Study of As-rich interfaces with exponentially decaying As content within InAs/AlSb superlattices

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Highly strained interfaces may exist between InAs and AlSb layers grown by MBE [1]. The composition and thickness of the interfacial layer influence strongly the electronic properties of InAs/AlSb based structures. However, they are hard to characterize and nominally identical growth run may give very different interfaces in different MBE systems.

In this work, we study the influence of As flux interruption procedure on the unintentional incorporation of As into AlSb layers. This effect can significantly alter the strain distribution in AlSb barrier by changing it into compositionally graded AlAsSb layer. In the first stage, the As flux temporal dependence was measured during mock growths, inside Veeco GEN10 MBE system using a beam flux monitor (BFM) at wafer position. A storage scope was used to record the BFM signal at 2ms intervals. When the As beam was interrupted, instead of abrupt flux drop, exponential decay was observed. An excellent fit was obtained using double exponent function (Fig. 1). As expected, very abrupt flux termination was observed with closing Sb shutter. Subsequently, three samples of 200Å/150Å InAs/AlSb superlattices with 5 repeats were grown on InAs(001) substrates at 420°C using As_2. Identical shutter/valve sequence was used as during the mock growths. When the deposition was switched from InAs to AlSb, at the shutter closure, the As cell valve setting was kept unchanged for sample A, decreased to achieve 80% flux reduction for sample B, and fully closed for sample C.

The dynamical simulations of the High-Resolution X-ray Diffraction (HRXRD) gave very good agreement with experiment assuming that the profile of arsenic content *y* in the $AlAs_ySb_{1-y}$ barrier followed the experimentally measured As_2 flux during the mock growths (Fig.1). This included the $In_xAl_{1-x}As_ySb_{1-y}$ interfacial monolayer (ML) at the start of the barrier. No additional strain was introduced at the second interface. For the growth performed with As beam interrupted only by the shutter, we find that the barrier composition y is still at 6.8% at the ends of the 150Å barriers. A considerable amount of As is incorporated even when both valve and shutter were closed for As interruption during barrier growth. However, in this case, arsenic is mostly confined to the first 5MLs.

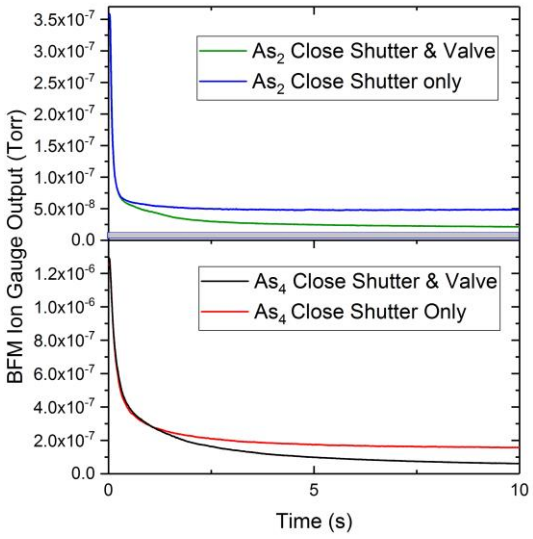

Fig. 1 BFM ion gauge output for As_2 and As_4 with valve open/close. The BFM background not related to arsenic is 1.1e08 Torr (shaded area). As_4 data in the lower pane is provided for comparison only.

[1] M. Vallet, et al., "Highly strained AlAs-type interfaces in InAs/AlSb heterostructures," Appl. Phys. Lett. 108, p. 211908, 2016. and references therein.

Supplementary Information:

