Optimization of the interfacial misfit array growth mode of GaSb epilayers on GaAs substrate

D. Benyahia, Ł. Kubiszyn, K. Michalczewski, A. Kębłowski, P. Martyniuk, J. Piotrowski, A. Rogalski

PII: S0022-0248(17)30684-X
DOI: https://doi.org/10.1016/j.jcrysgro.2017.11.015
Reference: CRYS 24373

To appear in: *Journal of Crystal Growth*

Optimization of the interfacial misfit array growth mode of GaSb epilayers on GaAs substrate

D. Benyahia[1*], Ł. Kubiszyn[2], K. Michalczewski[1], A. Kębłowski[2], P. Martyniuk[1], J. Piotrowski[2] and A. Rogalski[1].

[1]Institute of Applied Physics, Military University of Technology, 2 Kaliskiego Str., 00-908 Warsaw, Poland
[2]Vigo System S.A., 129/133 Poznańska Str., 05-850 Ożarów Mazowiecki, Poland

[*]Corresponding author: djalal.benyahia@wat.edu.pl

***Abstract*—The growth of undoped GaSb epilayers on GaAs (001) substrates with 2° offcut towards <110>, by molecular beam epitaxy system (MBE) at low growth temperature is reported. The strain due to the lattice mismatch of 7.78% is relieved spontaneously at the interface by using interfacial misfit array (IMF) growth mode. Three approaches of this technique are investigated. The difference consists in the steps after the growth of GaAs buffer layer. These steps are the desorption of arsenic from the GaAs surface, and the cooling down to the growth temperature, under or without antimony flux. The X-ray analysis and the transmission electron microscopy point out that desorption of arsenic followed by the substrate temperature decreasing under no group V flux leads to the best structural and crystallographic properties in the GaSb layer. It is found that the 2 µm-thick GaSb is 99.8% relaxed, and that the strain is relieved by the formation of a periodic array of 90° pure-edge dislocations along the [110] direction with a periodicity of 5.6 nm.**

***Index Terms*—**
A1. High resolution X-ray diffraction;
A3. Molecular beam epitaxy;
B1. Antimonides;
B1. Gallium arsenide substrate;
B2. Semiconducting III-V materials.

I. Introduction

The epitaxy of the antimony-based compound semiconductors on different substrates (GaAs, Si, or GaP) is of high interest for several applications in infrared optoelectronics, as well as ultra-high speed low-power-consumption electronics [1]. This attractiveness is due to the unique band structure alignment, small effective mass, and high electron mobility [2–4]. Thus, these **combinations of** materials have received a lot of attention, and considerable progress has been realized in device fabrication and invention, for example, field effect transistor [5], semiconductor lasers [6], and infrared detectors [7]. Whereas new advancements have permitted the growth of high quality GaSb layers on native substrate, GaAs **substrates are** preferable thanks to its several advantages. Indeed, GaAs substrate is cheaper, can be made with semi-insulating properties, and has favorable thermal characteristics. However, a huge lattice mismatch of 7.78% exists between GaAs and GaSb materials. Consequently, the critical thickness is predicted to be a couple of monolayers; beyond it, misfit dislocations would be **generated**. Moreover, in systems with such high mismatch, the misfit **dislocation** arrays include pure-edge, 60°, as well as mixed dislocations [8–10]. **The** growth of a thick layer leads to the evolution of threading dislocations, typically on the order of 10^9 cm^{-2} [11], which run through the depth of the grown layer. These threading dislocations limit the performance of the device [12]. Different techniques have been used to reduce the deleterious effects of these threading dislocations, including compositionally graded metamorphic buffer (MB) layers [13,14], beryllium related hardening mechanism [15], and interfacial misfit dislocation (IMF) growth mode [16]. The MB approach presents numerous shortcomings, for instance, the necessity to grow thick buffer layer (>1 µm), poor thermal conductivity, and substantial material degradation due to the existence of threading dislocations [17]. On the other hand, when the whole strain due to the lattice mismatch is alleviated by a periodic array of Lomer dislocations along [110] and [11-0] directions, the epitaxial layer should be free of threading dislocations. This is the principle of interfacial misfit array (IMF) growth mode, that was recently suggested and demonstrated to be efficient in decreasing the dislocations' density from 10^8-10^9 cm^{-2} to 10^5 cm^{-2} [18]. The growth of GaSb layers using IMF technique has some discrepancy in the previous reported works. While all groups agree that the desorption of arsenic after the growth of GaAs buffer layer is the primordial condition for IMF formation, the transition from arsenic to antimony overpressure **was** performed at **either** GaAs **or** GaSb growth temperatures. In addition, the cooling of the substrate temperature from GaAs growth temperature to that of GaSb **was** performed under arsenic overpressure [16], antimony flux [18], or without any group V flux [19]. Recently, Tan *et al.* [20] demonstrated the IMF array formation by using As-to-Sb anion exchange process, performed on an As-terminated GaAs surface. Besides, the **Sb-terminated** reconstruction **on the GaAs surface was** found to be an effective way to enhance the quality of GaSb layers [21]. Sb-terminated reconstruction can exhibit **(1×3)**, (2×8), and (2×4) patterns depending on **the temperature at which the Sb flux is supplied** [20]. Jia *et al.* [22] demonstrated that the (2×8) reconstruction promotes the formation of an IMF array of pure-edge misfit dislocations.

In the present work, we investigate different approaches used in the formation of IMF array in the growth of GaSb layers on GaAs substrate. The main dissimilarity between the three approaches is the **steps between** the end of GaAs buffer layer growth **and the start of GaSb growth**. Our GaSb layers are