InAs/AlSb multilayers grown on (001) InAs substrate are currently developed for short wavelength quantum cascade lasers (2-5 µm). The operation of these devices strongly depends on the properties of the interfaces, which are very complex due to the change of both group III and group V elements. Two different extreme interfaces can thus be envisaged: AlAs or InSb interfaces, where very important strain effects (respectively -7% and 7%) are expected.

The aim of this work is to characterize interface properties as a function of the growth sequences. Especially, we tried to grow three different kinds of interface: spontaneous, AlAs forced and InSb forced using dedicated growth sequences. The samples have been grown by molecular beam epitaxy at 450°C.

The interfacial strain state has been characterized by HRTEM analysis using the Geometrical Phase Analysis (GPA) method. Information about the tensile or compressive character of the interfacial stress can be achieved. This strain state is related to the chemical composition of the interfaces themselves but several chemical compositions can correspond to the averaged strain value. The chemical composition of these interfaces has also been investigated by aberration corrected HAADF-STEM. Several chemical compositions can fit the HAADF intensity profile. The combination of HRTEM and HAADF allowed for discriminating more precisely the interface composition. Then the results are discussed considering the physical elementary mechanisms of epitaxial growth.

We used this analytical method to study the interface formation in relation with the growth sequence. We showed that spontaneously, AlAs type interface with a moderate tensile stress is formed on both, AlSb on InAs and InAs on AlSb interfaces (cf. Fig1; Fig.2). We assume that this kind of interface is favored due to its high thermal stability and energy bond, which leads to the most stable configuration. When forced interfaces are tentatively introduced, interfaces with a strong tensile stress (AlAs type) are achieved at both interfaces. Interfaces with a strong compressive stress (InSb type) can be achieved at AlSb on InAs interface while it is not possible at InAs on AlSb interfaces (cf. Fig.3). We show that these configurations can be explained using simples rules as: the heaviest element of one column can segregate versus the lightest element of the same column, V column element can desorbs while III column element cannot, the chemical bond with the highest thermal stability is favored.

Reference

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Fig. 1: (a) HREM image of InAs-AlSb superlattice along the [1–10] zone axis with spontaneous interfaces; (b) $e_{yy}$ maps and profiles determined from the geometrical phase analysis of the HREM image (0.8 nm spatial resolution).

Fig. 2: HAADF image of the sample showed on Fig.1 and intensity profile along the growth direction.

Fig. 3: HAADF image of a sample with ‘forced’ interfaces and intensity profile along the growth direction. Interfaces 1 and 2 are, respectively, AlAs and InSb ‘forced’ type.