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Negative Differential Resistance in a Novel GaAs Delta-Doping Tunneling Diode

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In this letter, we show a novel GaAs delta-doping induced triangle-like double-barrier quantum well diode. The double barriers are induced by the δn^+-i-δp^+-i-δn^+ structure grown by delta-doping technique. The current-voltage characteristics exhibits two different types of negative differential resistance (NDR) at low and high bias, respectively. At low bias, N-type NDRs with peak-to-valley ratio 1.5 were observed due to resonant tunneling effect. An S-type NDR existed at high bias. This results from impact ionization in high electric field.

Recently, great attention has been paid to NDR phenomena, proposed and demonstrated by Esaki, Tsu, and Chang,[1,2] in double-barrier heterostructures. For now, most studied double-barrier resonant tunneling diodes are heterostructures except for a lateral resonant tunneling in a[3] double-barrier field-effect transistor. In this letter, we show a double-barrier quantum well (DBQW) homostructure with an undoped GaAs well (60 Å) between two delta-doping[4] induced triangle-like GaAs barriers (70 Å). The barrier is a triangle-like barrier irrespective of the broadening effect of delta-doping regions. It consists of the δn^+-i-δp^+-i-δn^+ structure.

Figure 1 shows a schematic cross section of the device structure. The structure was grown on an n^+-GaAs substrate at Ts = 570 °C by molecular beam epitaxy. δn^+ and δp^+ have concentrations 2.5×10^{13} cm^{-2} and 5×10^{13} cm^{-2}, respectively. Mesa diodes with active area 350x280 cm^2 were formed by chemical etching in the etching solution $1H_2SO_4:8H_2O_2:100H_2O$ for ten miutes. AuGe/Ni was used to make the ohmic contact. The sample was sintered at 450 °C for 2 minute within a flowing N_2 ambient. The device was measured by Tektronix 577 curve tracer.

The barrier height is estimated[5] to be 0.12 eV. Figure 3(a) shows the band diagram at thermal equillibrium. Figure 2 shows the current-voltage (I-V) characteristics measured at 300 °K. Figure 2(a) and 2(b) show the I-V characteristics at low and high bias, respectively. In Fig.2(a), the I-V curve exhibits symmetrical N-type NDR phenomena with peak-to-valley ratio (PTVR) 1.5. Figure 3(b) and 3(c) exhibit the band diagrams before and under the resonant tunneling condition, respectiely. In Fig.2(b), a S-type NDR is observed. This results from impact ionization in high electric field[6,7]. The generated holes are accumulated in the maximum of the valence band because of heavy effective mass. This results in potential distribution and thus an S-type NDR is observed.

In summary, a DBQW homostructure is fabricated and studied. The I-V characteristics show N-type NDRs and an S-type NDR at low and high bias, respectively. The former is due to resonant tunneling effect. The latter results from the impact ionization in high electric field.

1) L.L. Chang, L. Esaki and R. Tsu: Appl. Phys. Lett.24(1974) 593.
2) R. Tsu and L. Esaki: Appl. Phys. Lett.22 (1973) 562.
3) K. Ismail, D.A. Antoniadis and Henry I. Smith: Appl. Phys. Lett.55(1989) 589.
4) E.F. Schubert, J.E. Cunningham and W.T. Tsang: Phys. Rev.B36(1987) 1348.
5) K. Ploog, M. Hauser and A. Fischer: Surf. Sci.174(1986) 120.
6) E.F. Schubert, J.E. Cunningham and W.T. Tsang: Appl. Phys. Lett.51(1987) 817.
7) W.C. Liu, R.L. Wang, W.S. Lour, C.Y. Sun and C.C. Hong: Jpn. J. Appl. Phys.29 (1990) L7.

