COMMENTS

Alloy Clustering in $Al_xGa_{1-x}As$

In the light of reported spectroscopic evidence for extensive clustering in thin $Al_xGa_{1-x}As$ barriers ($L_B \lesssim 70$ Å) of GaAs quantum-well heterostructures (QWH) grown by metal-organic chemical-vapor deposition (MO-CVD),[1] plus the statement that "data are not presently available indicating how sensitive cluster formation is to the specific growth process," we have reexamined data on five samples grown by molecular-beam epitaxy (MBE) with L_B from 19 to 77 Å and remeasured two samples (one with $L_z = 54$ Å GaAs wells and $L_B = 52$ Å $Al_{0.3}Ga_{0.7}As$ barriers, the other $L_z = 188$ Å, $L_B = 19$ Å) looking specifically for the effect reported by Holonyak *et al.*, i.e., islands of GaAs in the $Al_xGa_{1-x}As$ layers. A search for peaks in the photoluminescent spectra at the expected positions for wells $2L_z + L_B$ wide[2] (the technique used by Holonyak *et al.*) and for a second set of transitions in the excitation spectra due to $2L_z + L_B$ wells (a technique not utilized by Holonyak *et al.*) failed to show any indication of wells wider than $\sim L_z$.[3]

Alloy clustering of the type reported[1] should smear the QWH interfaces. However, it has been observed that the excitation spectrum linewidth of optimally grown MBE QWH is well described by islands at the interface of about one atomic layer thick and >300 Å in lateral dimensions.[4] More recent studies indicate that the parameters of such islands are very sensitive to the growth conditions, especially to the substrate temperature T_s during growth. The island height is found to change from one monolayer at the optimum T_s to five monolayers at $T_s \pm 50$ °C.

There exists earlier *nonluminescent* evidence for very abrupt QWH interfaces in MBE material. Absorption studies by Dingle[5] point out an abruptness in the QWH interfaces of ~one monolayer. More direct structural studies of GaAs-$Al_xGa_{1-x}As$ superlattices by x-ray diffraction[6] and transmission electron microscopy[7] (TEM) have also shown sharp interfaces. In addition the TEM study showed the sensitivity of the optimal T_s to the stoichiometry of the layers, a fact which might correlate with the absence of clustering reported[1] for QWH with AlAs barriers.

In conclusion, high-quality QWH which show no spectroscopic or other evidence of clustering can be produced by MBE. The sensitivity of the QWH interface to the growth parameters might explain the extensive clustering reported,[1] but such clustering cannot be regarded as an intrinsic growth mode of these alloys.

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[1] N. Holonyak, Jr., W. D. Laidig, B. A. Vojak, K. Hess, J. J. Coleman, P. D. Dapkus, and J. Bardeen, Phys. Rev. Lett. 45, 1703 (1980).

[2] Unpublished data from R. C. Miller demonstrate that quantum effects are discernible in MBE QWH for L_z up to at least 1000 Å.

[3] Some relevant data for the second sample are given in C. Weisbuch, R. C. Miller, R. Dingle, A. C. Gossard, and W. Wiegmann, Solid State Commun. 37, 219 (1981).

[4] C. Weisbuch, R. Dingle, A. C. Gossard, and W. Wiegmann, J. Vac. Sci. Technol. 17, 1128 (1980).

[5] See, for example, the detailed discussion in R. Dingle, *Festkörperprobleme*, edited by H. J. Queisser (Vieweg, Braunschweig, 1975), Vol. XV, p. 21.

[6] R. M. Fleming, D. B. McWhan, A. C. Gossard, W. Wiegmann, and R. A. Logan, J. Appl. Phys. 51, 357 (1980).

[7] P. M. Petroff, A. C. Gossard, W. Wiegmann, and A. Savage, J. Cryst. Growth 44, 5 (1978).

