Effect of Mesa Formation Process on Negative Differential Conductance of GaInP/GaAs Triple Barrier Resonant Tunneling Diodes

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Quantum effects in solid states have been investigated and demonstrated, mainly relying on physical and technical variety about III/V semiconductors on the basis of their excellent material properties against silicon, artificial and/or self-organized fabrication techniques of ultra-fine heterostructures. Resonant tunneling is one of typical quantum effects revealing negative differential conductance (NDR), which has been observed for wide variety of material combination for a quantum well and tunnel barriers. Characteristics of resonant tunneling diodes are seriously affected by not only properties of tunnel barrier and/or quantum well layers in nanometers but also the device fabrication process as most III/V semiconductor devices are. In this report, influence of different etching processes for device mesa definition on the NDR characteristics of GaInP/GaAs triple barrier resonant tunneling diodes (TBRTDs) is investigated.

Figure 1 shows a schematic conduction band potential diagram of the TBRTD and the layer structure. Structural parameters are designed to obtain the resonant tunneling current flow when two quantum levels are coincident ideally under about 0.16 [V] of applied voltage.

In the GaInP/GaAs TBRTD fabrication process, wafers were grown by metal organic chemical vapor deposition (MOCVD) and a mesa structure with *D*=20 μm of the nominal diameter was defined. Ohmic contacts were formed by using Pd/Ge against n+-GaAs. Different mesa etching processes, surface cleaning methods and metal electrode configurations were employed. Fast atom beam (FAB) used here was a dry etching technique by producing neutral particle beam of Ar. Wet chemical selective etching (WSE) used here was H_3PO_4:HCl:H_2O =1:1:1 for GaInP, for H_2SO_4:H_2O_2:H_2O =1:8:80 GaAs, respectively. Br-methanol was also tried as a non-selective etchant. Prior to the metal deposition, we tried ozone cleaning process for a sample after developing a photo resist. Coplanar waveguide (CPW) configuration was aimed at RF measurement.

Figure 2 shows DC current-voltage (*I*-*V*) characteristics for different etching process and/or configuration of metal electrodes. Various NDR characteristics were observed, and we focused on variations of 1) peak voltage which could be reduced by lowering parasitic series resistance, 2) peak current which would be enhanced by enlarging effective lateral size of current path, 3) valley current which became large due to leak current.

Better performance was observed for a case A) where FAB and ozone cleaning were employed, however, finite value of valley current component and inconsistency of the peak voltage between measurement and theory remain to be consider together with properties of the grown wafer. Nevertheless, mesa formation processes was carefully investigated towards the optimization of device performance in GaInP/GaAs TBRTDs.

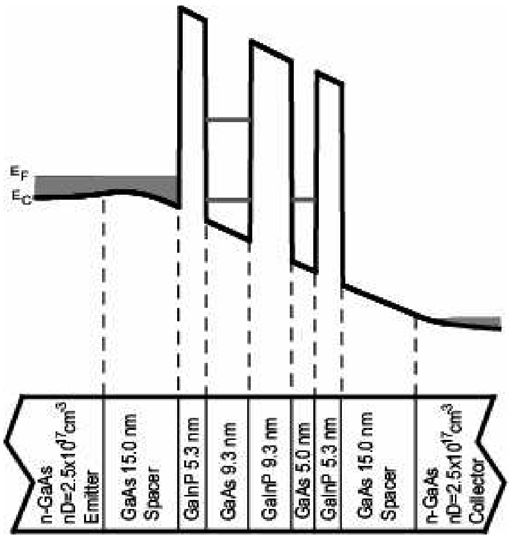

Fig.1 Conduction band diagram and the layer structure of GaInP/GaAs triple barrier resonant tunneling diodes under a certain applied voltage

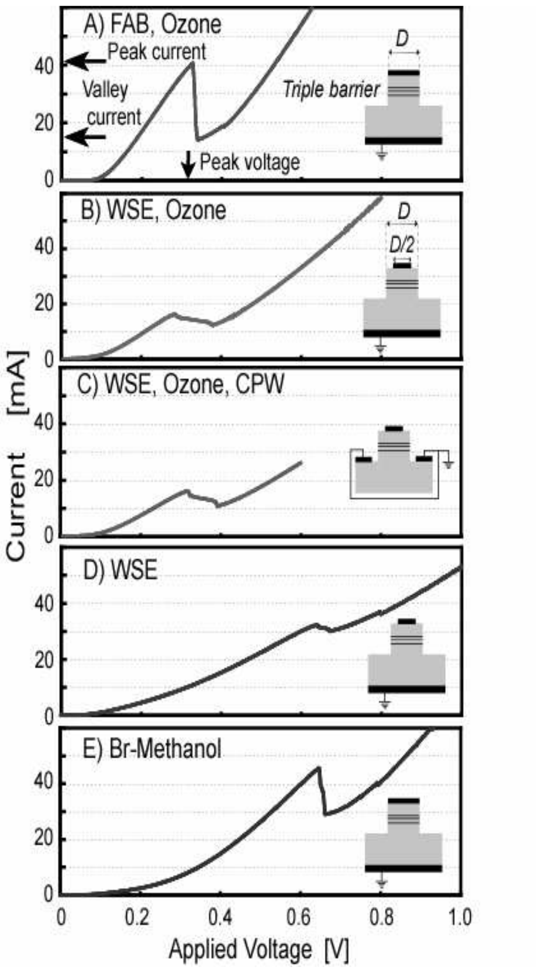

Fig.2 Various current-voltage characteristics of GaInP/GaAsTBRTDs fabricated by different mesa etching process and metal electrode configuration. Measured temperature was 20 K. All wafers were grown by MOCVD at the same time. A) Fast atom beam (FAB) dry etching and ozone cleaning processes were employed, B) Wet chemical selective etching (WSE) and ozone cleaning, C) WSE and ozone cleaning, D) WSE without ozone cleaning, E) Br-methanol etching without ozone. Configuration of metal electrodes is shown in each inset referring black solid layers as ohmic metals.