Structural and Optical Properties of PbTe/CdTe/InSb Heterostructures Grown using Molecular Beam Epitaxy

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Rock-salt lead chalcogenides are of much current interest for several reasons, including their direct band gap in the infrared (IR) wavelength range [1]. Integrating II-VI and IV-VI chalcogenides with III-V compounds into epitaxial heterostructures combines the advantages of wide-band gap II-VI binaries and alloys, good for electrical and optical confinement, with narrow-band gap III-V and IV-VI compounds. IV-VI active layers are also of interest for room temperature operational IR devices because IV-VI materials have significantly smaller Auger coefficients than the III-V or II-VI materials [2]-[4], a property that could be utilized to enhance IR laser and photodetector performance [5]. Thus, the heterocrystalline epitaxial integration of rock-salt lead chalcogenides with zincblende II-VI and III-V semiconductors on commercially available III-V semiconductor substrates can potentially enable a wide range of novel material properties and device applications.

In this study, heterovalent and heterocrystalline structures composed of InSb, CdTe, and PbTe layers were grown on ¼ 2” (001) InSb substrates in a single-chamber MBE system. High-quality materials were achieved using careful control of the growth conditions at the interface between two different crystal structures with matched lattice constants in plan. For the PbTe/CdTe heterostructures (Fig. 1), CdTe growth was initiated on the Cd-terminated InSb surface by opening the Te cell shutter, whereby a (2×1) surface reconstruction was observed immediately. The surface reconstruction during the PbTe growth on CdTe, which eventually transitioned to a streaky (1×1) pattern during the PbTe growth when a Te surface soak of 60 seconds was used between the bottom CdTe buffer and the PbTe layer, suggests that the common Te atoms at the interface help to promote layer-by-layer growth of PbTe. This contrasts the case of PbTe grown directly on InSb, where the use of a Te overpressure on InSb resulted in a spotty surface reconstruction throughout the growth. PL properties of the samples were tested between 13 to 300 K, with an increase in peak emission energy with temperature. Crystal quality was determined from XRD and TEM.

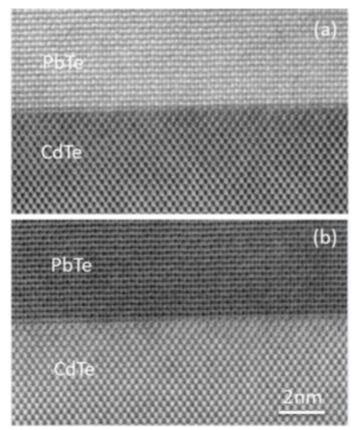

Figure 1. Aberration-corrected scanning TEM images showing abrupt nature of PbTe/CdTe interface: (a) high-angle annular dark-field; (b) large-angle bright-field

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[5] P. J. McCann, K. Namjou, and X. M. Fang, Appl. Phys. Lett. 75, 3608 (1999).

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Supplementary information:

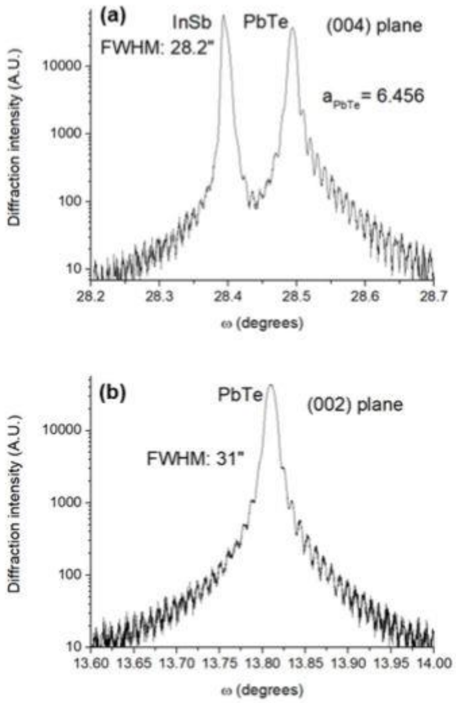

Figure 2. XRD ω-2θ measurements of 500-nm-thick PbTe grown directly on an InSb (001) buffer layer. PbTe and InSb peaks are visible in the (004) diffraction pattern (a), but only the PbTe peak is visible in the (002) diffraction pattern (b).

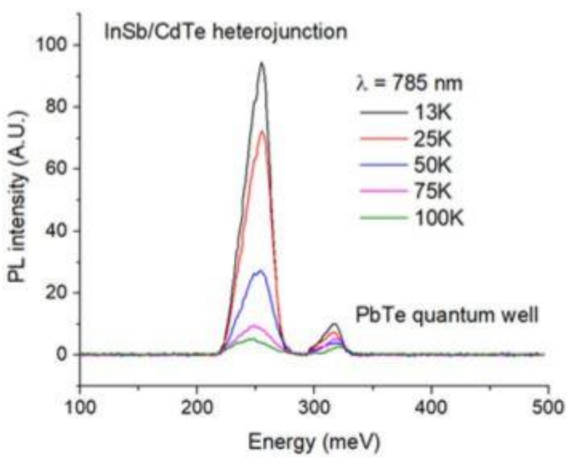

Figure 4. (Color online) PL spectra of PbTe/CdTe quantum well.

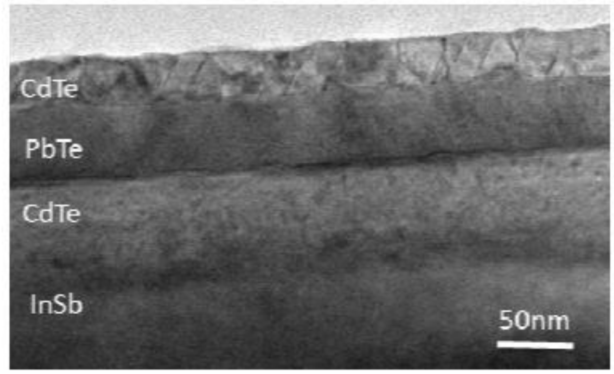

Figure 3. Cross-section TEM image showing

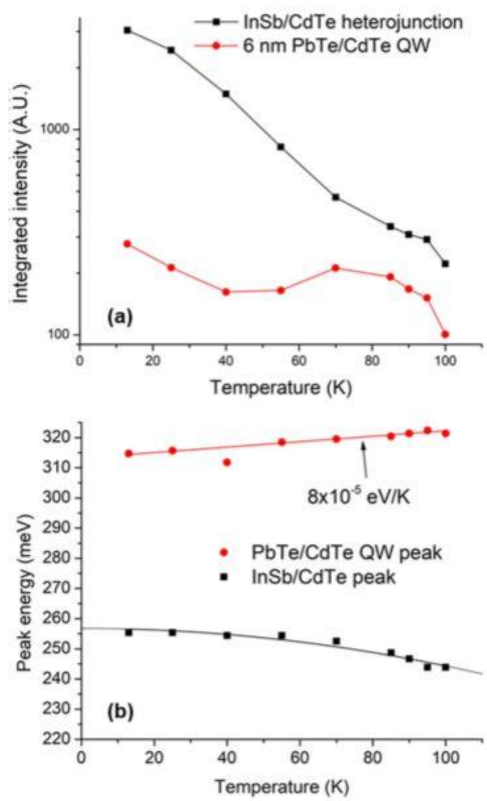

Figure 5. (Color online) (a) Integrated intensity of spectrum peaks from 6-nm-thick PbTe quantum well sample. (b) Peak energy values for the same PbTe quantum well structure showing divergent temperature dependence.