Epitaxial growth of vertical III-V semiconductor nanowires on graphene

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Semiconductor nanowires (NWs) have today advanced to a level beyond thin films with respect to design freedom, including structuring of both material composition and crystal phase with high spatial precision, making them promising for a number of electronic and optoelectronic device applications[1]. Graphene on the other hand, a zero-bandgap semiconductor, has some unique and complementary properties to conventional semiconductors that is believed to revolutionize future devices[2]. Apart from being an excellent electrical and thermal conductor, graphene is also transparent and flexible and thus has the potential to become an ideal electrode material for especially optoelectronic devices[3, 4]. Thereby, if these complementary materials classes can be combined, various unique hybrid devices can be realized.

In this work, we show that by utilizing the reduced contact area of NWs, epitaxial growth of semiconductors on graphene can be achieved.[5] Highly uniform vertical GaAs NWs were grown both on graphite and few-layer graphene using molecular beam epitaxy. Scanning electron microscopy and cross-sectional transmission electron microscopy studies revealed the epitaxial relationship of the NWs with the graphitic substrates in spite of a lattice mismatch of 6.3%. In addition, we present a generic atomic model which describes the epitaxial growth configurations of the semiconductor atoms on graphene and should in principle be applicable to all conventional semiconductor materials. Finally, a prototype of a single GaAs nanowire photodetector was also fabricated which demonstrates a high-quality material essential for successful optoelectronic device applications.

References

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Figures

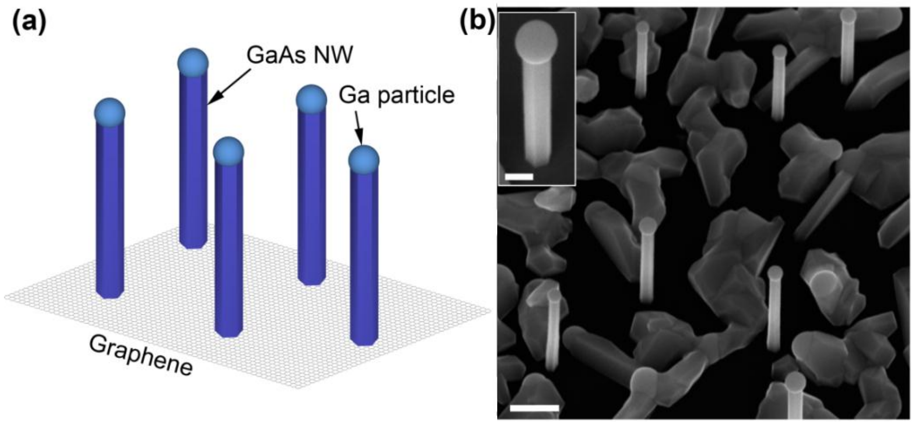

Figure 1. (**a**) Schematic drawing of self-catalyzed GaAs nanowires on a graphitic surface. (**b**) SEM image of nanowires grown on graphite by a two-temperature growth technique. In the inset a tilted-view image of one of the nanowires shows a uniform hexagonal cross-section. The scale bars are 200 nm in the main figure, and 100 nm in the inset [5].

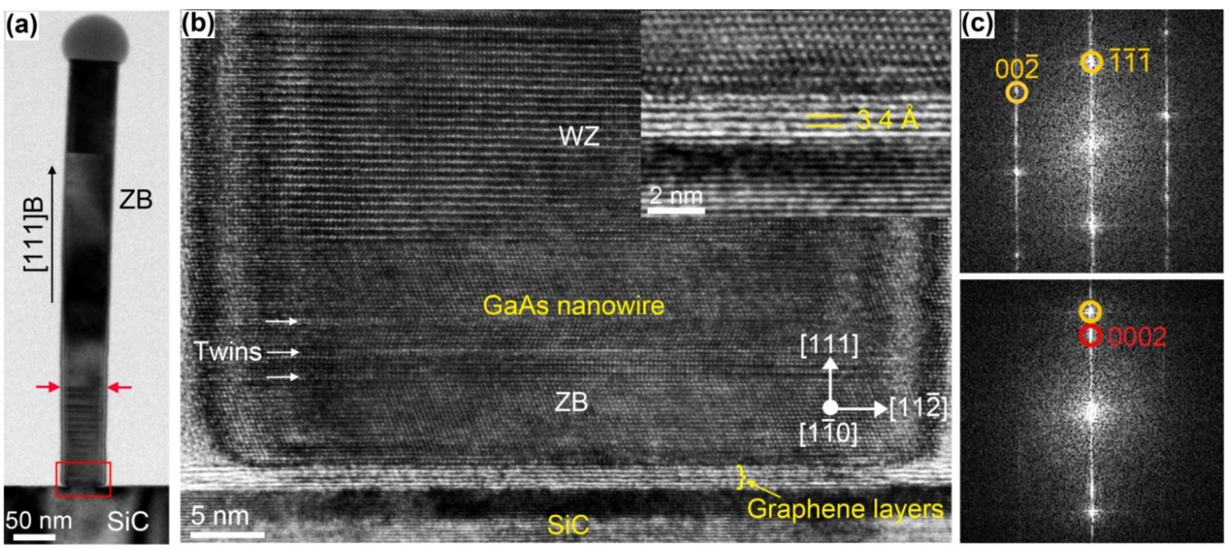

Figure 2. TEM images of a representative GaAs nanowire grown on few-layer epitaxial graphene synthesized on a 6H-SiC(0001) substrate. (**a**) Cross-sectional bright-field TEM image of the selected vertical GaAs nanowire. The bottom part of the nanowire has a mixture of ZB and WZ segments with twins and stacking faults, whereas the rest of the nanowire (above the two red arrows) is nearly defect-free ZB. (**b**) Cross-sectional high-resolution TEM image showing the interface region of the graphene layers and the vertical GaAs nanowire marked with a red box in (a). Inset shows a magnified high-resolution TEM image of the nanowire/graphene/SiC interface area from the center part of (b), where the lattice fringes of the GaAs nanowire and the (0002) graphene layers separated by ~3.4 Å can be seen. (**c,d**) Fast Fourier transforms from the high-resolution TEM image in (b), from the nanowire/graphene/SiC and graphene/SiC interface regions, respectively [5].