Chapter 1
CNTFETs:
Introduction and Types

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ABSTRACT

In recent years, carbon nanotube (CNT) emerged as one of the promising materials that shows various advantages over silicon material (e.g., aggressive channel length scaling due to absence of mobility degradation, variable bandgap with single material, ultra-thin body device that is possible due to smaller diameter [1-3nm], and compatibility of CNT with high-k materials resulting in high ION). Moreover, CNTs show both metallic and semiconducting properties; hence, by using metallic CNTs, interconnects can be realized to fabricate a circuit purely consisting of CNTs. This chapter will provide introduction to carbon nanotubes field effect transistor (CNTFETs) starting from material properties of carbon nanotubes and followed by how it can be used as semiconductor channel in field effect transistor (MOSFET) to form CNTFET. The different types of CNTFETs will be discussed based on the type of CNT used along with their advantages and disadvantages.

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1. INTRODUCTION

With discovery of CNTs in 1991 (Iijima, 1991), the researchers were interested to know the fundamental properties and technological prospective due to its low dimensional nanostructure. Fundamental properties of CNTs include low dimensionality (Dresselhaus et al., 2007), absence of dangling bonds (Li et al., 2008), near ballistic transport (Rahman et al., 2005), much weaker effect of Fermi pinning (Leonard, Francois & Tersoff, 2000) and exhibiting both metallic & semiconducting properties (Dresselhaus, Dresselhaus & Saito, 1995). The most important characteristic of CNT is that its diameter and bandgap are dependent on its atoms arrangement known as chirality. Hence designers can control the diameter and bandgap by changing the atoms arrangement. CNTs have been used to build prototype nanodevices ranging from carbon nanotube field effect transistor (CNTFET), electromechanical sensors (Mahar et al., 2007) and displays (Choi et al., 1999) in research labs and show outstanding characteristics as compared to conventional devices.

Based on the number of shells present in nanotubes, CNT can be classified into two types i.e. single walled CNT (SWCNT) (McEuen, Paul, Fuhrer & Park, 2002), if there is only single shell; and multi wall CNT (MWCNT) (Li, Hong, Yin, Banerjee & Mao, 2008), if there are more than one shells. The first ever discovered CNT in 1991 was MWCNT but after two years researchers managed to synthesize SWCNT. With discovery of SWCNT, they are used for further development of the CNTFETs as compared to MWCNTs due to better control of bandgap (Ostling, Tomanek & Rosen, 1997).

Among the various applications, this chapter will be mainly focused on the field effect transistor application of CNTs i.e. CNTFETs. Semiconducting SWCNTs act as channel in field effect transistor and depending on the way SWCNT is used/placed, CNTFETs are categorized into four type i.e. Schottky barrier CNTFET (Hazeghi, Arash, Krishnamohan & Wong, 2007), conventional CNTFET (Clifford, John, Castro & Pulfrey, 2004), partially gated CNTFET (Guo et al., 2002) and tunnel CNTFET (Appenzeller, 2005). Schottky barrier CNTFETs consist of undoped CNT that results into Schottky barrier with metals at drain and source sides. Conventional CNTFET consists of doped CNT as channel and work as conventional MOSFET. Partially gated CNTFET consists of partial gate region covering channel, and tunnel CNTFET consists of oppositely doped source and drain regions. This chapter is basically focused on the detailed description of different types of CNTFETs with their advantages and disadvantages for various applications.