Anion Exchange of GaAsSb/GaInAs Interfaces

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Abstract:

The objective of this project is to investigate and study the anion exchange process at the interfaces of GaAsSb/GaInAs hetrostructures. These superlattices were grown using Molecular Beam Epitaxy and characterized using High Resolution X-Ray Diffraction (HRXRD). GaInAs exposed to Sb_2 flux, and GaAsSb exposed to Sb_2 and As_2 flux were studied in this work. The composition and thickness profiles of these grown samples were further determined using dynamical simulations. Comparisons between both studies were presented in order to better understand the As/Sb exchange process at the interfaces of GaAsSb/GaInAs.

Introduction:

Bandgap engineering has been a prominent area of research during the past decade. Lately, several potential device applications in the mid-infrared region (2 µm-5 µm) have generated much interest in arsenside and antimonide based photodetectors. Such devices have applications in chemical sensing, atmospheric sensing, gas monitoring, high speed IR-imaging and even medical diagnostics. These devices are physically realizable using type II multiple quantum well structures.

A type II quantum well structure has a staggered band alignment as shown in Figure 1. The electron transitions in such a structure are spatially indirect.

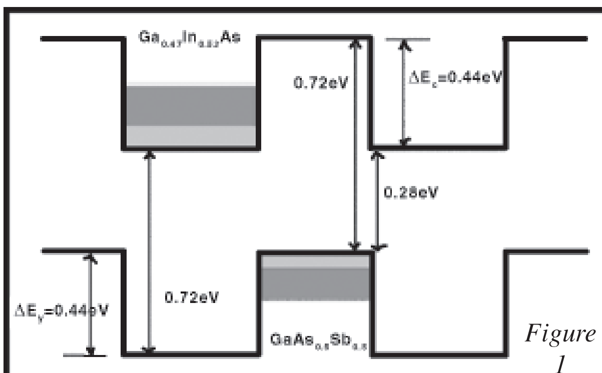

Figure 1

More and more interfaces are needed to maximize the number of electron transitions. Anion mixing at the interfaces can create traps in the mid-gap reducing the efficiency and sensitivity of the photodetector. Hence the structure of the interfaces is a very critical parameter as it has direct effects on the optical and electronic properties of the device.

The focus of this work is to characterize the anion exchange process at the interfaces of GaAsSb/GaInAs hetrostructures. To achieve this goal, three different studies were performed.

- GaInAs exposed to Sb_2 flux
- GaAsSb exposed to As_2 flux
- GaAsSb exposed to Sb_2 flux

Ten period superlattices were formed to introduce more interfaces to allow for an effective study of the properties.

Procedure:

All samples for the study were grown in a customized Varian Gen II solid source MBE system. The growth chamber is equipped with group III effusion cells such as Ga, In, Al groups, and group V valved crackers for As, Sb and P. All samples were grown on InP substrate with a growth temperature was set to be 525-530°C. The exposure time was varied in the samples to change the exchange process.

The structure of the samples was analyzed by standard x-ray diffraction techniques. Dynamical simulations were conducted on the samples using RADS software to determine composition and thickness profiles.

Results and Conclusion:

The first study was performed by exposing GaInAs to Sb_2 flux to study the Sb-As exchange process. The exposure times were varied from 10 to 30s. Initially the interface layer was simulated as a single layer with a constant composition to model Sb exchange. Earlier work shows that Sb segregation is a common phenomenon in As based layers [1, 2]. Thus the interface structure was optimized to include Sb segregation by adding another exponentially gradient interface layer where As composition decays by the following equation:

$$y = y2 * e^{-t}$$

where y2 is the composition of As in the constant composition layer and t is the thickness of the segregation interface layer. X-ray scans for all three samples are shown in Figure 2. The satellite peaks are non-existent in the 10 second sample; some visible peaks can be seen in the 20 second sample whereas sharp satellite peaks are observed at the 30 second sample. The simulated results are shown in Table I.

T_{sb}	Sb Exchange			Sb segregation	
	$Ga_{0.47}In_{0.53}As$	GaInAs(1-y)Sb(y)	y_{Sb}	GaInAs(1-y)Sb(y)	y_{Sb}
10s	247.4Å	0.19 Å	0.2	0.10 Å	0.28
20s	250.9 Å	0.64 Å	0.2	0.50 Å	0.51
30s	246.7Å	2.07 Å	0.2	1.00 Å	0.71

The Sb exchange layer composition is virtually constant over the entire range of exposure times. The table also indicates that the thickness of the interface layer and the Sb segregation is directly proportional to the exposure time for a certain growth temperature. The x-ray scans for all three samples reveal sharp isolated peaks at either side of the substrate peak located at 6000 and -6000 relative seconds, approximately (Figure 2). This phenomenon was initially attributed to either Sb or In segregation but the modeling of the structures defied that assumption. Earlier work on similar material systems show no evidence of such an occurrence [1, 2]. At this stage these peaks could not be explained using dynamical theory alone. Other processes must be utilized to explore this phenomenon further.

The second structure was obtained by exposing GaAsSb to Sb_2 flux for 30 seconds followed by the immediate overgrowth of GaAsSb layer. The x-ray simulations indicate minimal exchange at the interface layer (< 2.5%) (Figure 3a). Furthermore, the structure also shows some strain developing at the interface layer as the layers are 10% relaxed. The relaxation could be due to the quality of MBE growth.

The final structure was produced by As_2 flux exposure to GaAsSb layer for 30 seconds (Figure 3b). Unfortunately x-ray simulations couldn't produce satisfactory models for the scans, thus the thickness and composition profiles for this sample could not be determined.

Future Work:

Further research is needed to explain the As for Sb exchange process at the GaInAs on GaAsSb interface. The GaAsSb structure can be grown again under the same conditions to observe any reproducibility of results. The exposure times of As_2 flux can be varied to study the effect of exposure times on the structure. Furthermore, XRD study can be supplemented with XSTM and PL to achieve proper results.

Acknowledgments:

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References:

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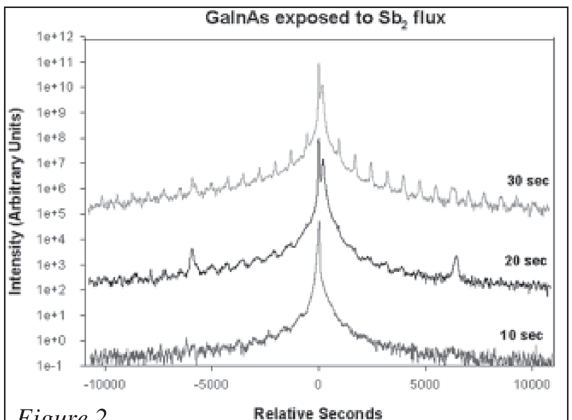

Figure 2

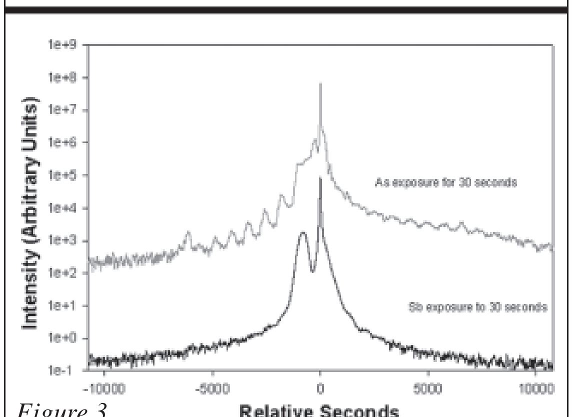

Figure 3