Comment on "Chemical Mapping of Semiconductor Interfaces at Near-Atomic Resolution"

Weisbuch *et al.*[1] first proposed that the interfaces of a GaAs/AlGaAs quantum well (QW) could be flat within a monolayer. Improvement of the growth conditions then led to the observation of splittings in the luminescence of QWs, interpreted by assuming that large areas of the interface would be flat at the atomic level.[2,3] Since these first studies, splitting of the excitonic lines has been observed, both in GaAs/AlGaAs and in GaAs/AlAs QWs, quasisystematically when using techniques of growth interruption.[4] We cannot describe here all the features expected and observed for such a splitting, and, rather, refer the reader to Ref. 3 for a detailed discussion. Deviations from the expected splitting can generally be well accounted for by variations of the mean island diameter.[3] Confirmation of the inferred flatness has not yet been obtained by high-resolution transmission electron microscopy (HRTEM).

In a recent Letter, Ourmazd *et al.*[5] study by HRTEM the interfaces of a GaAs/AlGaAs QW. They conclude that the interface is rough over a few monolayers, in a sample where other studies are interpreted in terms of large portions of the interface being atomically flat,[6] and we agree that they studied one of the best available samples. So, their result is in contradiction with the proposed interpretation of the origin of luminescence lines.

It is also incompatible with the results recently obtained by different teams, including ours, on the growth on purposely misoriented substrates. The results of such studies can be found in different publications.[7] They are all explained by a growth process that would favor the nucleation of atoms at the edge of an interface step oriented along $(\bar{1}10)$. In particular, vertical superlattices (SLs) have been obtained by deposition of half monolayers on a disoriented substrate.[7] Such a result is inconsistent with the interface being rough.

The growth of very-short-period SLs has been achieved by different teams.[8] In such a case, spreading of the interfaces over more than one monolayer would result in an alloy, in disagreement with the results of x-ray and TEM observations. Of course, we do not mean that interface roughness does not exist, but that it can be minimized in the best samples.

One possible explanation for the observation of rough interfaces is the use of 400-keV electrons to study the samples. Indeed, our own experiments demonstrate that after 2-min exposure of a GaAs/AlAs superlattice of high quality to a 400-keV beam, the image is blurred. Evidence for such radiation damage can only be obtained if the quality of the interfaces is high enough: typically if the SL is grown under conditions that allow the observation of luminescence splitting. All these results suggest that the high voltage used for the chemical mapping of the sample might be too high and might lead to interdiffusion at the interface. A rough estimate gives for the Ga and As displacement threshold voltages of 230 and 260 keV, respectively.[9]

Furthermore, we have recently carried out a HRTEM study[10] of GaAs/AlAs superlattices grown on misoriented surfaces, using optimized conditions with a microscope operating at 200 keV. On such samples, we do observe high interface flatness and steps of one monolayer roughly following the distribution imposed by the misorientation. The observation of steps is only possible if the parameters of the misorientation are perfectly known and the electron beam is oriented along the edge of the steps (the step direction is fixed by the sample structure). In the case of nonmisoriented samples, the possible chances to align the *e* beam with a step are minimal and this precludes the observation of interfacial steps.

B. Deveaud, B. Guenais, A. Poudoulec, and A. Regreny
Centre National de'Etudes de Télécommunications
22300 Lannion, France

C. d'Anterroches
Centre National d'Etudes des Télécommunications
38000 Meylan, France

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[1]C. Weisbuch, D. Dingle, A. C. Gossard, and W. Wiegmann, Solid State Commun. **38**, 709 (1981).

[2]B. Deveaud, J.-Y. Emery, A. Chomette, B. Lambert, and M. Baudet, Appl. Phys. Lett. **45**, 1078 (1984).

[3]B. Deveaud, A. Regreny, J.-Y. Emery, and A. Chomette, J. Appl. Phys. **59**, 1633 (1986)

[4]See, for example, H. Sakaki, M. Tanaka, and S. Yoshino, Jpn. J. Appl. Phys. **24**, 84 (1985); T. Hayakawa, T. Suyama, M. Kondo, S. Yamamoto, S. Yano, and T. Hijikata, Appl. Phys. Lett. **47**, 952 (1985).

[5]A. Ourmazd, D. W. Taylor, J. Cunningham, and C. W. Tu, Phys. Rev. Lett. **62**, 933 (1989).

[6]C. W. Tu, R. C. Miller, B. A. Wilson, P. M. Petroff, T. D. Harris, R. F. Kopf, S. K. Sputz, and M. G. Lammont, J. Cryst. Growth **81**, 159 (1987).

[7]See, for example, Y. Tokura, H. Saito, and T. Fukui, J. Cryst. Growth **94**, 46 (1989); P. M. Petroff, M. Gaines, M. Tsuchiya, R. Simes, C. Coldren, H. Koemer, J. English, and A. C. Gossard, J. Cryst. Growth **95**, 260 (1989).

[8]See, for example, B. Guenais, A. Poudoulec, P. Auvray, M. Baudet, A. Regreny, and B. Lambert, J. Cryst. Growth **88**, 125 (1988).

[9]*Introduction to Analytical Electron Microscopy,* edited by J. J. Hren, J. I. Goldstein, and D. C. Joy (Plenum, New York, 1979).

[10]A. Poudoulec, B. Guenais, C. d'Anterroches, and A. Regreny, J. Cryst. Growth (to be published).

