Growth and Characterization of InAs and InSb Quantum Dot Superlattices in Ternary Alloy Matrices: Toward an Optimized Strain-Balanced Quantum Dot Detector

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Recently infrared detector based on intersubband transitions in InAs/GaAs and (In,Ga)As/GaAs quantum-dot superlattices have been proposed and demonstrated (1). However, detectors of this type examined to date are unsuitable for practical applications in focal plane arrays because of their high dark currents and low operating temperatures, both of which are far from theoretical estimates.

One potential explanation of the poor performance observed to date in the quantum-dot infrared photodetectors (QDIPs) is that the structures considered to date are not strain-balanced. As layer upon layer of quantum dots are grown, the net shear stress at the buffer layer/superlattice interface increases to the point that a critical thickness (corresponding to the average strain in the superlattice) is reached and dislocations form. For example we show in Figure 1 a (004) x-ray diffraction (XRD) spectrum of an InAs/GaAs quantum-dot superlattice. This superlattice is just at the critical thickness; if the amount of InAs deposited per layer were to increase, the peaks would broaden tremendously.

We have fabricated QDIPs from material having XRD spectra similar to Figure 1. A typical low-temperature photocurrent spectrum is shown in Figure 2, where we demonstrate significant photocurrent for light polarized both parallel and perpendicular to the layers in the sample.

We have proposed a *strain-balanced* QDIP with a ternary matrix material as a way to overcome the accumulation of stress. In such a structure, the alloy composition of the matrix can be "tuned" in such a way that it's tensile strain cancels the compressive strain in the dots. These types of structures have been considered previously (2) for II-VI systems but not, to our knowledge, for any III-V systems. We have investigated a number of material system combinations including both InAs and InSb dots in matrices of (In,Ga)As, (In,Al)As, Ga(As,Sb), and Al(As,Sb) on InP substrates. Figure 3 shows an example of a layer of InSb dots grown on an (In,Ga)As buffer layer that is lattice matched to an InP substrates. As can be seen from the figure, these dots are as well formed as those typically seen in III-V systems.

We will show data on structural properties of various III-V semiconductor strain-compensated quantum dot superlattices and, based on the results, propose optimized candidates for strain-balanced QDIPs.

(1) D. Pan, E. Towe, and S. Kennerly, Appl. Phys. Lett. **73**, 1937 (1998).
(2) M. Pinczolits, G. Springholz, and G. Bauer, Phys. Rev. B. **60**, 16 (1999).

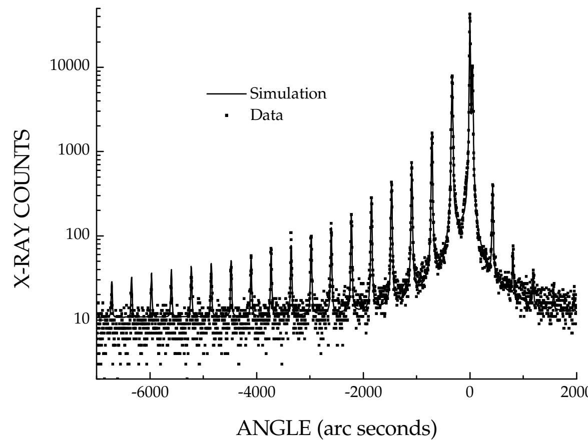

Figure 1. (004) x-ray diffraction spectrum of a 33-period InAs/GaAs quantum dot superlattice.

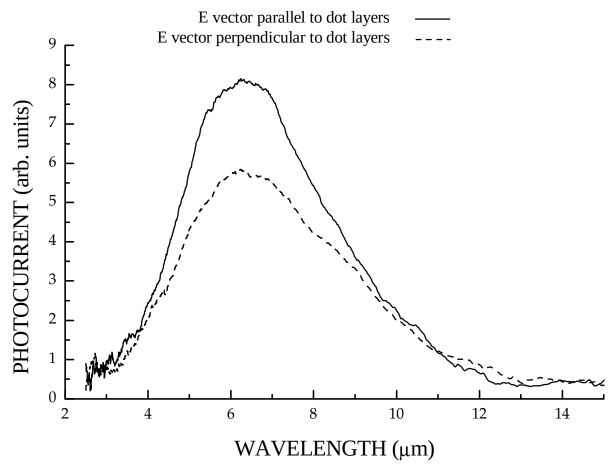

Figure 2: Photocurrent spectra for a 33-period InAs/GaAs quantum dot detector structure for light polarized parallel and perpendicular to the quantum-dot layers.

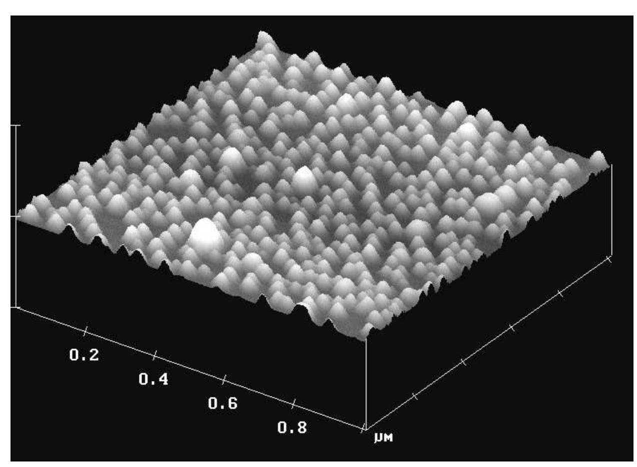

Figure 3: Atomic force micrograph of InSb quantum dots grown on a ternary (In,Ga)As buffer layer lattice matched to InP: (a) top view and (b) perspective view.