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Stacked Multi-Quantum-Wires Grown on Vicinal GaAs(110) Surfaces by MBE

Takehiko Kato*, Toshikazu Takeuchi, Yoshiji Inoue, Koichi Inoue, Shigehiko Hasegawa and Hisao Nakashima

The Institute of Scientific and Industrial Research, Osaka University,
8-1 Mihogaoka, Ibaraki, Osaka 567 Japan

tel. :+81-6-879-8411 fax. :+81-6-879-8414

We have previously demonstrated that GaAs quantum wires (QWRs) are naturally formed by molecular beam epitaxy (MBE) on vicinal GaAs (110) surfaces with coherently aligned giant growth steps due to the thickness modulation at the step edges[1]. In the present paper, we stack many QWRs vertically on the surface, to make dense bundle of uniform QWRs. The uniformity is improved by adapting 2-step growth, in which , the substrate temperature is changed between the giant step formation and the QWRs formation. The stacked QWRs are characterized by the transmission electron microscopy (TEM) and by the photoluminescence (PL) measurement.

Samples were grown by gas-source MBE using AsH_3 on vicinal GaAs (110) misoriented toward (111)A and on GaAs (100) substrates for comparison. First, to form coherent giant growth steps, a 5-period GaAs/$Al_{0.5}Ga_{0.5}As$ (30nm/30nm) multilayer were grown on a 200nm GaAs buffer layer at 500℃. In the succeeding process, $Al_{0.5}Ga_{0.5}As$(b=1,3,30nm)/GaAs(d=1,3nm)/$Al_{0.5}Ga_{0.5}As$(b nm) QWs were stacked at 550℃. The total periods of stacked layers were n=30, 5 and 1.

The cross-sectional TEM image (Fig.1) clearly shows the coherent giant steps. Since the GaAs layer thickness at the step edges is thicker than that on the terrace, QWRs are formed at step edges. When the QWRs are stacked as shown in Fig.1 the QWRs are aligned to <331> direction approximately. The PL from single layer of the [b=30, d=1, n=1] sample (a) shows a peak at about 1.73eV, as shown in Fig. 2, which corresponds nearly to the PL peak energy of a GaAs 3nm quantum well. This indicates the thickness modulation at the step edges. The PL peak position of the [b=3, d=1, n=30] sample (b) is red-shifted slightly as compared with that of the single layer sample, owing to the QWR-QWR coupling, and further, the red-shift of the PL from the [b=1, d=1] samples (c) and (d) is remarkable. The PL spectral width of the [b=1,d=1,n=30] sample (d) is not broadened (even narrower) as compared with that of the [b=1,d=1,n=5] sample (c). This means the uniformity of the QWRs is conserved during stacking process, consistently with the TEM observation.

