通信波長帯ナノワイヤレーザの波長制御

Widely-controllable wavelength of telecom-band nanowire lasers

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Semiconductor nanowires (NWs) offer the possibility of reducing the footprint of devices for 3D integration and enduring large lattice mismatch for breaking the limitation of material combination. Telecom-band NW lasers are extremely important for optical data communication, spectroscopy, and medical diagnosis. Although ultraviolet, visible, and near-infrared NW lasers have been demonstrated, room-temperature (RT) telecom-band NW lasers have not been realized due to the material issues. Recently we have demonstrated telecom-band (1.5-1.6 μm) NW lasers at RT by using multi-stacked InP/InAs heterostructure NWs [1]. The high controllability of synthesis approach enables one to tune the emission wavelength in a wide range through quantum confinement effect [2]. Hence this provides a high potential to realize the function of wavelength modulation in the whole telecom-band window. Here we report the controllable wavelength in 1.2-1.6 μm in the InP/InAs heterostructure NW laser by tuning the flow rates of the source materials of indium and arsenic.

We synthesized the multi-stacked InP/InAs NWs in a metalorganic vapor phase epitaxy (MOVPE) system via the self-catalyzed vapor-liquid-solid (VLS) mode (Fig. 1a). The well-established growth technique enables us to tune the luminescence by the thickness of InAs active layer through the quantum confinement effect [2, 3]. We modulate the thickness of InAs active layer (Fig. 1b) by tuning the flow rates of the source materials of indium and arsenic (TMIn and TBA). We dispersed NWs from as-grown samples onto Au-covered SiO_2/Si substrate for micro-PL measurement in single NW level at RT (Fig. 1c). The cleaved facets can function as two reflection mirrors and construct a Fabry-Perot (FP) cavity for lasing operation. Ti:Sapphire laser (pulse repetition rate: 80MHz) is used as the pump source. We have found that the luminescence spectrum is tuned to short-wavelength range with decreasing flow rates, indicating the tailored thickness of the InAs active layer (Fig. 2a). When the excitation pump power is increased, we have seen stimulated emission reproducibly for a number of NWs (Fig. 2b). Clearly, the laser wavelength range is controlled by the growth parameters of the flow rates of TMIn and TBA. Hence, the whole telecom-band window can covered by the InP/InAs NW with modulated thickness of the InAs active layer.

In conclusion, we have demonstrated the controllable wavelength in 1.2-1.6 μm in the telecom-band NW laser. We believe that this work opens up new opportunities in optoelectronics and on-chip data communication. This work was supported by JSPS KAKENHI (15H05735 and 16H03821).

References: [1] Zhang 他、2016応物秋、14p-D62-6. [2] G. Zhang, et al. Nanotechnology **26** (2015) 115704. [3] G. Zhang, et al. ACS Nano **9** (2015) 10580.

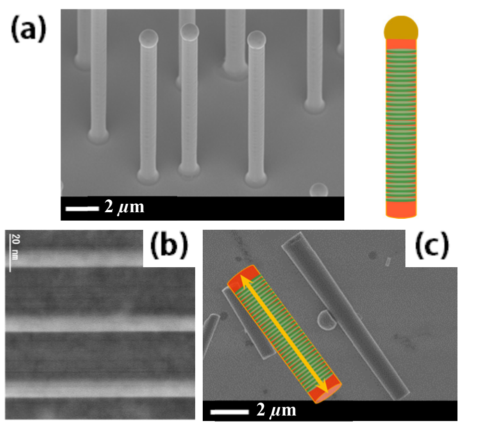

Fig. 1. a, SEM image of vertically aligned NWs grown on InP (111)B and schematic diagram of the multi-stacked InP/InAs NWs. **b**, High-resolution HAADF-STEM image of the InP/InAs heterostructure. **c**, NWs dispersed onto Au-covered SiO_2/Si substrate. The inset schematically indicates the NW FP cavity structure formed by the cleaved facets.

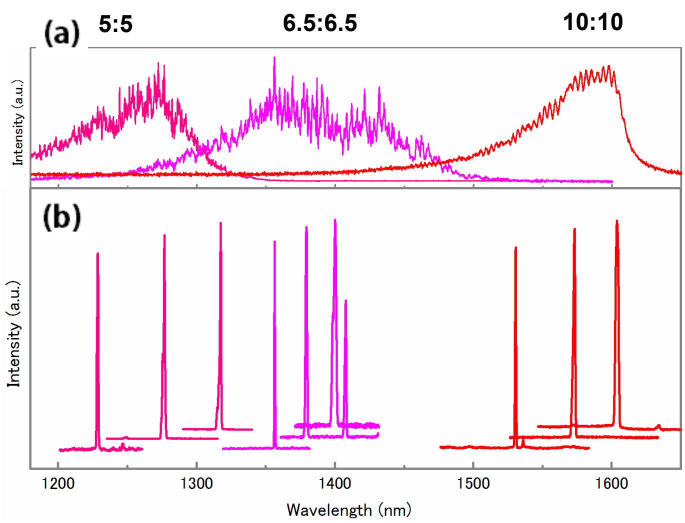

Fig. 2. Micro-PL and lasing spectra at RT. **a**, Typical spontaneous emission spectra of single NWs grown under different flow rates of TMIn and TBA (sccm), as indicated inside. **b**, Stimulated emission spectra of single NWs with varied InAs thickness.