Negative Differential Resistance in trench-type narrow InGaAs Quantum Wire

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Negative differential resistance (NDR) effects, which typified tunneling diode, and the gunn diode, are of fundamental interest and are also important for their possible applications to microwave, switching, and memory devices[1-3]. We report the observation of pronounced NDR in new type narrow InGaAs/AlGaAs quantum wire (QWR) FET. On the other hand, selective growth of III-V semiconductors on non-planar substrates has been accepted as a promising method for fabricating QWRs. In this study, we report the novel formation of narrow (10x20nm) InGaAs/InAlAs QWRs on a (311)A InP V-grooved substrate in molecular beam epitaxy (MBE) and propose their applications to the QWR FETs. Here, Atomic Hydrogen (H) was irradiated during the layer growth as well as for surface cleaning of InP(311)A substrate prior to growth. Atomic H was supplied via a cracking cell consisting of tungsten filament, which was heated up to about 1700ºC.

Figure 1 shows a cross-sectional view of the trench-type InAlAs barrier layer grown on a InP (311)A V-grooved substrate perpendicular to [01-1]. The structure of trench-type with (111)A and (331)B facets have formed in the InAlAs barrier layer growth, which were fabricated under an As_2 flux. Under an As_4 flux, however, trench-type structure cannot be formed. Figure 2 shows a cross-sectional view for InGaAs QWR layer grown on the InAlAs trench-type structure. The InGaAs QWR layer was grown under an As_4 flux in order to enhance the migration of group-III atoms to the bottom of the InAlAs trench structure. Figure 3 shows a photoluminescence spectrum for InGaAs QWR sample at 12K. The excellent optical properties for the trench-type QWRs have confirmed in photoluminescence spectra and cathode-luminescence measurements.

We demonstrate the NDR characteristics including high peak-to-valley ratio and low onset voltage in a trench-type InGaAs QWR-FET on a (311)A InP V-grooved substrate. Figure 4 shows the I_d-V_{ds} characteristics at 40K. The gate width and spacing between the source and drain contacts are 2 μm and 3 μm, respectively. The NDR characteristics are clearly observed in the range of V_{ds}=0.1V to V_{ds}=0.2V by increasing V_g. Trench-type InGaAs QWR-FET indicate clear NDR characteristics with a low onset voltage (V_{NDR} = 0.12V) and a high peak to valley current ratio (PVR=4.3) at 40K.

In general, the narrower channel width and shorter gate length effectively improve the V_{NDR} due to the reduced scattering probability [4]. Here, we have incorporated with 100 nm gates in trench-type InGaAs QWR for obtaining a more pronounced NDR characteristics. We have also observed NDR characteristics with a low onset voltage (V_{NDR} = 0.1V) in 100 nm gate trench-type InGaAs QWR-FET.

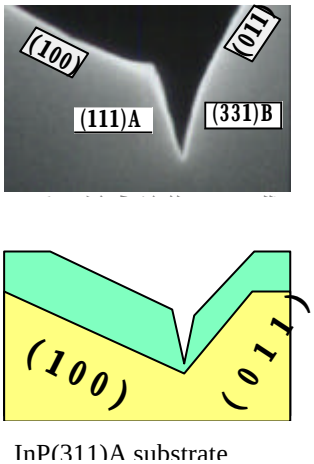

Fig.1 Cross-section of a trench-type structure including a schematic illustrating. The trench-type of the InAlAs barrier layer consist of (111)A and (331)B facets grown under an As_2 flux.

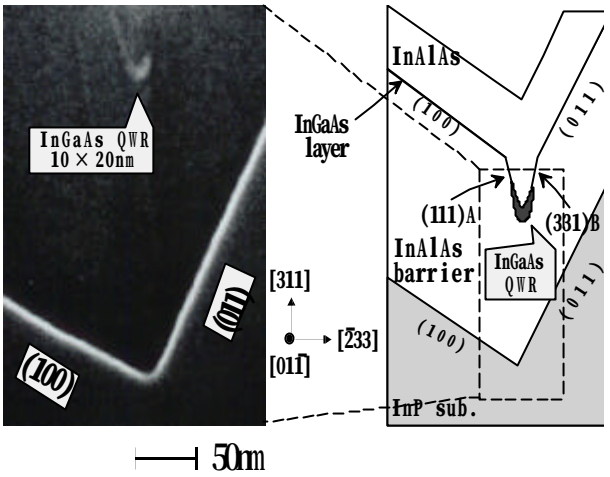

Fig.2 Cross-sectional view of an InGaAs QWR grown on the InAlAs trench-type structure. The InGaAs QWR layer was grown under an As_4 flux.

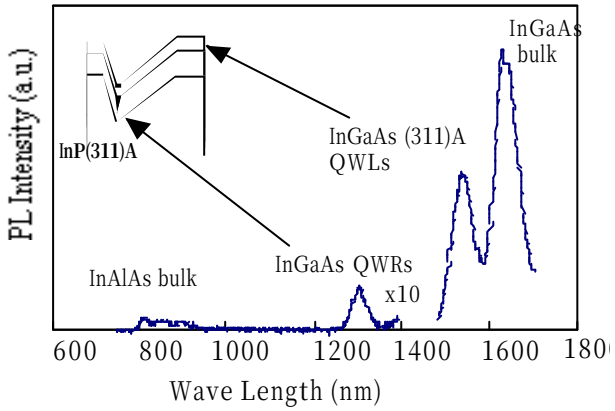

Fig.3 PL spectrum for InGaAs QWRs with atomic Hydrogen grown on (311)A InP substrate. The PL peak at 1300 nm and 1540 nm originate from the InGaAs QWRs and (311)A quantum wells(QWLs), respectively. (Inset: InGaAs QWRs and QWLs structures)

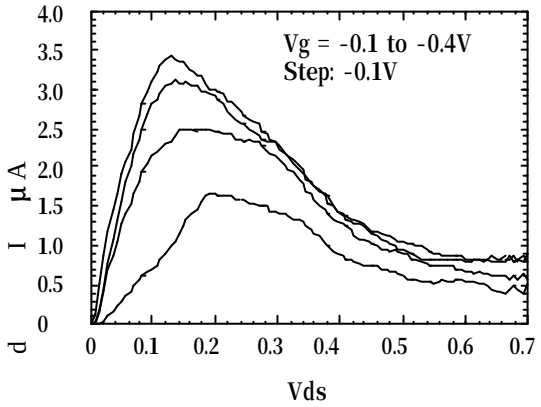

Fig.4 I-V characteristics of a trench-type InGaAs QWR-FET at 40K. NDR characteristics are clearly observed.

References

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