Reference [1] : M. Takeuchi *et al.* : Jpn. J. Appl. Phys. **34** (1995) 4411

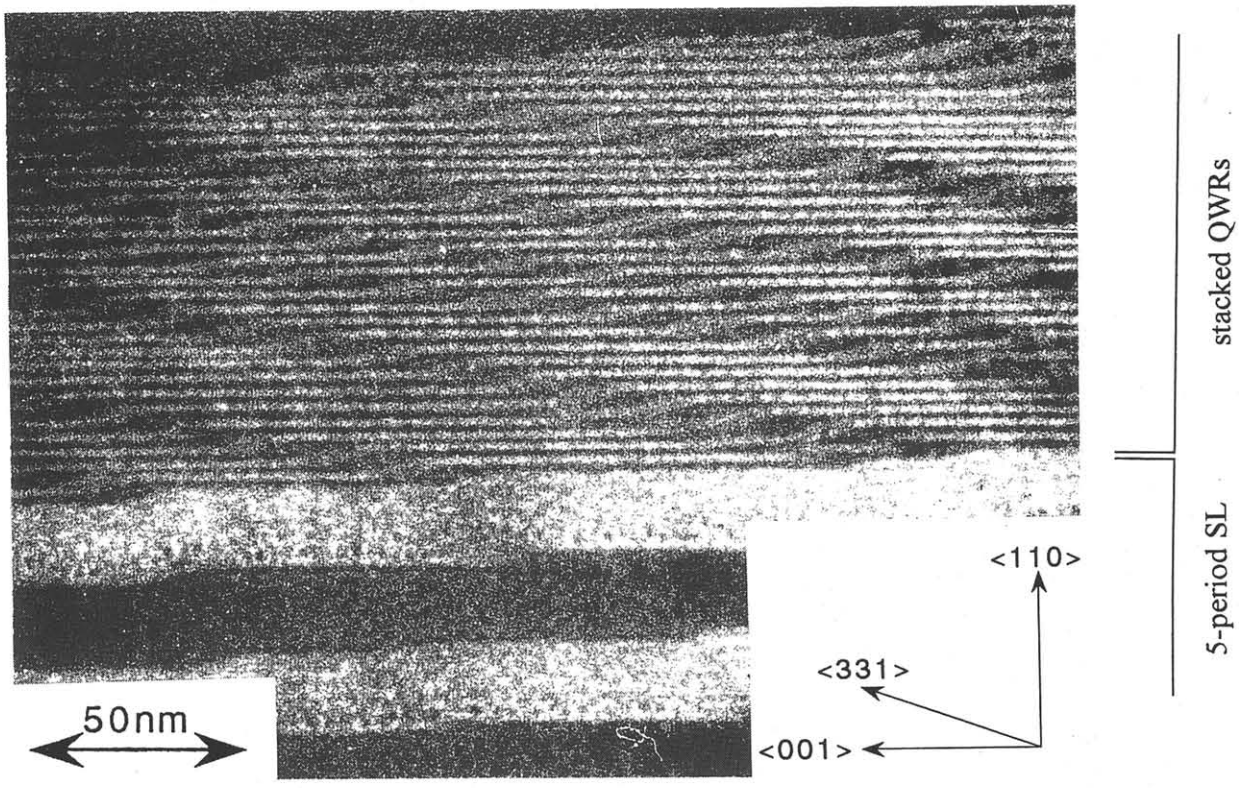

Fig.1 Cross-sectional TEM image.
Bright layers are AlGaAs, and dark layers are GaAs.

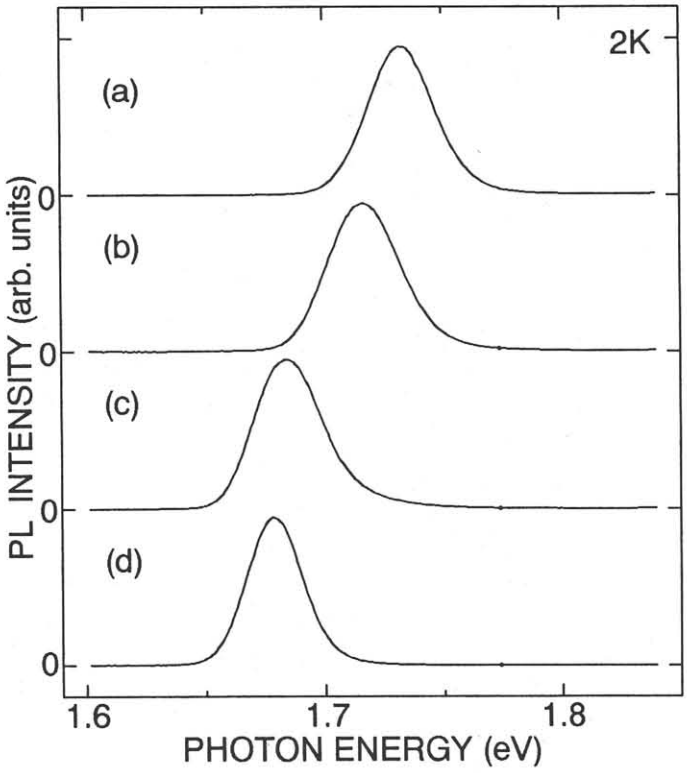

Fig.2 PL spectra of n-period $Al_{0.5}Ga_{0.5}As$(b nm)/GaAs(d nm) stacked QWRs;(a) b=30, d=1, n=1 (single layer), (b) b=3, d=1, n=30, (c) b=1, d=1, n=5, (d) b=1, d=1, n=30.