Chapter 9
Performance Analysis of Mixed-Wall CNT Interconnects Using Colliding Bodies Optimization Technique

Girish Kumar Mekala
Vidya Jyothi Institute of Technology, India

Yash Agrawal
Dhirubhai Ambani Institute of Information and Communication Technology, Gandhinagar, India

Rajeevan Chandel
National Institute of Technology, Hamirpur, India

Ashwani Kumar
National Institute of Technology, Hamirpur, India

ABSTRACT

In recent years, carbon nanotube (CNT) interconnects have emerged as a potential alternative to copper interconnects due to their several magnificent properties. Due to fabrication issues, realization of densely packed CNTs with uniform diameters in a bundle structure is difficult to achieve. Consequently, it is advantageous to obtain a combination of CNTs with non-uniform diameters in the bundle, thereby leading to a densely packed mixed-wall CNT bundle (MWCB). In a MWCB structure, tube density plays a major role to determine the parasitic elements associated with the interconnects. For this, prospectively, colliding bodies optimization (CBO) technique has been incorporated. It is inferred from the study that the overall crosstalk noise, delay, and power dissipation of MWCB interconnect with higher tube density (i.e., obtained using CBO technique) are lesser than other CNT structures. Henceforth, it is determined from the proposed work that prospective CBO technique for advanced MWCB structure is highly efficient and effective for on-chip interconnects in IC designs.

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1. INTRODUCTION

In recent years, carbon nanotube (CNT) interconnects have emerged as a potential alternative to copper interconnects due to their significantly better electrical and thermal properties (Novoselov, 2004; Yu, 2000; Wei, 2001; Hone, 1999). CNTs can be broadly classified into single- and multi-walled nanotubes (SWCNTs and MWCNTs). The conductivity of individual SWCNTs is quite low due to high quantum resistance. Hence, to improve the conductivity of SWCNTs, bundle structures have been proposed by several researchers (Koo, 2007; Pu, 2009; Srivastava, 2009; Li, 2009). However, considering the wrapped direction of graphene layers, SWCNTs can be either metallic or semiconducting, whereas, MWCNTs always remain metallic due to their large diameters (Li, 2009).

Modeling and performance analyses of SWCNT and MWCNT interconnect to examine propagation delay, power dissipation, and crosstalk have been reported in literature (Giustiniani, 1986; Sarto, 2010; Kumar, 2015; Agrawal, 2016; Kumar, 2016). It is envisaged that fabrication of CNTs with uniform diameter is difficult to attain. Consequently, the CNT bundle comprising of CNTs with varying diameter configuration is considered (Zhu, 2006; Chenug, 2002). MWCBs possess relatively high conductance than those of the SWCNT bundle or a MWCNT (Haruehanroengra, 2007). In Wang (2007), have investigated that tube density is an important entity to determine the parasitics of on-chip interconnects. The work in Majumder (2014) shows that crosstalk induced delay can be significantly minimized by using high tube density. It is seen that the MWCB structure comprises of random size non uniform CNTs placed at different locations. This creates lot of free space within the MWCB structure (Yilmazoglu, 2011). Higher the free space, lower with the tube density. This decreases the performance of the system. Consequently, optimization of MWCB structure is essentially needed so that free space can be minimized and henceforth tube density can be improved. This can be attained by proper placing of CNT from larger to smaller diameter CNTs in MWCB structure.

In this research work, prospective colliding bodies optimization (CBO) scheme is incorporated to determine optimum tube density for MWCB on-chip interconnects. The performance analysis is performed at 22nm technology. The CBO algorithm has been widely explored by different researchers (Kaveh, 2014; Panda, 2014). This has been vividly adopted to solve different engineering problems. The optimization scheme and optimal tube density for MWCB structure have been very sparsely reported in literature yet. CBO technique is based on 1-dimensional collision between two adjacent objective bodies and it does not involve any tunable parameters (Kaveh, 2014). Along with using CBO algorithm, there is need to fit different CNTs within the rectangular shape of MWCB structure. The effective placement of CNTs in MWCB structure is performed using Huang's approach (Huang, 2004). This approach