Structural characterization of GaSb-based heterostructures grown on Si.

Mounib Bahri[1]*, Ludovic Largeau[1], Olivia Mauguin[1], Gilles Patriarche[1], Karine Madiomanana[2], Jean-Baptiste Rodriguez[2], Laurent Cerrutti[2], Eric Tournié[2].

[1]*Laboratoire de Photonique et Nanostructures (LPN), CNRS-UPR20, Route de Nozay, 91460 Marcoussis, France.*
[2]*Institut d'Electronique du Sud (IES), Université Montpellier 2, CNRS-UMR 5214, Place Eugene Bataillon , 34095 Montpellier cedex 5, France.*

*mounib.bahri@lpn.cnrs.fr; Téléphone : 0169636227;

1. INTRODUCTION

Monolithic integration of Gallium Antimonide (GaSb) heterostructures on Silicon (Si) is a promising road for producing efficient optoelectronics devices (lasers diodes [1], integrated photonic circuit...).

Three problems are to be overcome for growing such heterostructures on Si: First, the lattice mismatch between GaSb and Si (12.2%) which generates a high density of dislocations. Second, the growth of polar semiconductors on non-polar ones causes antiphase boundaries (APBs). Finally, the 3D growth mode of GaSb on Si which is due to the surface energy difference between the substrate and the films.

2. RESULTS

2.1 Experiments

we have investigated the structural properties of GaSb grown on Si by Molecular Beam Epitaxy (MBE) using the two complementary techniques X-Ray Diffraction (XRD) and Scanning Transmission Electron Microscopy(TEM/STEM).

TEM/STEM measurements have been done using a Cs corrected Jeol 2200FS microscope.

2.2 Interface GaSb/Si: defects and solutions

We have observed a 2D array of misfit dislocations at the interface GaSb/Si [2]. Coupling Grazing incidence XRD and STEM observations, we confirmed that this array is formed of a pure 90°-type dislocations (Lomer-type). The Geometrical Phase Analysis [3] (GPA) shows a well localized stress field around misfit dislocations. In addition to dislocations, we have identified impurities and holes in the substrate that can be a generation source of defects like twins. After optimizing the substrate cleaning process, the twinned volume in the GaSb film was reduced to 75%. The threading dislocations density was also reduced near the interface [4]. We have used a vicinal Si substrates with different angles of miscut to suppress APBs but those defects are always present. AlSb buffer layer was also used to ameliorate the crystalline quality of GaSb and evolve from a 3D islands growth mode to a 2D one [5]. In addition to the 3D islands growth of AlSb buffer, we have identified (using EDX) an AlSb wetting layer at the interface. We are now investigating an alternative route based on thermal treatment to prepare the substrate and reduce the APBs density.

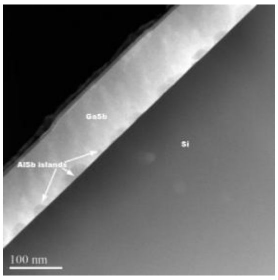

Figure1: STEM-HAADF image of GaSb/Si with AlSb buffer layer.

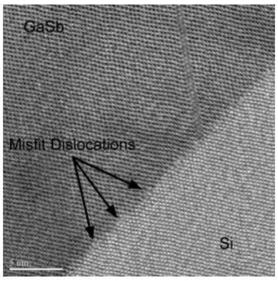

Figure2: STEM-BF micrograph of interfacial misfit dislocations on GaSb/Si.

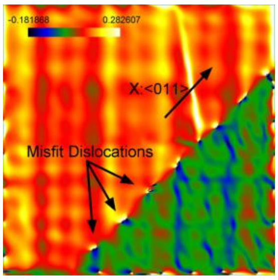

Figure3: Strain map parallel to the interface (ε_{XX}).

2.3 Threading Dislocations density evolution with thickness:

Threading dislocations propagate along the film thickness and act as a non-radiative recombination centers. We know that the threading dislocations density decreases slowly with increasing the thickness. Therefore, we introduced super-lattices (like GaSb/AlSb) to filter the threading dislocations and to favor their recombination by bending them at the super-lattice interfaces. we are now developing a Monte-carlo simulation model using the interaction radius between dislocations to fit the density evolution with thickness (with or without super lattice).

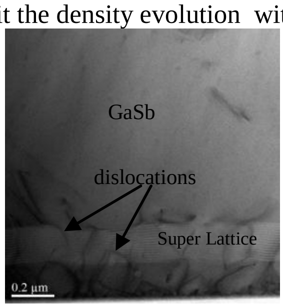

Figure4: dislocations filtering using an AlSb/GaSb super-lattice.

3. CONCLUSION AND AKNOWLEGEMNET

A high quality GaSb-based materials need a good surface treatment with an efficient super-lattice to block and suppress defects near the GaSb on Si interface.

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