28a-B8-4

自己触媒法 InP ナノワイヤの成長過程における直径制御

In-situ tuning of the nanowire diameter: a new dimension in the nanowire growth

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Introduction: Semiconductor nanowires (NWs) have been expected as the next-generation build blocks in optoelectronics, sensing, and electronics [1]. The vapor-liquid-solid (VLS) mode has been widely used for the growth of the NWs due to its high controllability. As the catalyst particle material, Au is mostly used. However, Au atoms are incorporated into the NW during the growth and thus may degrade the electronic and optical properties. The self-assisted VLS mode has therefore been developed to avoid the incorporation of foreign materials [2,3]. The In particle at the tip could be decreased during growth and finally removed by modifying the III source flow rate [3]. This indeed provides a new way to tune the NW diameter during the growth. Here, we demonstrate how to change the NW shape by tuning the diameter during growth and therefore enable to engineer the inside hetero nanostructures with high controllability.

Experiments and results: We performed the NW growth in a low-pressure MOVPE system [3]. In particles were formed on InP (111) substrate by introducing only TMIn source material at 320-360 ºC. The temperature was then decreased to the growth temperature (320 ºC) and the growth was initiated by introducing TMIn, TBP (or TBAs) materials. We grew InP/InAs NWs vertically on the InP(111).

Under the suitable III/V ratio, we grew the InP NWs with the uniform diameter (Fig. 1a). If the flow rate of TMIn is decreased, the In particle would decrease with growing. We grew the InP NW under the decreased flow rate of TMIn. With different growth time, the NW exhibits deferent shapes (90 min. in Fig. 1b and 30 min. in Fig. 1c). After the 2-step growth, we increased the TMIn flow rate again to grow a uniform segment. Figure 1d shows the InP NW with the 3-step growth, including two uniform segments and one tapering segment.

In principle, one can also tune the InAs QD diameter if the InAs is grown into the tapering segment shown in Fig. 1b. We carried out the NW growth experiment. The InP/InAs region in the tapering segment consists of 5 InAs segments and each InAs has 2 s growth time. Figure 2a shows the TEM image of the NW with the InAs segments indicated by the white arrows. One can clearly see the InAs segment (6-nm thickness) from the enlarged TEM image (Fig. 2b). The plot of the InAs QD diameter (Fig. 2c) clearly shows the decrease of the InAs QD diameter with growing. We also studied the optical properties of the InP/InAs NW by Micro-PL measurement.

This work was partly supported by KAKENHI (23310097).

References: [1] Huang, Pure Appl. Chem. **76** (2004) 2051; [2] Novotny and Yu: Appl. Phys. Lett. 87 (2005) 203111. [3] Zhang, et al., Appl. Phys. Exp. 5 (2012) 055201.

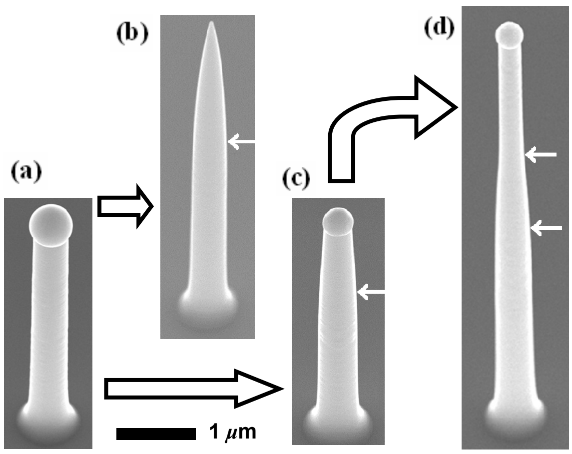

Fig. 1. SEM images (38º tilt) of InP NWs on InP (111). (a) A uniform InP NW, (b) and (c) InP NWs with 2-step growth, and (d) InP NW with 3-step growth.

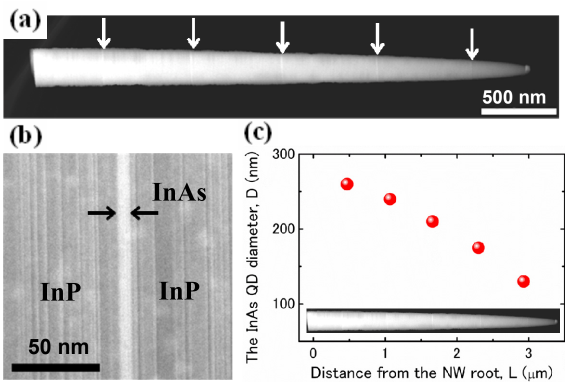

Fig. 2. TEM images of (a) the InP/InAs NW with decreasing diameter including 5 InAs segments and (b) the InP/InAs/InP heterostructure in the NW. (c) Plot showing the relation between InAs QD diameter and the distance from the root.