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InP/InAs ヘテロナノワイヤの歪み評価
Strain characterization of InP/InAs heterostructure nanowires

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Strain in semiconductors has significant effect on the band gap structure and has become a very effective tool to engineer their optical and electronic properties. Semiconductor and the heterostructure nanowires (NWs) will be the next-generation building blocks. Because of the particular one-dimensional structure, the lattice relaxation way is significantly different from the film structure [1]. To understand how the strain occurs and how it affects the optical and electrical properties, it is fundamentally important to characterize the stain in NWs. However, up to now there are very few reports about it, mainly by TEM, a destructive method. Here, we demonstrate the successful characterization of strain in NWs by Raman measurement, a nondestructive and very sensitive method.

We grew InP/InAs heterostructure NWs in indium-particle-assisted vapor-liquid-solid mode [2,3] (Fig. 1). The inset in Fig. 1(b) shows a single InP/InAs/InP double heterojunction. The high-resolution TEM characterization indicates the coherent growth of the heterostructures in the NW. Owing to the -3.1 % lattice mismatch of InAs/InP, there should be high compressive strain in InAs segment. We characterized the strain in the InAs by Raman scattering in terms of the shift of TO phonon peak. The multilayer structure enables to detect Raman signals with enough intensity and therefore find the phonon-related peak structure. The micro-Raman enables us to carry out the measurement in the single NW level. Figure 2 shows the typical spectrum of a single hetero NW. For comparison, we also show the Raman spectrum of pure InAs NWs. There is a blue-shift (~ 10 cm^{-1}) of the TO phonon peak from the InAs NW to the InP/InAs NW, indicating a highly compressive strain inside the InAs segment. We further clarified the influence of the NW diameter and the length of the InAs segment on the strain. We found the shift increases with the NW diameter and decreases with the length of the InAs segment. This is in good agreement with the theoretical prediction.

In conclusion, for the first time, we have characterized the strain in InP/InAs NWs by Raman measurement. We confirmed the compressive strain in InAs segment and clarified the diameter and segment length dependence of the strain.

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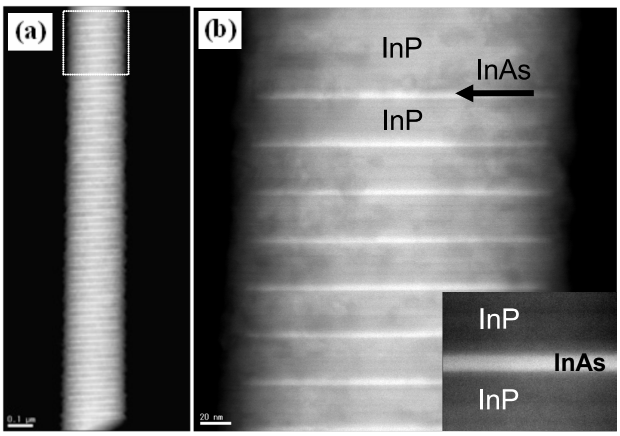

Fig. 1. HAADF-TEM images of (a) a multi-stacked InP/InAs NW with 60 InAs layers (b) the area indicated the dotted line in (a). The scale bar in (a) denotes 100 nm. The scale bar in (b) denotes 20 nm.

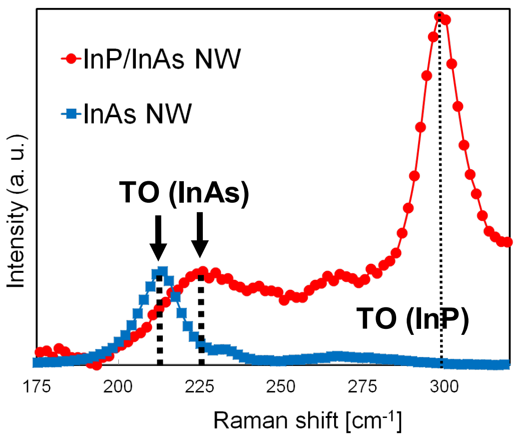

Fig. 2. Raman spectra of a multi-stacked InP/InAs NW and a pure InAs NW. TO phonon peaks from the InAs and InP segments of the two NWs are indicted.