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自己触媒法によって成長した InP/InAs ナノワイヤの光学特性

Optical property of multi-stacked InP/InAs nanowires grown in Au-free In-particle-assisted vapor-liquid-solid mode

NTT 物性基礎研 [1], ○Guoqiang Zhang[1], Danang Birowosuto[1], 舘野功太 [1], 後藤秀樹 [1]

NTT Basic Research Labs[1], ○G. Zhang[1], D. Birowosuto[1], K. Tateno[1], H. Gotoh[1]

E-mail: zhang.guoqiang@lab.ntt.co.jp

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 and grow high-purity NWs [2]. We have demonstrated the growth of InP and InAs NWs in the In-particle-assisted VLS mode [3,4]. This enables to form InP/InAs hetero-NWs along the axial direction via the same In particle. It is fundamentally important to study the optical property of the hetero-NW. Here, we report the controlled optical property of InAs segment in InP/InAs hetero-NW by micro-PL measurement.

Experiments and results: We performed the NW growth in a low-pressure MOVPE system [3,4]. 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). We analyzed the NW structure by TEM and studied the optical property by micro-PL and CL.

We grew multi-stacked InP/InAs hetero-NWs with 4 InAs segments. The growth time of the InAs segment is 0.5, 1, 1.5, and 2 s. Figure 1 shows TEM image of a single InP/InAs NW. There is an In particle at the NW tip. The arrows indicate the InAs segments in the InP NW. The high-resolution TEM images of these InP/InAs/InP double heterostructures are shown in Fig.2. The InAs segment exhibits increasing thickness with time. The InAs was grown in the InP NW even for 0.5 s growth time. These results indicate the high thickness-controllability of the self-assisted VLS mode.

We dispersed the hetero-NWs onto Au-patterned SiO_2/Si substrate for PL and CL measurement. The InAs segments show luminescence in 1.0-1.6 μm. Figure 3 shows the luminescence image of a single InP/InAs NW taken by an IR CCD camera when irradiated by a laser beam. Clearly, there are four emission spots in the NW. Further measurement by PL and cathodoluminescence (CL) indicates that there is thickness-dependent emission energy of the InAs segments. *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. [4] Zhang, et al., AIP Advances 3 (2013) 052107.

Fig.1

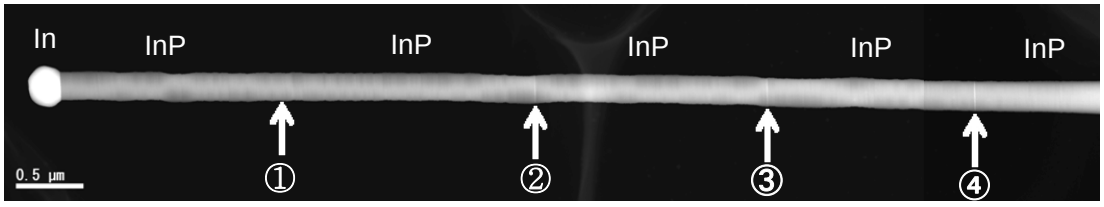

Fig. 1. HAADF-TEM image of a single multi-stacked InP/InAs NW with 4 InAs segments indicated by the arrows.

Fig.2

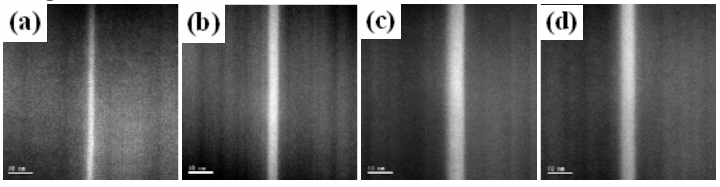

Fig. 2. HAADF-TEM images of the 4 InP/InAs/InP heterostructures in the NW. (a) to (d) corresponds to ①-④ regions shown in Fig. 1. The scale bars denotes 10 nm.

Fig.3

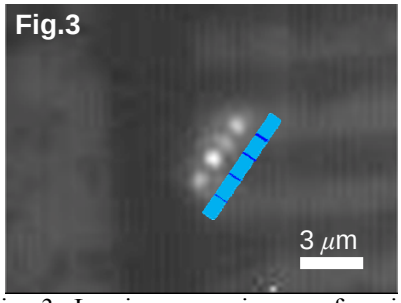

Fig. 3. Luminescence image of a single InP/InAs NW with four emission spots. The inset is a schematic of the hetero-NW.