ボトムアップ的手法で作製した通信波長帯室温動作 InAs/InP マイクロワイヤレーザ

Room-temperature telecom-band InAs/InP microwire laser by bottom-up approach

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Telecom-band lasers are extremely important for optical data communication, spectroscopy, and medical diagnosis. Semiconductor nanowires (NWs) or microwires (MWs) offer the possibility of reducing the footprint of devices for 3D integration and enduring large lattice mismatch for breaking the limitation of material combination. Hence they are being extensively studied in optoelectronic devices. Although ultraviolet, visible, and near-infrared NW lasers have been demonstrated, room-temperature telecom-band NW (or MW) lasers have not been realized due to the material issues. Here we demonstrate the telecom-band MW lasers at room temperature by using multi-stacked InP/InAs heterostructure NWs.

We synthesized the InP/InAs NWs in a metalorganic vapor phase epitaxy (MOVPE) system in the self-catalyzed vapor-liquid-solid (VLS) [1, 2]. Indium particles were formed on InP substrate by introducing trimethylindium (TMIn) source material. The well-established growth technique of InP/InAs hetero-NW [1] enables us to tune the luminescence to telecom band by the thickness of InAs active layer through the quantum confinement effect. To increase the gain medium volume, we have grown InP/InAs MWs consisting of InAs active layers as many as 400 layers (Fig. 1). There is no VPE growth occurring on the NW side (Fig. 1b), indicating a high controllability in terms of VPE and VLS growth.

We dispersed the MWs from the as-grown substrate onto SiO_2/Si substrate covered with a thin gold film (Fig. 2a). Most indium particles were removed from the tips during the dispersion process. The cleaved (111) facet can therefore function as two reflection mirrors. Hence the MW can form a Fabry-Perot (FP) cavity. We performed micro-PL measurement for single NWs with 800-nm femtosecond Ti:sapphire laser for the excitation. These MWs exhibit strong luminescence in telecom band at room temperature (Fig. 2b). We have observed significant evolution of spectrum when increasing the excitation power (Figs. 2b and 2c). We further measured L-L characteristics (Fig. 2d). S-shaped L-L curve convincingly show the NW exhibit indeed laser operation. High reproducibility of these results on multiple NWs has been demonstrated.

In conclusion, we have established the technique to grow InP/InAs MWs with superior optical property and have demonstrated the telecom-band MW lasers at room temperature for the first time. We believe that this work opens up new opportunities in optoelectronics and on-chip data communication.

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References: [1] G. Zhang, et al. Nanotechnology **26** (2015) 115704. [2] G. Zhang, et al. ACS Nano **9** (2015) 10580.

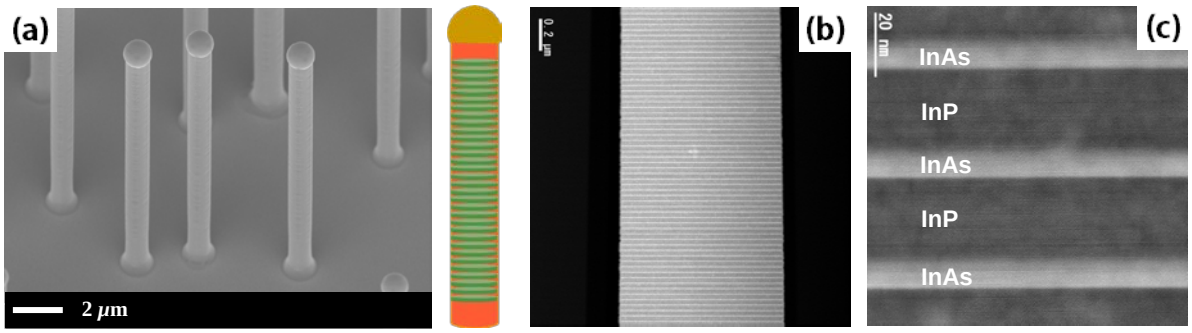

Fig. 1. InP/InAs MWs with 400 InAs layers. **a**, SEM image of MWs grown on InP (111)B and schematic diagram of the multi-stacked InP/InAs heterostructure MW. **b** and **c**, HAADF-STEM image of multiple InP/InAs heterostructures.

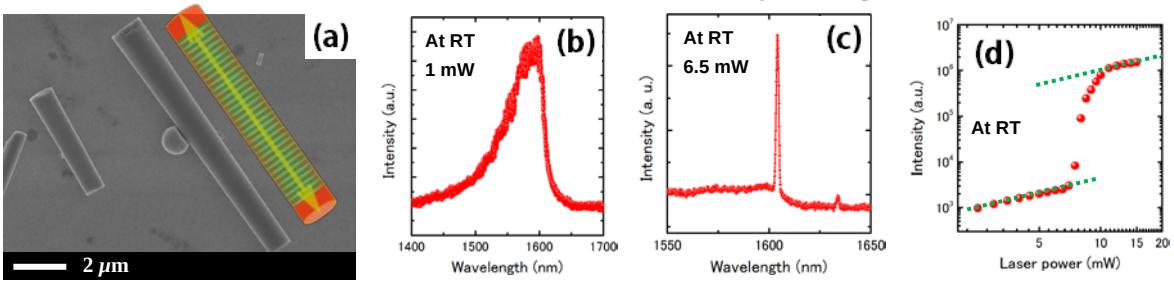

Fig. 2. Micro-PL and lasing at room temperature. **a**, SEM image of a dispersed MW. The inset is a schematic diagram of the MW cavity structure. **b** and **c**, PL spectra under 1 and 6.5 mW excitation laser power. **d**, L-L characteristics.