Comprehensive Study of Frequency Properties for Carbon Nanotube Transistors

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Recently, very high frequency properties of carbon nanotube field-effect transistors (FETs) are attracting extensive research interests due to their high mobility and near ballistic transport (J. Appenzeller etc., Applied Physics Letters, vol. 84, pp. 1771-1773, 2004; P.J. Burke, Solid State Electronics, vol. 48, pp. 1981-1986, 2004; S. Rosenblatt etc., Applied Physics Letters, 87, 153111, 2005). To explore the performance limit of CNTFETs for very high frequency applications, it is important to understand time-dependent transport in CNTFETs. Self-consistent, quasi-static quantum simulations have been applied to assess the high-frequency performance (J. Guo etc., IEEE Trans. on Nanotechnology, vol. 4, pp. 715-721, 2005; L. Castro etc., vol. 4, pp. 699-704, 2005). However, the validity of quasi-static approximation needs to be examined. In addition, a full time-dependent simulation is necessary to examine some very important characteristics, such as frequency-dependent conductance.

Our study on AC characteristics of CNTFETs is based on the novel time domain simulation approach we proposed (Y. Chen and T. X. Wu, IEEE AP-S/URSI Symposium, “Microwave Frequency Properties of Nanoelectronic Devices”, July 2005). Further research is presented to investigate this problem comprehensively. The dependence of small signal transconductance and gate capacitance on the frequency of the applied bias is examined. The intrinsic cut-off frequency, a device metric important for radio-frequency (RF) applications, and the intrinsic switching time, a metric important for digital switch applications, are computed using the full time-dependent simulations. The validity of the widely used quasi-static approximation is examined. These physical analysis results are expected to deepen our understandings of device physics and theoretical limits of novel nanoscale transistors for potential very high frequency applications.