Relaxation of a strained quantum well at a cleaved surface

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Scanning probe microscopy of a cleaved semiconductor surface provides a direct measurement of the elastic field of buried, strained structures such as quantum wells or dots, but allowance must be made for relaxation at the surface. A well with a larger natural lattice constant, such as InGaAs surrounded by GaAs, bulges at a free surface to reduce its elastic energy. We have calculated this relaxation analytically for the exposed edge of a strained quantum well within classical, linear elasticity theory for a homogeneous medium. Results are given for a well of constant composition or an arbitrary variation along the growth direction, where the composition can be recovered from a Hilbert transform of the slope of the surface.

The theory is compared with cross-sectional scanning tunneling microscopy of InGaAs quantum wells in GaAs. Consistent values for the composition of the wells were obtained from counting In atoms, X-ray diffraction, and photoluminescence. The lattice constant on the surface and the normal relaxation are first compared with a calculation for isotropic material. Qualitative agreement is good but the theory gives only about 80% of the observed displacement. Some of this difference can be explained by the larger size of indium atoms compared with gallium, and the different surface reconstruction and buckling behavior of InAs and GaAs (110) surfaces upon cleavage.

The theory was therefore extended to include the anisotropic elastic behaviour. Although the semiconductors are cubic, cleavage on a (110) plane reduces the symmetry of the problem and the calculation was performed for a special orthotropic material. This reduces the relaxation and increases the discrepancy between theory and experiment. Possible explanations for this include nonlinear response and interfacial forces, which we are investigating.

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