An AlInAsSb/GaSb Superlattice Analysis – The Digital Alloy Iduced Conduction Band States

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Abstract **Photoreflectance (PR) and photoluminescence (PL) has been measured on the set of four samples containing 12 periods of a GaSb and an AlInAsSb digital alloy with various average Al fractions, both 12nm thick. Using 8kp with envelope function approximation, PL and PR spectra are qualitatively explained. States in conduction bands are classified in three general groups, which are used during further systematic description of various superlattice cases.**

Keywords—8kp model, envelope function approximation, AlInAsSb/GaSb, digital alloy, superlattice, photoluminescence, photoreflectance

I. Introduction

Despite the fact, that $Al_xIn_{1-x}As_ySb_{1-y}$ alloys lattice matched to GaSb (henceforth referred to as AlInAsSb) has many applications in mid-infrared and near-infrared optoelectronic devices, they still are challenging materials to grow and be used in heterostructures. Due to wide miscibility gap these alloys are difficult to grow and methods like digital alloying with component binaries, AlAs, AlSb, InAs, and In Sb are used to achieve materials, which are meant to have homogenous alloy properties [1]. In this work, there are shown qualitative electronic differences between such digital alloys and homogenous alloys meant to be used in heterostructures containing unstrained GaSb.

II. Samples and Methods

A. Samples and Experiment

Four samples were grown on GaSb substrates by solid-source MBE. The main part of each structure consist 12 periods of AlInAsSb digital alloy (DA) and GaSb, both 12nm wide. Samples differs from each other by an AlInAsSb DA average compounds fractions. Samples containing DA with average Al fraction y=0.4, 0.5, 0.6, 0.7 are henceforth referred to Al40, Al50, Al60, and Al70 respectively. Photoreflectance (PR) and photoluminescence (PL) has been measured on the set of samples in 300K in order to perform optical characterization.

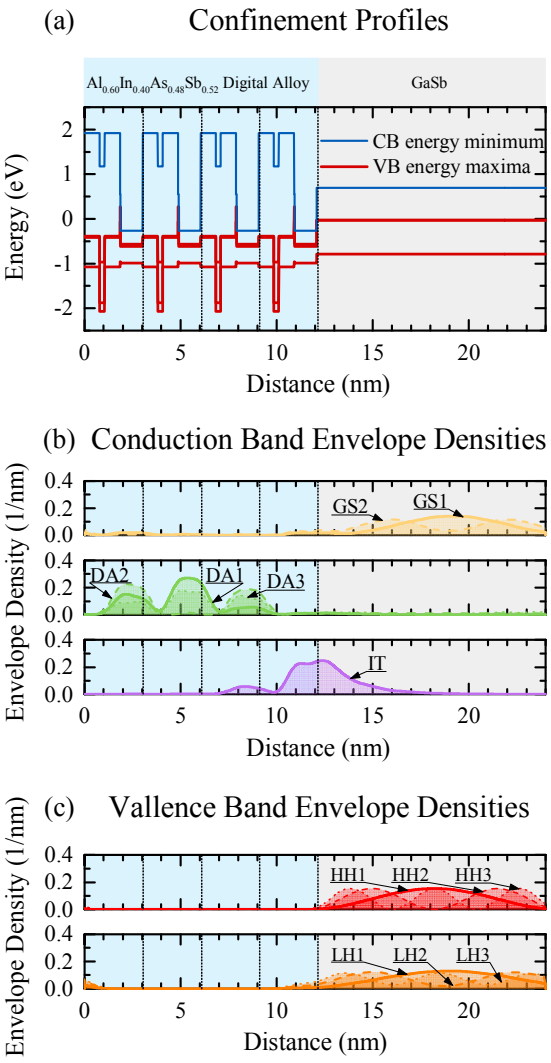

Fig. 1. (a) one period of AlInAsSb DA and GaSb conduction band and vallence band extrema in growth direction, (b) first five condution band states envelope square modulus in in gamma point, (c) first three vallence band states envelope square modulus in in gamma point identified as heavy holes and light holes

B. *Theoretical Model*

Envelope-function method and 8**kp** model [2] are used to qualitatively explain and understand possible transitions and their strength dependence on Al fraction in the samples. Periodic AlInAsSb/GaSb region is of interest in this work, so in theoretical model appropriate superlattices are analyzed by defining only one period of AlInAsSb DA on GaSb with periodic boundary conditions. One period of confinements in Al60 is presented in Fig. 1 (a).

