Extended Abstracts of the 2009 International Conference on Solid State Devices and Materials, Sendai, 2009, pp711-712

Gate induced Cross-over between Fabry Perot and Quantum Dot Behavior in a Single-Walled Carbon Nanotube Hole-Transistor with Double Gate Structure

T. Kamimura*[1,2,3], and K. Matsumoto[1,3,4]
[1]AIST, 1-1-1 Umezono Tsukuba, Ibaraki, 305-8568, Japan
[2]JSPS, [3]CREST-JST, [4]Osaka Univ. ISIR
Tel: +81-29-861-5516, *E-mail: t.kamimura@aist.go.jp

We have succeeded in fabricating the double gated SWNT quantum transistor operated by Fabry Perot and quantum dot behavior. The two behaviors are controlled by the control gate and observed by sweep gate.

The schematic sample structure is shown in Fig. 1. The four electrodes are fabricated on the one SWNT. SWNT is completely purified. The distances between the electrodes, are L_1 = 69.4 nm, L_2 =90.3 nm and L_3 =119 nm, respectively. Moreover, large voltage up to 6 V is applied at L_2 and cut the SWNT. Thus, L_1 is used as the channel of the SWNT hole-transistor with side gate as shown in Fig. 1. The SWNT hole-transistor also has back gate at the back side of the substrate. The side gate V_{SG} and the back gate V_{BG} are used for the control gate and sweep gate, respectively.

Fig. 2(a) - (d). show the $d^2I_D/dV_D{}^2$ mappings as a function of V_D and V_{BG}, where I_D is drain current and V_D is drain voltage. When V_{SG} = 0 V is applied, the device shows Fabry Perot quantum interference pattern at around V_{BG} = -19 V and Coulomb diamond characteristic at higher V_{BG} than V_{BG} = -17 V as shown in Fig. 2(a) and Fig. 2(b). Thus, the cross-over between Fabry Perot and quantum dot behavior is observed as shown in Fig. 2(a). When V_{SG} = -25 V is applied, the device shows Fabry Perot quantum interference pattern at around V_{BG} = -14 V and Coulomb diamond characteristic at higher V_{BG} than V_{BG} -12 V as shown in Fig. 2(a) and Fig. 2(b). Fig. 2(e) and Fig. 2(f) are the enlargement characteristics shown in the square region by dot line in the Fig. 2(a) and Fig. 2(c), respectively. At the cross-point of the two dot lines, which are corresponding to the quantum levels in the SWNT, $d^2I_D/dV_D{}^2$ show high value pattern, which are called Fabry Perot quantum interference pattern. The shift of the V_{BG} region showing the Fabry Perot quantum interference pattern and Coulomb diamond characteristic by V_{SG} is about 5 V.

Fig. 3 shows the $d^2I_D/dV_D{}^2$ mapping as a function of V_{SG} and V_{BG}, in which V_D is the constant of 1 mV. The white regions are corresponding to the Coulomb oscillation peaks and Fabry Perot quantum interference pattern, the slope V_{SG}/V_{BG} of which is 0.2. Therefore, the modulation of the potential energy in the SWNT by V_{SG} = -25 V is corresponding to the modulation of the potential energy in the SWNT by V_{BG} = -5 V. This estimation is in agreement with the $d^2I_D/dV_D{}^2$ mapping as a function of V_D and V_{BG} as shown in Fig. 2(a) – (d).

We have succeeded in controlling cross-over between Fabry Perot and quantum dot behavior in a single walled carbon nanotube hole-transistor by double gate. The ratio of the modulation of the potential energy in the SWNT by V_{SG} to that by V_{BG} is 0.2.

[1] Nature 411, 665 (2001)

[2] Jap. J. Appl. Phys 48, 015005 (2009).

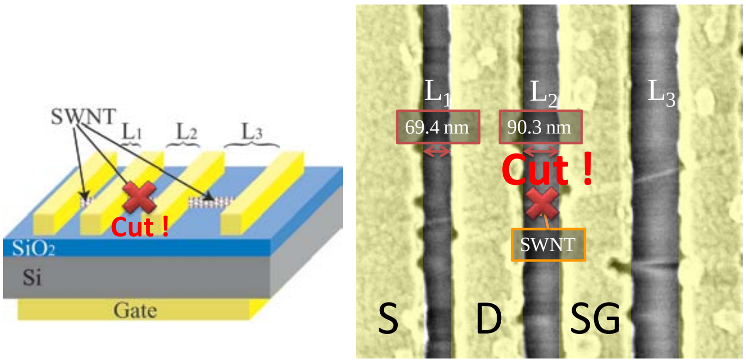

Fig. 1 Schematic sample structure and SEM image around channel.

