HW 8 CNTs and Tunneling and SET fundamentals ECE/ENGR 4243-6243 F. Jain 101816

Q.1 Recently (Physics Today, October 2014 p. 14, copy attached) it was reported that some research groups have succeeded in making carbon nanotubes with n=m=6 using c96H54 precursor that attaches to Pt catalyst during the chemical vapor deposition.

(a) Are these tubes metallic or semiconducting?

(b) What is novel in this approach **(Grad Students?)**

Q2 Why metallic tubes are not desirable in making CNT-FETs if they are mixed with semiconducting nanotubes.

Q.3(a). Schematically show an n-channel CNT-FET and a p-channel CNT FET using SiO2 as the gate insulator and nSi and p-Si being the gate material, respectively.

Q3(b). Identify n-FET and p-FET in figure below. What are their threshold voltages in the n- and p-type CNT FETs shown below?

Q3(c) how would you make an inverter gate out of an n-FET and p-type CNT FET.



**Part B Tunneling, Coulomb Blockade, Single Electron SET**

Q.1. Find the probability of transmission across AlGaAs barriers of thickness 60 and 70Å. Assume the barrier is sandwiched between two layers of n-GaAs layers.

The barrier height is EC. **Given:**

Effective masses: GaAs well AlGaAs barrier

 me =0.0665mo me =0.0916mo

mhh = 0.34 mo mhh = 0.466 mo

 mlh = 0.094 mo mlh = 0.107 mo

Eg as a function of aluminum fraction AlxGa1-xAs =1.424 +1.247 (x)

mhh= heavy holes, mll=light holes.



Fig. 1 AlGaAs barrier sandwiched by n-GaAs layers (which are thicker than the AlGaAs barrier).

Q.2. Find the probability of resonant transmission across two AlGaAs barrier of thickness 70Å. Assume the GaAs well to be 50Å and use the energy levels computed in HW2.



**Figure 2. GaAs well sandwiched between two AlGaAs barrier.**

Q3. Find the voltage needed to transfer a charge to the GaAs quantum dot (Fig. 3) from the GaAs bulk layer at either end. Here, AlGaAs represent the barriers surrounding the dot. Assume the dot x-dimension to be Lx=200Å. The barrier thicknesses are 100Å in x-direction. The dot dimensions are Ly= Lz= 100Å in the other two dimensions.



Fig. 3 GaAs dot sandwiched between two AlGaAs barrier from all three sides.

Q.4 Derive the tunneling probability equation #23 (p.155) in a double barrier device. **Grad credits.**

Q.5(a). Explain Coulomb blockade electron transport (such as shown in Fig. 7.18 Hanson Chapter 7) in a quantum dot island with capacitance 5 x 10-15F.

Q.5b. Explain the role of gate in a single electron transistor (Fig. 7.21) using Coulomb blockade.

Q.6 Compare the charging energy of a nano-capacitor 1.1x10-15 F with ½ (kT) and at what temperature it will be much larger than 1/2kT.