Iso-electronic Sb Impurities in GaAs Studied by Cross-sectional Scanning Tunneling Microscopy

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For a number of reasons, such as As-Sb exchange reactions occuring at the surface, Sb has a tendency to accumulate on the growth surface resulting in a slower incorporation and Sb segregation in the upper layers [1, 2], making it challenging to grow high quality $GaAs_{x-1}Sb_x$. Moreover, Sb dopants can have the tendency to cluster and form unwanted pairs which will negatively influence the optical and electronic properties of the material.
A GaAs/GaAs:Sb structure comprising of eight 50-nm-thick GaAs:Sb layers of increasing Sb content was grown by molecular beam epitaxy with the aim of producing high quality Sb-containing material with sharp interfaces. The structure was characterized by X-ray diffraction, transmission electron microscopy and cross-sectional scanning tunneling microscopy. In particular, we investigated the behaviour of iso-electronic Sb dopant in dilute GaAs:Sb at the atomic scale by low-temperature cross-sectional scanning tunneling microscopy (X-STM). Sb atoms up to five layers below the surface are visible in the filled-state X-STM images which show different features (Fig. 1a). These features are classified and are related to their depth below the cleaved surface by comparison with the contrast observed for Bi in InP (Fig. 1b). We studied Sb incorporation and segregation for the layers at lower Sb content using Muraki's model for segregation and short-range ordering of Sb in terms of nearest neighbors pairs formation. Unexpectedly, we observe Sb to be rapidly incorporated and to have a rather limited a tendency to segregate, resulting in sharp interfaces. Moreover, Sb does not have an enhanced tendency to form pairs and cluster and instead distributes randomly in the host material (Fig. 1c, d). Therefore, we found that under the employed growth conditions good quality non-clustered material with sharp compositional interfaces of Sb in GaAs can thus be grown.

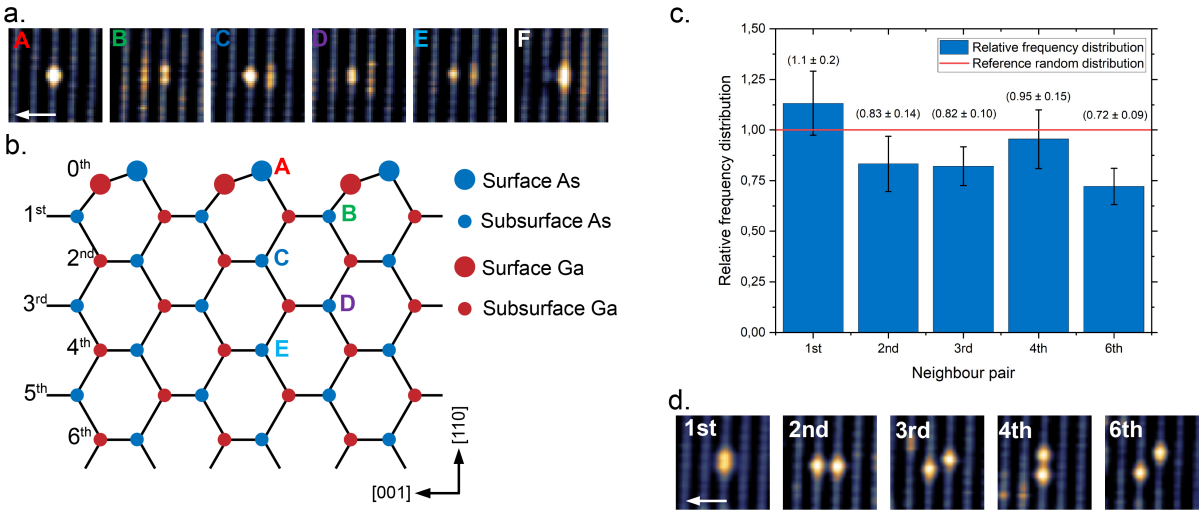

Fig. 1. a. 3.0 × 3.0 nm^2 filled-state LT X-STM images of Sb atoms located at different depth in the GaAs host, $V_b = -3$ V, $I_t = 50$ pA. b. The position of the Sb atoms (A-E) are reported in the schematic side view of the (110) GaAs surface. c. Relative occurrence of nearest neighbour AA pairs and CC pairs in L2. d. 3 × 3 nm^2 filled-state LT X-STM images of the different Sb-Sb pairs (AA) observed in L2 ($V_b = -3$ V, $I_t = 50$ pA). The white arrow indicates the growth direction.

References

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