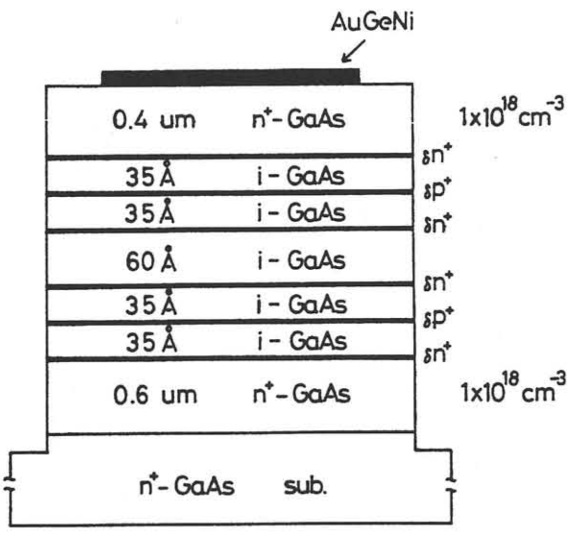
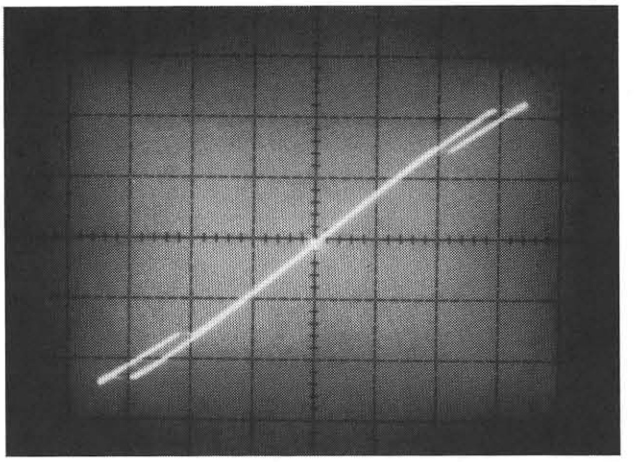
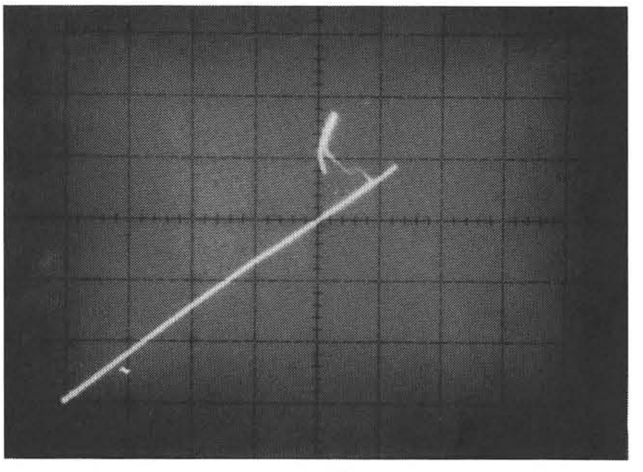


Fig.1 The schematic cross-section of the device structure with δn^{+} and δp^{+} concentrations 2.5×10^{13} cm^{-2} and 5×10^{13} cm^{-2}, respectively.



(a)



(b)

Fig.2 The room-temperature current-voltage characteristics of the device (a) measured with AC mode at low bias, (b) measured with DC mode at high bias.

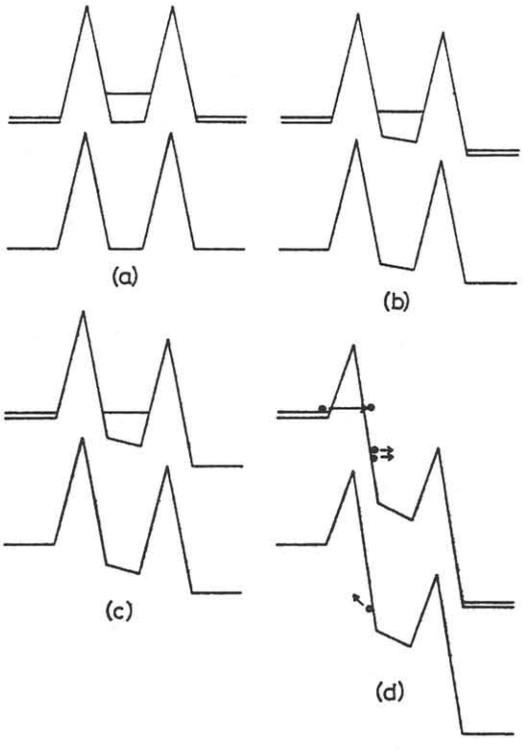


Fig.3 The band diagram (a) at thermal equilibrium, (b) at very low bias, (c) under resonant tunneling condition, (d)under impact avalanche breakdown.