InP/InAsナノワイヤの通信波長帯発光ダイオード
Telecom-band light emitting diodes based on InAs/InP heterostructure nanowires

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Telecom-band light sources are extremely important for optical data communication. Semiconductor nanowires (NWs) offer the possibility of enhancing the degree of freedom 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 light emitting diodes (LEDs) have been demonstrated, room-temperature telecom-band NW LEDs have not been realized due to the material issues limited to GaN, CdSe, GaAs, and InP etc. Here we demonstrate telecom-band NW LEDs operating 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. Diethylzinc (DEZn) and ditertiarybutyl sulfide (DTBS) are used as the source materials for the doping control of p- and n-type InP segments. The active region contains 5-10 periods of InP/InAs superlattice-like units (Fig. 1). We used p-InP (111)B substrate for the NW growth. The as-grown NWs were chemically etched to remove the indium particles at NW tips. The NWs were then embedded in transparent benzocyclobutene (BCB) material. Reactive ion etching (RIE) was used to partly remove the BCB material at the surface to expose the NW tip for the subsequent contacts with electrodes. The ITO and Au-Ni-Zn was deposited for the contact of n-type InP NW and p-type InP substrate (Fig. 2). The electrical characteristics show typical I-V curve of a diode (Fig. 3). We studied the electroluminescence (EL) property by using a Micro-PL system. The device exhibits luminescence when biased (Fig. 4a). We confirmed the EL spectrum from a single NW with a peak λ of 1.22-1.23 μm (Fig. 4b). The well-established growth technique of InP/InAs hetero-NW [1] enables to tune the luminescence peak by the thickness of InAs active layer. Currently, we could tune the EL luminescence to the peak λ of 1.32 μm (O band).

In conclusion, we have demonstrated telecom-band NW LEDs at operating room temperature by using multi-stacked InP/InAs heterostructure NWs grown via indium-particle-assisted vapor-liquid-solid mode. This work opens up new opportunities for the realization of NW-based telecom-band lasers, which may potentially be integrated Si CMOS process in monolithic integration way. (We thank Drs. K. Tomioka of Hokkaido Univ. and K. Kawaguchi of Fujitsu Lab. for their advices and comments on device fabrication. This work was supported by JSPS KAKENHI, Grant NO.: 15H05735 and 16H03821.)

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

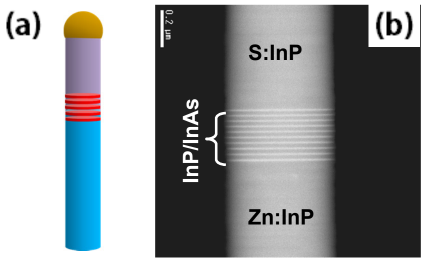

Fig. 1. (a) Schematic diagram of the p-i-n NW with multiple InP/InAs units. (b) HAADF-STEM image of a NW with the 10-layer InAs active layers.

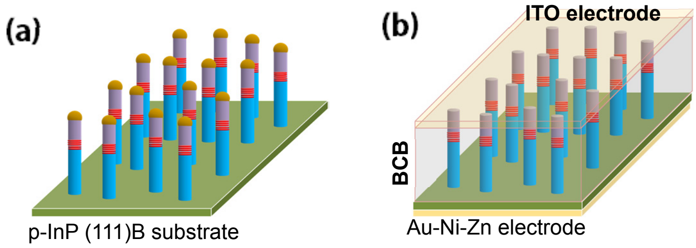

Fig. 2. Schematic diagrams of (a) as-grown NWs on p-InP (111)B substrate and (b) fabricated device for LED. The NWs were embedded in transparent BCB polymer material.

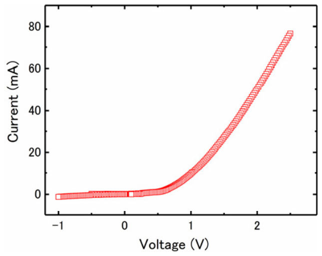

Fig. 3. Typical I-V curve exhibiting diode-like characteristics.

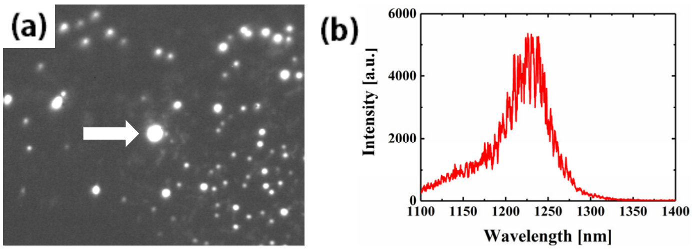

Fig. 4. (a) Spatially-resolved EL image (156μm×195 μm) of NW LED when biased at 2.3 V (current: 66 mA). (b) EL spectrum collected from a single NW shown in (a) by a white arrow.