Stacking-fault-driven formation of atomically-abrupt heterointerfaces in III-V nanowires

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III-V compound semiconductor nanowires have been considered as next-generation building blocks.[1] Atomically-abrupt heterointerfaces, as ideal structures, are quite challenging to be realized in III-V nanowires due to reservoir effect[2] and interface diffusion. Stacking faults, which usually exist in bottom-up-synthesized III-V nanowires, are generally believed to be a kind of plane defect. In this study, we show stacking faults, despite the defect feature, can drive formation of atomically abrupt heterointerfaces in III-V nanowires. Furthermore, we have also clarified the formation mechanism.

We grew III-V nanowires in a MOVPE system via self-catalyzed vapor-liquid-solid (VLS) mode. Usually, due to epitaxial growth, <111>-oriented InP(As) nanowires are vertically aligned on substrates.[3-4] When an SiO_2 amorphous substrate is used, the <112>-oriented InP(As) nanowires are resulted (Fig. 1a). Stacking faults are parallel to the growth direction. The As/P compositional ratio exhibits clear difference on two sides of a stacking fault (Fig. 1b).

We have further analysed structure and composition of the nanowires by using Cs-STEM with sub-angstrom spatial resolution. Regions on two sides of a stacking fault exhibit different polarities, namely, A and B, along the growth direction (Fig. 1c). The upward and downward side regions have clearly different compositions, i.e., $InAs_{0.8}P_{0.2}$ and $InAs_{0.59}P_{0.41}$, respectively. Growth front faces are alternatively-changed {111}A and {111}B separated by stacking faults. The {111}A front face exhibits higher incorporation efficiency of As into crystalline domains compared with that for {111}B front face. Furthermore, each domain region exhibits homogeneous composition and the domain composition exhibits an atomically-abrupt change at the stacking fault (Figs. 1d and e). These results reveal that the polarity inversion, caused by stacking fault, leads to different composition (As/P ratio) in adjacent domains with an atomically-abrupt interface. We have also found the same growth phenomenon in other nanowires (InGaP), indicating general feature of the synthesis approach in III-V nanowires.

In summary, we demonstrate that stacking-fault-driven formation of atomically-abrupt heterointerfaces in III-V nanowires. We reveal that the formation mechanism is the polarity-dependent composition ratio on adjacent domains of a stacking fault. This work offers a new approach to form atomically-abrupt interfaces and opens up opportunities for new novel nanostructures with new functionalities.

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Refs: [1]M. D. Birowosuto, *et al. Nature Mater.* **13** 279 (2014). [2] K. A. Dick, *et al.*, *Nano Lett.* **12** 3200 (2012). [3] G. Zhang, et al., *Science Adv.* **5** eaat8896 (2019). [4] G. Zhang, et al., *Jpn. J. Appl. Phys.* **59** 105003 (2020).

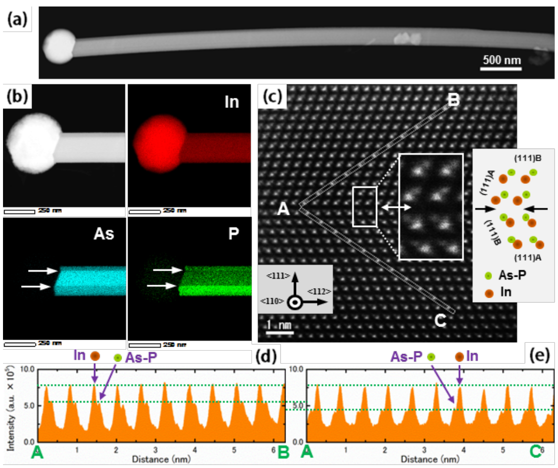

Figure 1: (a) HAADF-STEM image of a <112> InAsP nanowire with an indium particle tip. (b) HAADF-STEM image and elemental mapping of nanowire/particle area. Adjacent domains separated by stacking faults show different As/P composition ratio (upside: $InAs_{0.8}P_{0.2}$, downside: $InAs_{0.59}P_{0.41}$). Scale bars represent 250 nm. (c) HAADF-STEM image of a region with a stacking fault. The inset image directly reveals the different polarities, {111}A and {111}B, of two regions. (d) and (e) Intensity profiles of III and V atoms along A→B and A→C lines shown in (c). The green dotted lines are guides to the eye.