

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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Nanomaterials Engg Kamakhya Prasad Ghatak, Madhuchhanda Mitra, 2018-11-05 The work studies under different physical conditions the carrier contribution to elastic constants in heavily doped optoelectronic materials In the presence of intense photon field the authors apply the Heisenberg Uncertainty Principle to formulate electron statistics Many open research problems are discussed and numerous potential applications as quantum sensors and quantum cascade lasers are presented **Index of Conference Proceedings**, 1996 Covalent Ceramics III: Volume 410 Aloysius F.

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Bormann, 1996-07-25 Materials with metastable structures and microstructures have been used with success to create unusual structural and functional properties and property combinations Highly nonequilibrium technologies for creating metastable materials have been devised which allow materials to be prepared far away from the thermodynamic equilibrium Using these methods materials can now be designed to possess specific properties tailored to fit an application rather than fitting an application to the properties of available materials However as these materials are metastable with respect to structural and compositional changes under temperature there is great concern for understanding and controlling their limitations This book features both fundamental as well as applied aspects of the subject by stressing the structure property relationships the conditions for stability of these materials and the requirements for technological applications In addition to the synthesis processing characterization properties and applications of such materials attention is also focused on the

modelling of structures phenomena and processes Topics include synthesis and processing thermodynamic and kinetics phase transformations and properties and applications

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Optoelectronic Materials: Volume 417 Eric D. Jones, Angelo Mascarenhas, Pierre Petroff, 1996-07-02 While the effects of spontaneous ordering or composition modulation on the properties of semiconductors and optoelectronic devices have been studied with great interest over the past several years an understanding of the physics and chemistry of these two related phenomena is still in its infancy This book brings together researchers from around the world to address issues concerning the physics chemistry and growth parameters for spontaneous ordering and composition modulation Developments in the use of artificial patterning to obtain new structured materials on a microscopic scale are featured Advances in characterization techniques are also presented Topics include spontaneous ordering self assembled structures and quantum dots self organized epitaxial structures composition modulation studies and optoelectronic materials

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Speck, 1996-03-29 Our understanding and control of epitaxial oxide heterostructures has progressed along multiple frontiers including magnetic dielectric ferroelectric and superconducting oxide materials This has resulted in both independent rediscovery and the successful borrowing of ideas from ceramic science solid state physics and semiconductor epitaxy A new field of materials science has emerged which aims at the use of the intrinsic properties of various oxide materials in single crystal thin film form Exploiting the potential of these materials however will only be possible if many fundamental and engineering questions can be answered This book represents continued progress toward fulfilling that promise Technical information on epitaxial oxide thin films from industry academia and government laboratories is presented Topics include dielectrics ferroelectrics optics superconductors magnetism magnetoresistance Polymer/Inorganic Interfaces II: Volume 385 Materials Research Society. Meeting, 1995 Polymer inorganic interfaces play a fundamental role in a wide range of applications yet understanding of the fundamental interactions between polymers and inorganic phases and how they affect the strength and durability of the interface is still in its infancy This proceedings volume addresses various aspects of polymer inorganic interfaces including surface preparation and treatment characterization and interface performance In addition applications where the interface and its properties play a significant role such as in biointerfaces microelectronics polymer composites and interpenetrating polymer networks are discussed Contributions to the volume examine various inorganic material polymer interfaces with an emphasis on composites epoxy resins polyurethanes poly methyl methacrylate

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Thermodynamics and Kinetics of Phase Transformations: Volume 398 James S. Im, 1996-09-10 The emphasis of this book is on the quantitative analysis of transformation kinetics integrated with thermodynamics Solidification is a success story for quantitative kinetics analysis The work reported concentrates on phase selection under extreme processing large undercooling or ultrarapid quenching of the liquid Theoretical treatments are concerned mainly with the analysis of morphological instabilities during directional solidification at more conventional rates The coverage of particle beam effects is distinguished by the materials studied alkali halides minerals semiconductors and metals The thermodynamics of interfaces are a particular focus especially in connection with the solid state formation of amorphous phases A highlight of the book is the coverage of the Johnson Mehl Avrami Kolmogorov analysis of overall transformation kinetics This venerable treatment is revisited and new insights and limitations are explored Topics include transformations in undercooled liquids directional solidification particle beam induced transformations interfaces thermodynamics and reactions amorphous materials structure and transformations solid state transformations and ordering and phase separation *Defect and Impurity Engineered Semiconductors and Devices*, 1995 Epitaxial Oxide Thin Films and Heterostructures, 1994

Metal-Organic Chemical Vapor Deposition of Electronic Ceramics II: Volume 415 Seshu B. Desu, David B. Beach, Peter C. Van Buskirk, 1996-02-28 The use of high performance ceramic materials in microelectronics holds the potential for the development of a wide range of novel high value products For example ferroelectric ceramic capacitors are key to the development of high density ferroelectric nonvolatile memory FRAM High dielectric constant para electric capacitors are potentially useful for the production of high density dynamic random access memory DRAM and for decoupling capacitors in high speed microprocessors Electro optic materials are useful as waveguides tunable filters and switches in advance communication applications Researchers come together in this book to discuss both the application of metal organic chemical vapor deposited MOCVD materials to microelectronics and the nuts and bolts of the technique A wide variety of opto electronic superconducting ferroelectric and other advanced ceramic materials are discussed Problems of dealing with low volatility precursors design of new precursors and characterization of CVD processes are addressed Topics include nonoxide ceramics precursor chemistry and delivery process analysis and characterization and oxide ceramics

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