DOI 10.5162/IMCS2012/P1.5.1

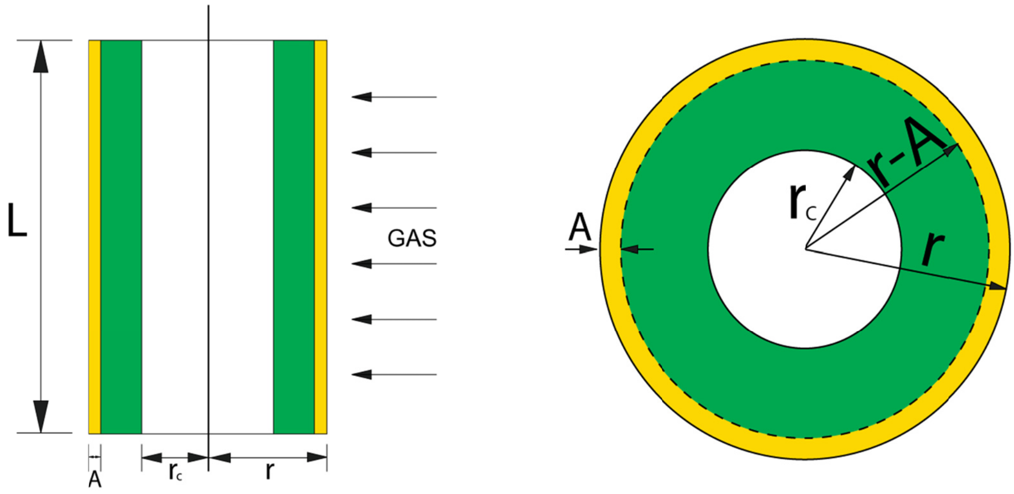

Fig.1 Longitudinal and cross sections of nanotube

$$\eta = 1 - \sqrt{1 - \frac{2n_A}{n_0}}. \quad (7)$$

Note that the non-equality

$$\frac{r_C}{r} < \sqrt{1 - \frac{2n_A}{n_0}} \quad (8)$$

should be taken into account. That means rather high level of changes in the concentration of electrons in depletion layer A is necessary.

For the p-type NT n_A / n_0 will be changed on p_A / p_0. Both versions (n-type and p-type) are promising for the manufacture of gas sensors.

Back-gate CNFET

The physical structure of back-gate transistor is shown in Fig. 2. This model based on the compact Spice model of CNFET [1], with some simplifications and modifications.

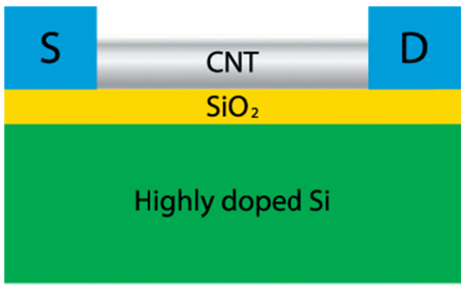

Fig.2 The physical structure of back-get CNFET

The equivalent circuit model is shown in Fig. 3. We consider the current (Isemi) between source (S) and drain (D) as [1]:

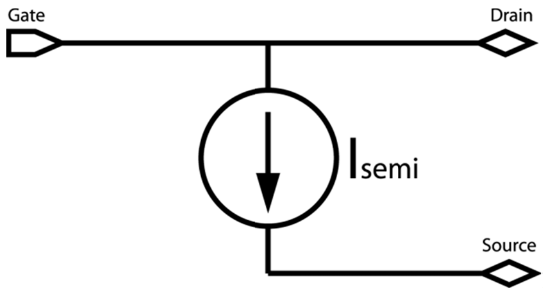

Fig.3 The equivalent circuit model of back-gate CNFET

$$I_{semi}(V_{DS}, V_{GS}) = 2\sum_{m=1}^{M} \sum_{l=1}^{L} (T_{LR} J_{m,l}(0, \Delta\Phi_B)|_{+k} - T_{LR} J_{m,l}(V_{DS}, \Delta\Phi_B)|_{-k}), \quad (9)$$

where V_{DS} and V_{GS} are potential differences, T_{LR} and T_{RL} are transmission probabilities [1], $J_{m,l}$ is the current density[1]. $\Delta\Phi_B$ is the channel surface-potential change in response to the changes in the gate and source/drain bias. In order to calculate $\Delta\Phi_B$, we solve charge conservation equations [1]

$$Q_{cap} = Q_{CNT},$$

$$Q_{CNT} = \frac{4e}{L_g} \sum_{m=1}^{M} \sum_{l=0}^{L} \left(\frac{1}{1 + e^{(E_{m,l} - \Delta\Phi_B)/kT}} + \frac{1}{1 + e^{(E_{m,l} - \Delta\Phi_B + eV_{DS})/kT}} \right),$$