III. Experiment Explanation

A. *States Systematization*

Calculations performed for all samples showed, that with some simplification it can be said, that first important hole states are localized in GaSb layers (HH and LH) and first important electron states can be divided into three main groups: localized on interfaces states with tail into GaSb layer (IT), states localized mainly in digital alloy (DA), and states localized mainly in GaSb layers (GS). These states for Al60 are shown in Fig. 1 (b) and (c). The simplification is useful for further description but it is important to mark, that the less it is accurate the less energy difference between states of different groups are. With proper conditions, these state are mixed.

B. *Interpretation of Visible Transitions in PL and PR*

It is found, that low energy oscillations in ER spectra presented in Fig. 2 are connected with transitions IT-HH1, IT-HH2, and IT-LH2. Strong oscillations in the spectra close energy 0.8 eV are connected with transitions between GS1-HH1 and GS1-LH1. Low energy oscillations and PL strengthening with Al fraction increase is identified as effect of TS tile into GaSb layer lengthening.

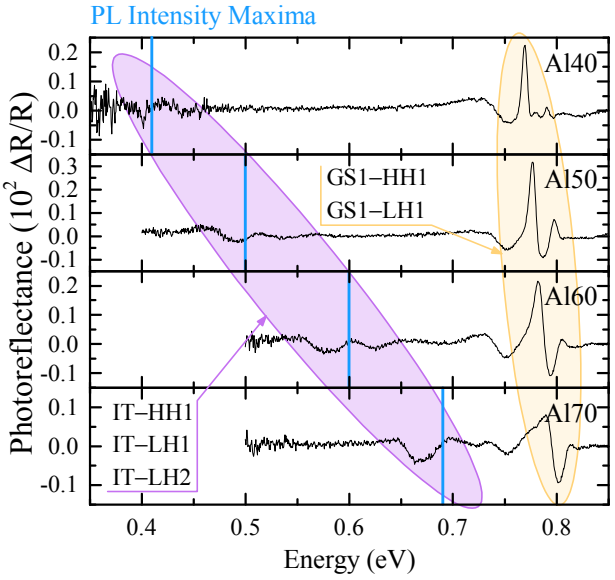

Fig. 2. Spectra obtained from photoreflectance measurements for the set of samples. Blue lines marks energies of photoluminescence intensity maxima. Yellow and purple regions circles oscilations connected with GS1 and TI states respectively.

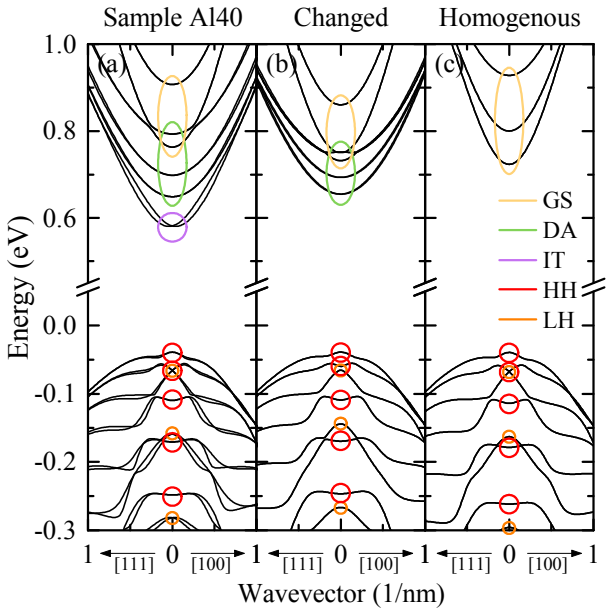

Fig. 3. Spectra obtained from photoreflectance measurements for the set of samples. Blue lines marks energies of photoluminescence intensity maxima. Yellow and purple regions circles oscilations connected with GS1 and TI states respectively.

IV. Comparative Modelling

In order to better understand issue concerning AlInAsSb DA grown on GaSb, two additional sets of superlattices are analyzed. With slight modification, the first new concerned set is designed in such a way that IT states do not exist within it, and second new set consists homogenous AlInAsSb instead of an appropriate DA. Such three sets of calculations derives convenient picture of when conduction states of each type are present in superlattice and why they appear. In Fig. 3. there is set of three electronic band structures calculated for Al40 (a), superlattice with modified DA (b), and superlattice with homogenous AlInAsSb (c).

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