Effect of Axial Strain on Switching Behavior of Carbon Nanotube Tunneling Field Effect Transistors

S. Souma, T. Nakano, H. Nagai, and M. Ogawa
Department of Electrical and Electronic Engineering, Faculty of Engineering,
Kobe University 1-1 Rokkodai, Nada, Kobe 657-8501, Japan
email: ssouma@harbor.kobe-u.ac.jp

INTRODUCTION

The integration density of integrated circuits has been increasing with amazing speed, and the critical issue of high off-state power dissipation comes along together. In fact, while the conventional MOSFETs operate with power supply voltages as low as two volts, now high performance transistors operating at practically lower voltages are desired. One of the important options to fulfill such demand is to use carbon nanotube tunneling field effect transistors (CNT-TFETs), since they not only are expected to operate with the sub-threshold swing below 60mV/decade at room temperature due to band-to-band tunneling [1], but also enables us to modify their electrical properties simply by changing their geometrical shapes. For instance, it is known that the on-current can be enhanced while reducing off-current in CNT-TFETs by applying the strain along the axial direction [2]. Motivated by such background, we study the influence of axial strain on the electronic transport for a model CNT-TFETs connected to electrodes.

METHOD

We assume that the source and the drain electrodes are p-type and n-type CNTs, where the band structures are assumed to be shiftd upper and lower in energy by means of the gate voltage (Fig. 1). In order to perform efficient simulation of such electromechanical phenomena in CNT, we employ the tight-binding model for electronic structure calculations [3]. We first analyze the band structures of semiconducting CNT under various strength of the axial strain (Fig. 2), and then calculate the transmission probabilities (Fig. 3) and the electrical transport properties by using the non-equilibrium Green's function method.

RESULTS AND DISCUSSIONS

Figure 2 shows the changing trend of bandgap energy by the axial strain for various semiconducting CNTs. This result means that the strain applied along the axial direction of CNT is effective for opening the bandgap. In Fig. 3 we plotted the transmission probability in (7,0) CNT-TFET, where we can clearly observe the band-to-band tunneling current. In Fig. 5-7, the gate voltage dependences of the drain current are plotted for two different dopin levels and three different axial strain ratios. These results demonstrate that the axial strain applied in the channel region of CNT is to be of benefit for reducing the subthreshold swing (SS) without reducing the on-current significantly when the heavy dopin level condition is achieved in the electrode.

CONCLUSION

We have investigated the effect of axial strain on the performance of CNT-TFET. Our simulations have demonstrated that the axial strain applied in the channel region of CNT-TFET is to be of benefit for reducing the subthreshold swing (SS) without reducing the on-current significantly when the heavy dopin level condition is achieved in the electrode.

REFERENCES

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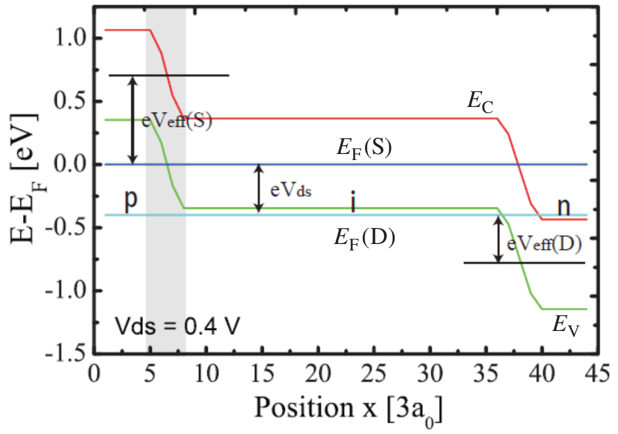

Fig. 1. Sketch of band profile in the p-i-n CNT-TFET structure, where the central channel region is composed of 30 unit cells.

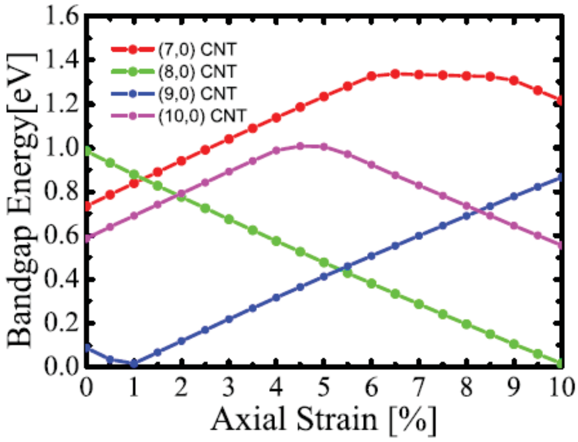

Fig. 2. Strain dependence of the bandgap energy in zigzag CNT with various diameters.