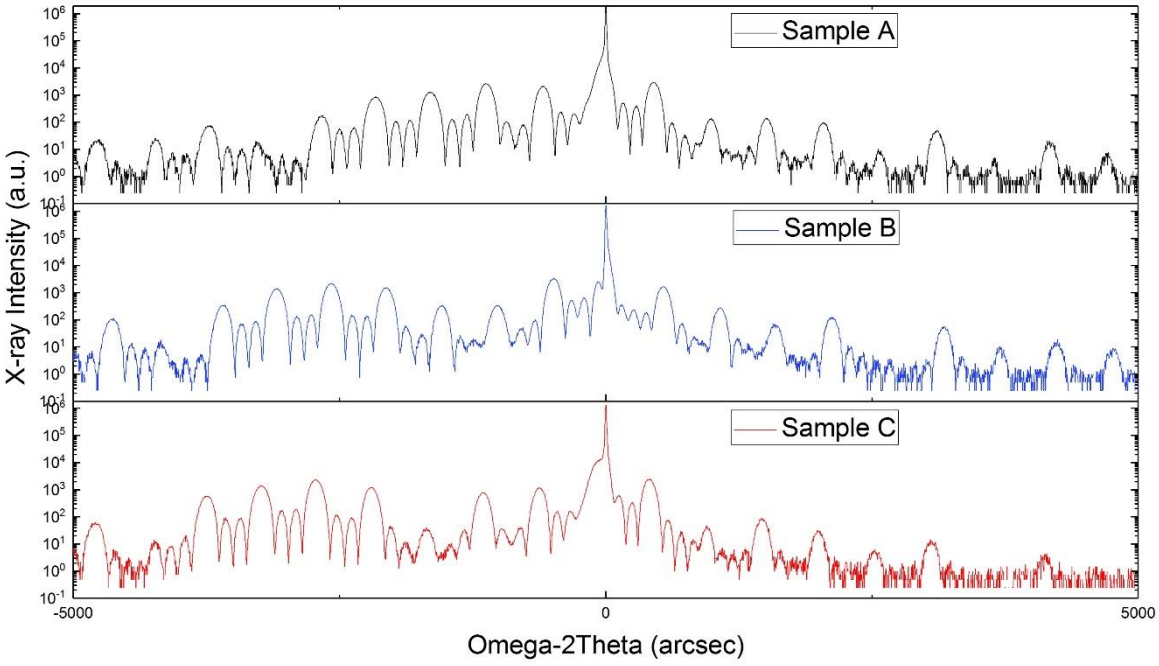

Fig. 2 XRD scanning results of Sample A (black), B (blue) and C (red). Same target structure applies to all three samples. The only variable is As valve setting: Sample A – open; Sample B – As flux decreased by 80%; Sample C – fully closed.

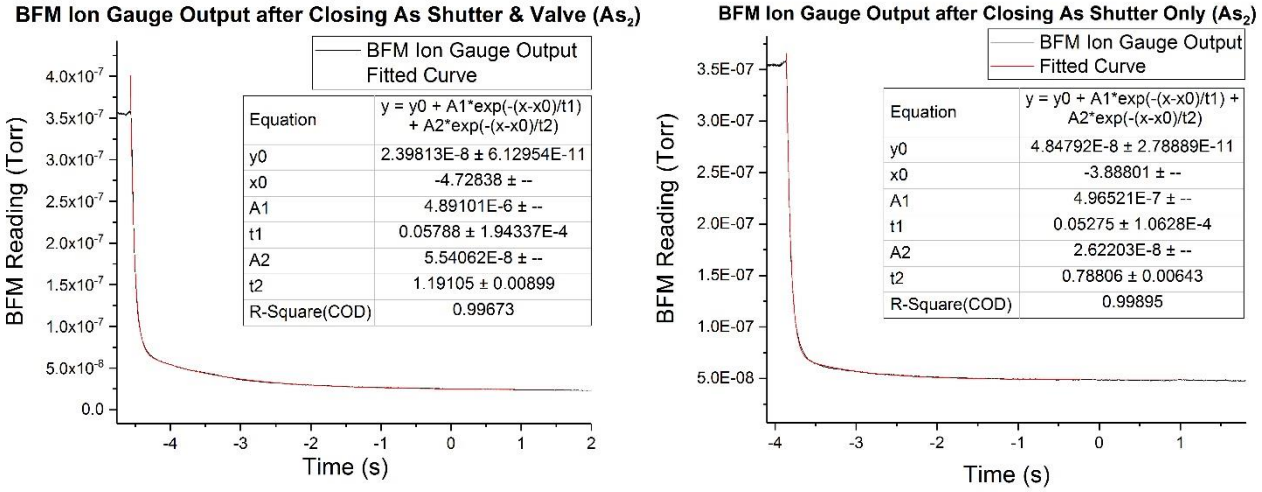

Fig. 3 Curve fitting results for As flux reading after closing shutter only or shutter & valve using addition of two exponential decay functions.

