Improved RF Characteristics of Carbon Nanotube Interconnects with Deposited Tungsten Contacts

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Carbon Nanofibers (CNFs) grown by Plasma Enhanced Chemical Vapor Deposition (PECVD) are potential next-generation interconnect materials due to their high current capacity [1] and excellent thermal and mechanical properties [2] [3]. Madriz *et al.* [4] designed and fabricated a test structure for RF characterization of CNF interconnects up to 50 GHz and developed a compact circuit model based on their results. Figure 1 shows the transmission characteristics for one of these devices. They asserted that CNF interconnect can be modeled as a resistor up to high frequencies with a negligible reactive component as long as the contact impedance is small [4]. Their devices showed that the contact impedance between the CNF and the electrode contacts can be reduced to some extent by Joule heating from dc current stressing, and can be further improved if a suitable metal is deposited on the electrode contacts. Saito *et al.* [5] had investigated the use of tungsten (W) as a contact material to study the breakdown characteristics of CNFs, and found that the contact resistance between CNF and Au electrodes was improved significantly. However, these devices were not characterized at high frequencies, which is critical for assessing their viability in future applications where high clock rates are needed.

In this study, we fabricate CNF interconnects with Au electrodes, and deposit W at the contacts. W deposits are produced by two techniques: Electron Beam Induced Deposition (EBID) with WF_6 as the source gas, and Ion beam Induced Depositions (IBID) with $W(CO)_6$ as the source gas. The SEM images of a typical device before and after W deposition are shown in Figures 2(a) and (b). The electrical characteristics of these CNF interconnect test devices obtained with these two methods are compared from dc up to 50 GHz and the circuit parameters including the contact impedance are extracted using the technique and test chip developed by our group [4]. A schematic of the test structure is given in Figure 2(c). Since the control of contact impedance is critical in the sub-20 nm technology nodes, improvements using materials and processes commonly used in silicon technology could go a long way in realizing the potential of using carbon nanostructures as the next-generation interconnect materials.

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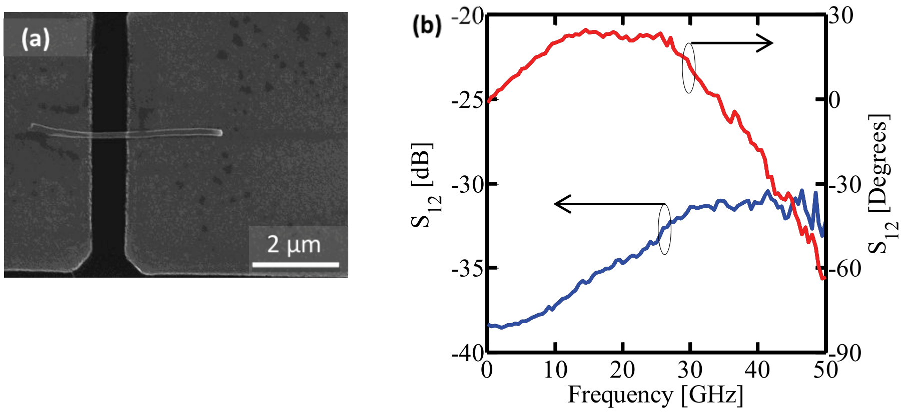

Figure 1: (a) SEM image of two port CNF interconnect test structure. (b) Transmission Coefficient (S21) of two-port CNF interconnect test structure.

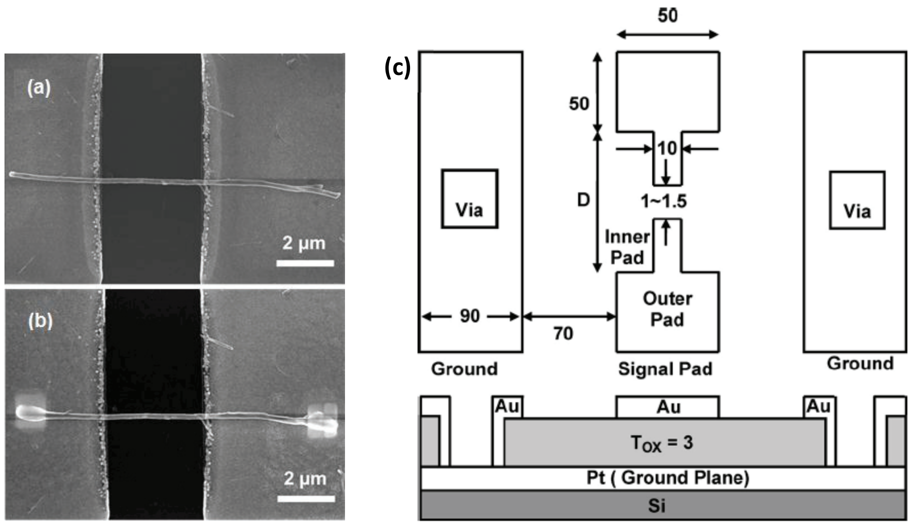

Figure 2: (a) CNF deposited between two Au electrodes and (b) after W deposition at the contacts. The test structure in (c) is used for high-frequency measurements (dimensions in μm, D is the variable separation between outer pads, drawing not to scale) [4].