminescence excitation experiments (1,2) under in-plane (100) stress were reported for GaAs-$Ga_{1-x}Al_xAs$ quantum wells ($x = 0.3$) of various thickness, grown in the (001) direction. We compute the electronic structure of these systems within the framework of the envelope-function approximation, using a six-band k.p model (3). The effects of uniaxial stress are included by means of the Pikus-Bir hamiltonian (4) for the valence band. We consider, following experimental information (5), a valence band discontinuity corresponding to 40% of the band gap difference. A quantity which is poorly known is the dependence of this discontinuity on stress. Recent indications (6,7,8) show that this dependence is rather weak.

In our calculation the band gap discontinuity has been therefore assumed to be independent of uniaxial stress.

When the stress is applied in the growth direction, the strain hamiltonian is diagonal and, in the framework of the envelope-function approximation, the pure light- or heavy-hole character at the zone center is retained. A stress applied in the plane of the interfaces, on the other hand, induces a mixing even at the Γ point.

Fig. (1) represents the calculated uniaxial stress dependences ot the higher transitions with respect to the lowest energy one E_{11H} (first conduction, first heavy hole transition) in comparison with experiments for a 22 nm GaAs-GaAlAs quantum well. We represent also those which are not allowed for symmetry reasons. Our results agree quite well with experiment, the differences arising probably from the fact that the exciton binding energy and its dependence on strain are ignored in the calculation.

The different behaviour of heavy and light subbands, the latter showing a stronger dependence on stress, the interaction between E_{11L}-E_{13H}, E_{12L}-E_{14H} and E_{22L}-E_{24H}, due to the strong coupling between the corresponding valence subbands, are the main features observed in this figure. The experimental results show that one of the peaks splits in two for high stresses. This was already observed in other experiments and could be due to an excited state of the E_{12H} excitonic transition which acquires an intensity equivalent to the 1s one for large stresses.

Fig. (2) shows the uniaxial stress dependences of the E_{11H} and E_{11L} transitions with respect to their values at zero stress as a function of the well width. Three different wells corresponding to 22, 11 and 4nm are analysed. The dashed lines correspond to the bulk behaviour for these transitions. The agreement between theory and experiment is qualitatively good, but we obtain smaller slopes for both transitions with respect to the experiment. The wider the well, the closer to the bulk is their behaviour. When the well is thin, the mixed character of the valence subbands increases and the slopes for heavy-like and light-like transitions are closer to each other.

The agreement between theory and experiment provides support for the envelope-function approximation as a suitable method to treat the electronic structure of quantum wells and superlattices under uniaxial stress (9,10).

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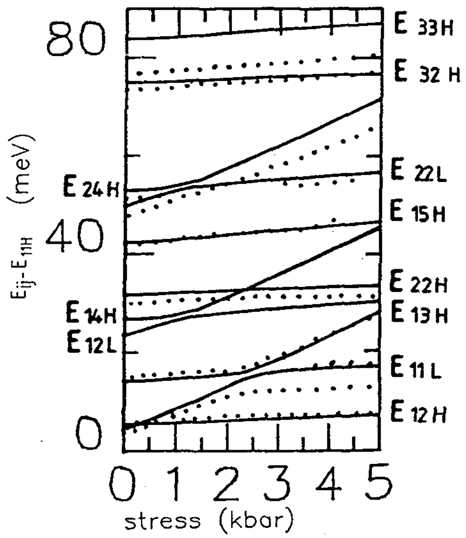

Fig. 1 The uniaxial stress dependences of higher energy excitonic transitions with respect to E_{11H}. The continuous lines represent the theoretical calculation. The dots are experimental results from Ref. 1 and 2.

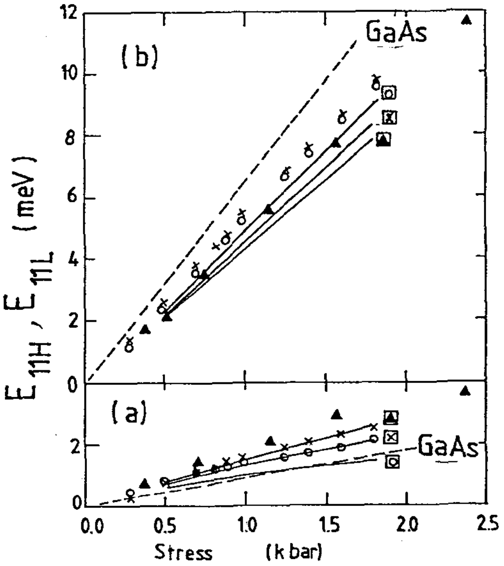

Fig. 2 The uniaxial stress dependences of A) E_{11H} and B) E_{11L} transitions (with respect to the zero stress values) as a function of well width. Black triangle, X, and 0 represent a 4 nm, 11 nm and 22 nm quantum well respectively. The theoretical result is represented by continuous lines. Dashed lines represent the GaAs bulk dependences for these transitions.