Site-defined InP/InAs heterostructure nanowires with tunable diameter by in-situ diameter-tuning technique

Despite many promising applications of bottom-up III-V compound semiconductor nanowires (NWs) in various fields; the tools for engineering the semiconductor properties are restricted to those controlling the length, heterostructure, and composition. Innovative opportunities may be opened up in the advanced synthesis approach and new functionalities if the diameter can be tuned during growth in a controllable way. On the other hand, for various applications in optical device, solar cell, flexible electronics, and vertically-structured transistor devices, the site-defined NW array is desired. In this work, we demonstrate site-defined InP/InAs heterostructure NWs with tunable diameter by in-situ diameter-tuning technique.

We synthesized the InP/InAs NWs in a metalorganic vapor phase epitaxy (MOVPE) system in the self-catalyzed (or self-assisted) vapor-liquid-solid (VLS) [1]. The InP (211)B substrate is partly covered by 30-nm-thickness SiO2 masking film to form circular windows with microscale feature. Indium particles were formed on InP substrate by introducing trimethylindium (TMIn) source material. The particle array was formed in the self-migration of the indium atoms on the surface and accumulation of particles inside the window (Figs. 1a and 1b) [2].

We grew the InP NWs starting from the microscale-featured indium particle by the self-catalyzed VLS mode (Figs. 1c and 1d). We tune the indium particle size and the NW diameter by modulating the flow rate of the indium source material. There is clear difference of the diameter between the root and the tip. While the initial indium particle size is 1 µm (Fig. 1b), the NW shrinks with length and the diameter close to the NW tip appears to be 0.2 µm (Fig. 1d). We then grew multiple same-thickness InAs quantum disks (QDisks) in the tapering InP NWs with modulated diameter (Fig. 2a). We studied the optical property by combining the cathodoluminescence (CL) unit into a SEM system at 8 K. The InAs QDisks exhibit luminescence in 1200-1500 nm (Fig. 2b). It appears that the diameter tailors the photon emission energy of the ground state: the larger diameter, the higher emission energy (Figs. 2d-2g). This allows the formation of quantum nanostructures with both tunable diameter and thickness in the individual NW.

This work establishes the technique for site-defined NWs with nanoscale diameter starting from the particle with the microscale feature by using the diameter-tuning technique. This indeed realizes a new functionality of bridging the gap between the microscale and nanoscale features.

This work was supported by JSPS KAKENHI Grant Number 15H05735.