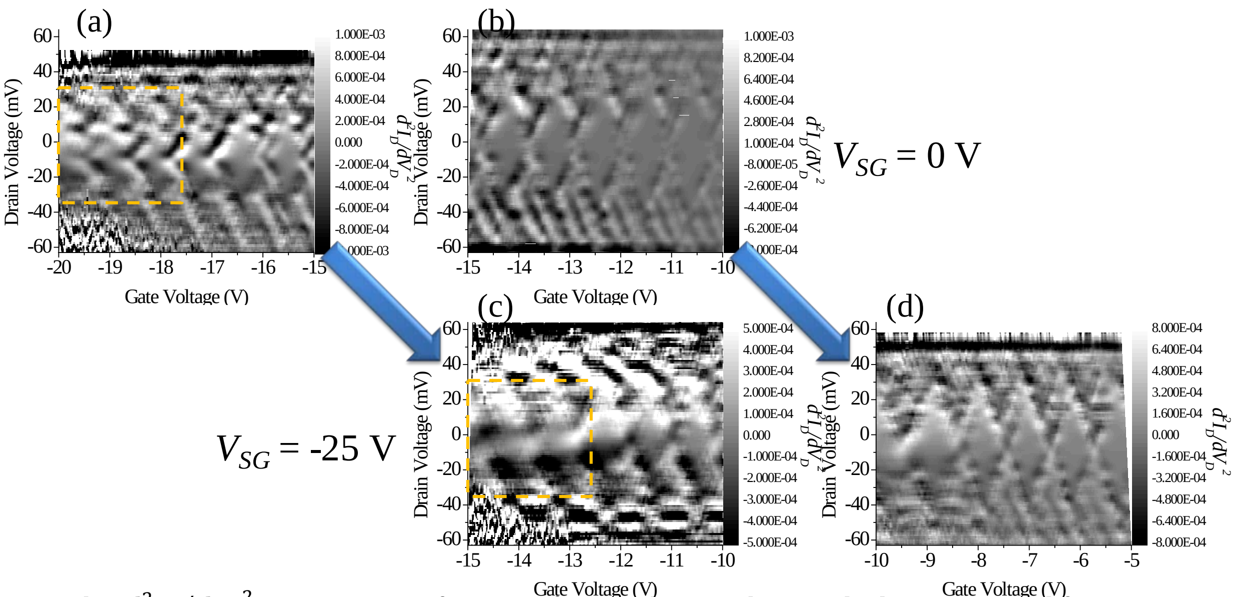

Fig. 2 the $d^2I_D/dV_D{}^2$ mappings as a function of V_D and V_{BG}, where applied V_D is ranged from -63 mV to 64 mV. (a) the $d^2I_D/dV_D{}^2$ mapping where V_{SG} = 0 V and V_{BG} is ranged from -15 V to -20 V. (b) the $d^2I_D/dV_D{}^2$ mapping where V_{SG} = 0 V and V_{BG} is ranged from -10 V to -15 V (c) the $d^2I_D/dV_D{}^2$ mapping where V_{SG} = -25 V and V_{BG} is ranged from -10 V to -15 V. (d) the $d^2I_D/dV_D{}^2$ mapping where V_{SG} = 0 V and V_{BG} is ranged from -5 V to -10 V.

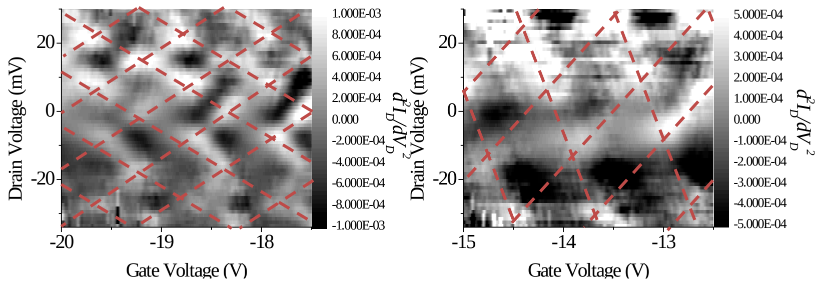

Fig. 2(e), (f) the enlargement characteristics shown in the dot square region in the Fig. 2(a) and Fig. 2(c), respectively.

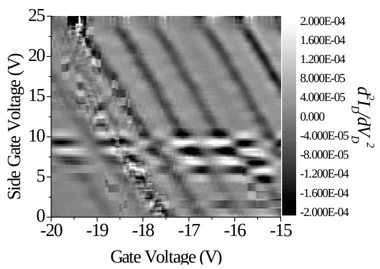

Fig. 3 the $d^2I_D/dV_D{}^2$ mapping as a function of V_{SG} and V_{BG}, in which V_D is the constant of 1 mV.