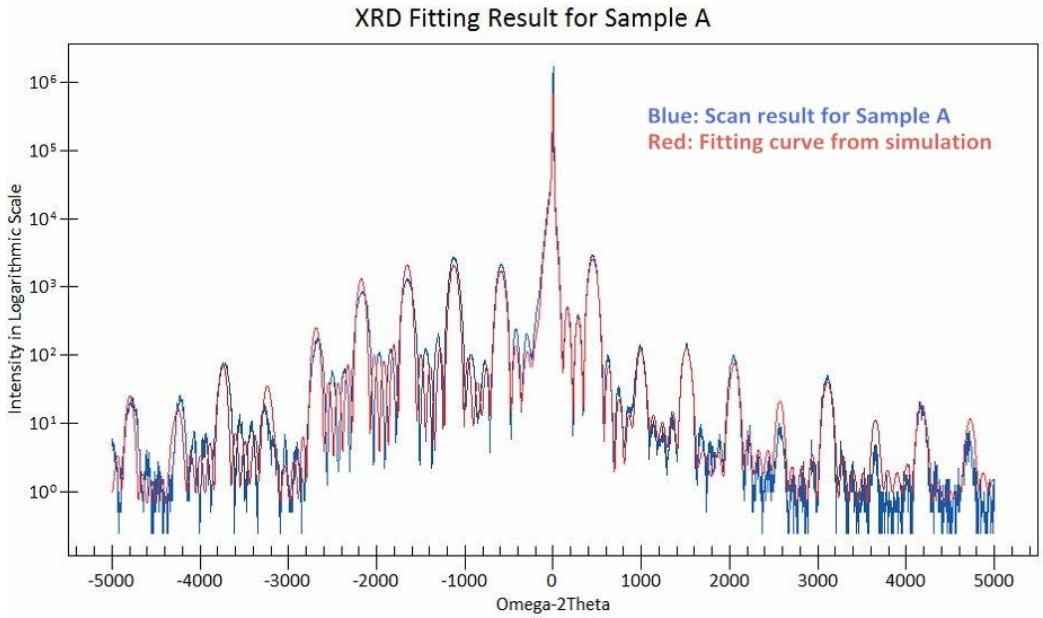

Fig. 4 XRD scan results of Sample A compared to simulation results. Sample A can be fitted with 1 ML of $In_{0.72}Al_{0.28}As_{0.72}Sb_{0.28}$ at the interface and $AlAs_ySb_{1-y}$, with *y* decreasing exponentially from 0.470 to 0.067, replacing AlSb layer.

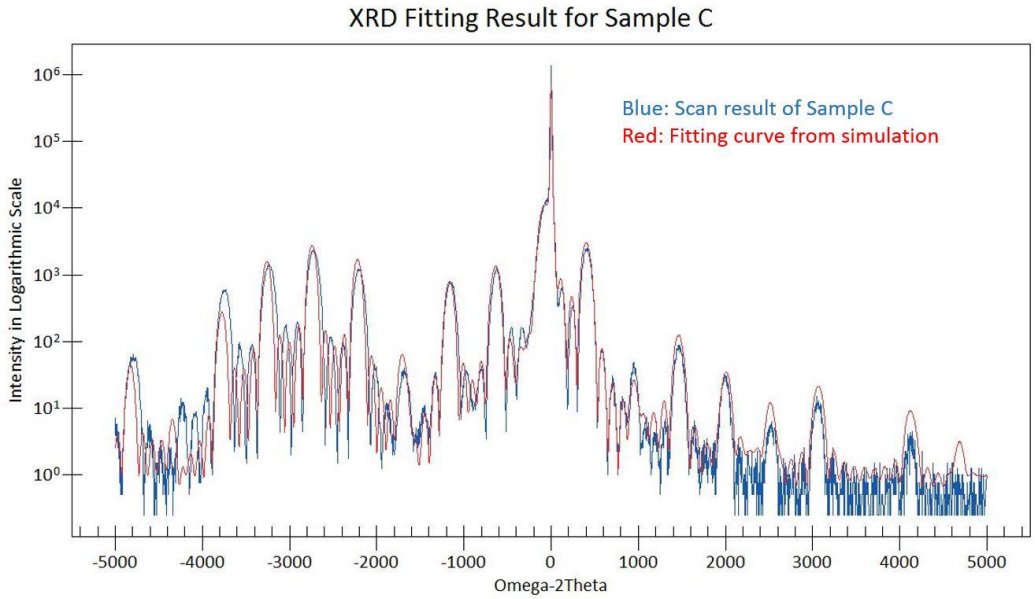

Fig. 5 XRD scan results of Sample C compared to simulation results. Sample C can be fitted with 1 ML of $In_{0.55}Al_{0.45}As_{0.55}Sb_{0.45}$ at the interface and $AlAs_ySb_{1-y}$ with *y* decreasing exponentially within the targeted AlSb layer.