

Strained-layer epitaxy of SnTe on CdTe (110)

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Bulk SnTe is a IV-VI compound which crystallizes in the NaCl structure. However, deposition of SnTe on CdTe(110) can force very thin films of SnTe to grow in the zinc-blende structure, leaving an "extra" electron per atom not involved in tetrahedral bonds. We present an angular-resolved photoemission study of this exotic heterostructure, and show that indeed the first ~ 4 monolayers of SnTe do grow in the zinc-blende structure. For films of more than ~ 10 layers in thickness, the film relaxes into the more favorable NaCl structure. The valence- and conduction-band offset between NaCl structured SnTe and CdTe(110) are $\Delta E_v = 1.01 \pm 0.05$ eV, and $\Delta E_c = 0.37 \pm 0.05$ eV, respectively. The Fermi level lies at the midpoint of the SnTe band gap.

I. INTRODUCTION

The possibility of tailoring specific electronic properties of solids by varying the periodicity of a superlattice structure composed of two different semiconducting materials has opened a new, fast-growing field in materials science.¹ Generally, the more technologically useful superlattices are comprised of two closely lattice matched isoelectronic semiconductors. The superimposed superlattice growth period together with the valence- and conduction-band offsets generate quantum wells for electrons and holes. The electronic properties of these quantum wells play a major role in determining the optoelectronic properties of the superstructure. They do not, of course, completely determine a superstructure device performance because additional parameters such as strain^{2,3} and built-in electrostatic or magnetic fields⁴ can be exploited to change and fine tune electronic levels for specific applications. Fast detectors consisting of isoelectronic materials and solid-state lasers systems sometimes benefit from such fine tuning. The ability to fine tune superlattice device characteristics becomes even more feasible if one considers using more exotic systems in addition to the "standard" nearly lattice matched isoelectronic ones. In particular, the selection of possible new materials increases dramatically if one considers not only naturally stable structures, but also forces the growth of metastable phases of non-isoelectronic materials in registry with potential substrate materials.

The aim of the present paper is to investigate the molecular-beam epitaxial (MBE) growth and interfacial electronic structure of one such non-isoelectronic heterostructure, SnTe on CdTe(110), in order to provide parameters such as valence- and conduction-band offsets, interfacial width, and reactivity. Since these parameters would critically determine the usefulness of SnTe/CdTe quantum well structures, their analysis is an absolute prerequisite to their successful MBE growth and the realization of a superlattice.

Putting aside for the moment the potential applications of SnTe/CdTe superstructures, the interface formation is of considerable interest by itself. SnTe is a group IV-VI *fcc* compound with an average of five valence electrons per atom,⁵ whereas CdTe is a zinc-blende structured II-VI compound with an average of four valence electrons per atom. The epitaxy of SnTe on CdTe raises the question of whether

SnTe will grow in its thermodynamic stable NaCl structure, or if the substrate will force it to grow up to a critical thickness in a metastable zinc-blende structure. If SnTe were to grow in the zinc-blende structure, a question remains about the status of the fifth electron per atom which would not participate in the tetrahedral bond configuration of the metastable epilayer.

Tetrahedrally bonded, so called α -Sn, is a semiconductor which can be grown epitaxially with nearly strain-free lattice match to CdTe. The possibility of growing thin SnTe films with the zinc-blende structure where Sn atoms substituting Cd atoms is not remote. The overlayer would result in a strained *n*-type film of an interatomic Sn-Te distance of ~ 2.77 Å if one adds the respective covalent radii. This distance is intermediate to that of the zinc-blende Cd-Te and NaCl Sn-Te distances. Since the lattice constant of SnTe is $\sim 2.58\%$ smaller than that of CdTe. The growth of a zinc-blende "buffer" layer of SnTe would help the epitaxial growth of the NaCl structured SnTe up to a critical thickness before strain is released in either a phase transition or through the formation of misfit dislocations.^{6,7} We have used angular resolved photoemission spectroscopy with soft x-ray synchrotron radiation and reflection high-energy electron diffraction (RHEED) to study the local electronic and structural properties of thin SnTe films grown *in situ* on CdTe(110). Based on surface sensitive Cd, Sn, and Te 4*d* core level spectra, we find that SnTe grows in the layer-by-layer mode at room temperature. The interface is fairly abrupt and nonreactive. The first few layers grow highly strained in the zinc-blende structure. Increasing thickness results in the formation of NaCl structured SnTe and reduces the strain as can be seen from the analysis of RHEED pattern.

II. EXPERIMENTAL

Growth of high-quality CdTe based semiconducting multistructures depends critically on the structural quality of the CdTe substrate material. Currently, there is still a lack to routinely purchase large-area CdTe single-crystal wafers of structural perfection comparable to those of high-grade GaAs. CdTe crystal substrates, which we used in the present investigation, were 10×10 mm² with a thickness of ~ 1 mm. They were mechanically polished and chemically etched to a

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Epitaxial Oxide Thin Films and Heterostructures, 1994 **Thin Films and Surfaces for Bioactivity and Biomedical Applications** Catherine M. Cotell, 1996

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