$$Q_{cap} = C_{ox} V_{GS} - \frac{C_{ox} \Delta\Phi_B}{e}. \quad (10)$$

Gas sensor made of carbon nanotubes

In order to implement the final model of gas sensor made of CNT, we combine models of nanotube and back-gate CNFET. From (4) and (9)

$$S = \frac{R_g}{R} = \frac{I}{I_g} = \frac{I_{semi}}{I_g}. \quad (11)$$

Therefore, the current (I_G) for given charge concentration ratio and gate, source, drain bias will be

$$I_G = \frac{I_{semi}}{S}. \quad (12)$$

Results and Discussion

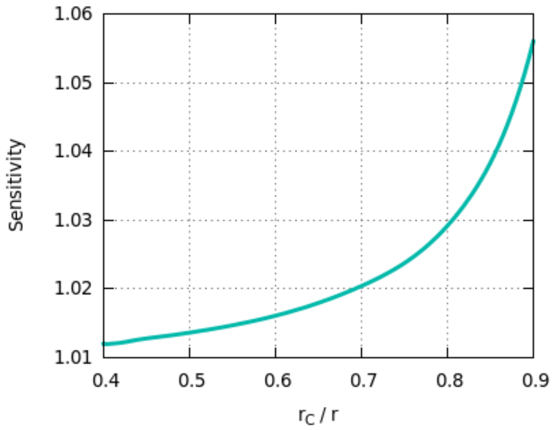

Fig.4 Sensitivity vs radiuses ratio

Fig.4 shows the sensitivity of nanotube due to inner and outer radiuses ratio change ($n_A/n_0 = 0.1$). The maximum resistive change of nanotube due to gas medium is about 5.7% for this case.

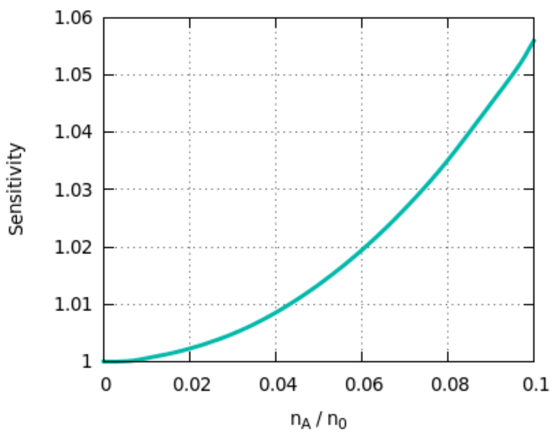

Fig.5 Sentivity vs charge densities ratio

Fig.5 shows the sensitivity of nanotube due to charge densities ratio change ($r_C/r = 0.9$). The maximum resistive change of nanotube due to gas medium is about 5.8% for this case.

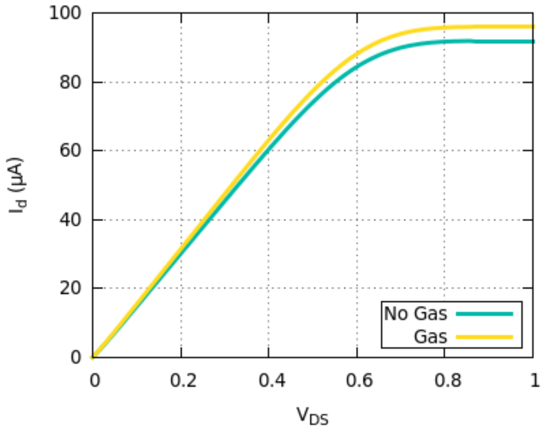

Fig.6 The change of I-V characteristic of gas sensor due to gas medium

Fig.6 shows the I-V characteristic change of gas sensor made of back-gate CNFET due to gas medium.

Conclusion

We present a mathematical model of gas sensor made of back-gate CNFET. In order to implement this model we carried out two models: nanotube model and back-gate CNFET. The resistive sensitivity of nanotube due to charge concentration change and physical structure of nanotube was considered. The change of I-V characteristic of gas sensors due to gas medium was considered. In result, we get a change of resistive sensitivity till 30%, which is appropriate for gas sensors.

References

[1] A Compact SPICE Model for Carbon-Nanotube Field-Effect Transistors Including Nonidealities and Its Application—Part I: Model of the Intrinsic Channel Region. J. Deng, H.-S. P. Wong. Dec. 2007 г., IEEE Trans. Electron Devices, стр. vol. 54, no. 12, pp. 3195–3205