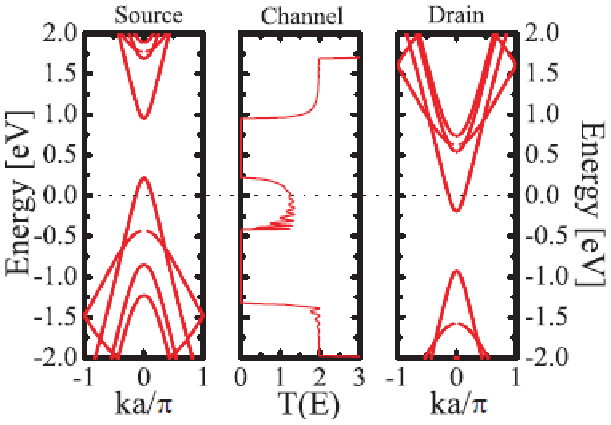

Fig. 3. Band structures in the source (left panel) and drain (right panel) (7,0) CNT electrodes, where the Fermi levels are 0.2 eV below E_V and 0.2 eV above E_C, respectively. The central panel is the transmission probability between two electrodes.

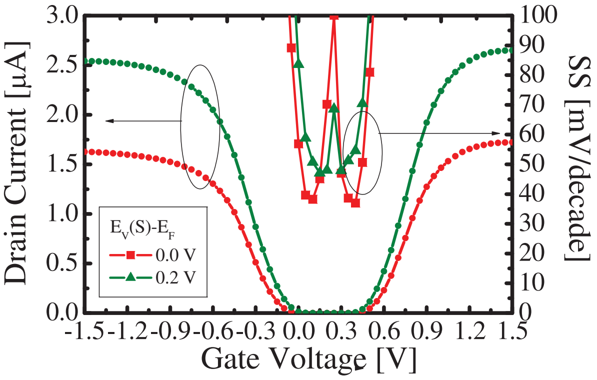

Fig. 4. Gate voltage dependence of the drain current in the absence of the strain. Results for two different doping levels are compared: small and large current magnitudes correspond to the light and heavy doping levels.

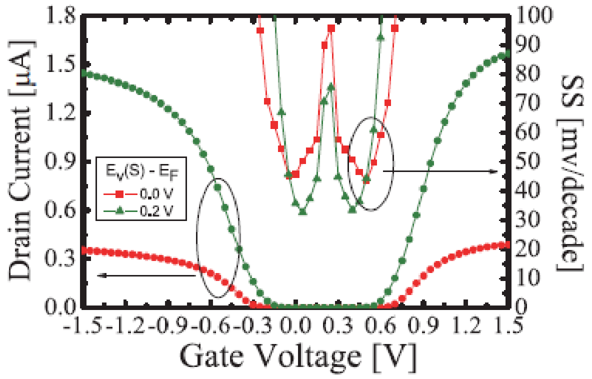

Fig. 5. Gate voltage dependence of the drain current in the presence of 2% axial strain.

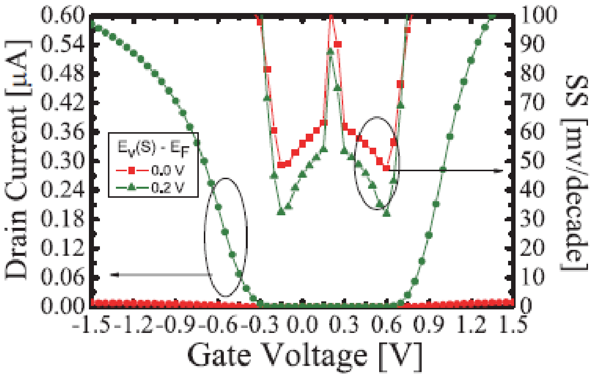

Fig. 6. Gate voltage dependence of the drain current in the presence of 4% axial strain.