<111>A-oriented InP nanowire array grown by self-catalyzed vapor-liquid-solid mode towards stacking-fault-free nanowires

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III-V compound semiconductor nanowires have been considered as next-generation building blocks for sensors, detectors, and opto-electronic devices.[1,2] An intrinsic property of III-V compound semiconductors is polar feature, which originates from the different electron affinity of III and V-group elements. In zinc-blend crystal structure, an (111) surface is preferentially terminated by either group III or V atoms, usually named (111)A and (111)B, respectively. Mostly, III-V compound semiconductor nanowires are grown along <111>B direction because (111)B has the lowest surface energy. Stacking faults have been found to exist for III-V nanowires grown along <111>B direction.[3,4] In contrast, fewer stacking faults exist in III-V nanowires grown along <111>A direction.[5-7] However, it remains challenging to grow <111>A-oriented InP nanowires with yield up to 100% by widely utilized particle-catalyzed vapor-liquid-solid (VLS) approach.[2,5] Here we report site-controlled growth of <111>A-oriented InP nanowire array with 100% yield by self-catalyzed VLS mode. The <111>A-oriented nanowires contain few stacking faults compared with the nanowires grown under an exact same growth condition.

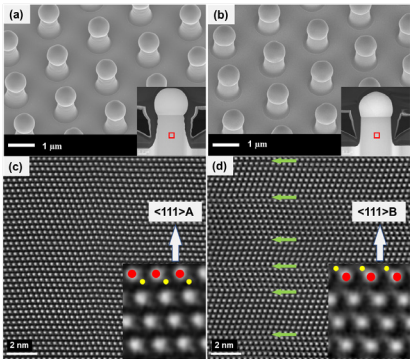

Fig. 1. SEM images (tilt: 38°) of InP nanowires with <111>A and <111>B orientations grown on InP (111)A (a) and (111)B (b) substrates, respectively. The insets are HAADF-STEM images of single nanowires. Regions shown in red rectangles are further analysed by Cs-TEM and shown in (c) and (d).

(c) and (d) HAADF-STEM images of <111>A and <111>B-oriented nanowires shown in (a) and (b), respectively. The inset images directly reveal different polarities, <111>A (c) and <111>B (d). The red and yellow dots represent indium and phosphorus atoms, respectively. Green arrows in (d) indicate stacking faults. In contrast, there are no stacking faults in (c) for the <111>A-oriented nanowire.

We grew III-V nanowires in an MOVPE system via self-catalyzed VLS mode.[8,9] To control the polar orientation, we used InP (111)A and (111)B substrates. site-controlled indium particles were formed at 500 °C via a self-aggregation process by using substrates selectively covered by SiN_x film.[10] These indium particles were then used to grow site-controlled InP nanowires at 350 °C. Typically, site-controlled InP nanowires were vertically grown on both (111)A and (111)B substrates (Figs. 1a, 1b). The polarity can be straightforwardly determined by Cs-STEM measurement (Figs. 1c, 1d). The Cs-STEM images directly reveal <111>A and <111>B polarities for nanowires grown on InP (111)A and (111)B substrates. Characterization of stacking fault defect indicates there are a few stacking faults for <111>B-oriented nanowires (Fig. 1d) (density: > 500 μm^{-1}). In contrast, few stacking faults are found in <111>A-oriented nanowires (Fig. 1c) (density: 13.6 μm^{-1}). Furthermore, we find that all stacking faults in <111>A-oriented nanowires are accompanied with sub-microscale {111} facets on nanowire side wall. The formation of these facet-accompanied stacking faults may be driven by alternatively changed (111)A and (111)B nanofacets on nanowire side.[4]

In summary, we demonstrate site-controlled growth of <111>A-oriented InP nanowire array with 100% yield by self-catalyzed VLS mode and reveal that there are few stacking faults in these nanowires. This work opens up new opportunities for stacking-fault-free nanowires and high-efficiency nanowire-based functional devices.

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