Chapter 65
Fabrication of Nanoelectrodes by Cutting Carbon Nanotubes Assembled by Di-Electrophoresis Based on Atomic Force Microscope

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ABSTRACT

Presented is a new fabrication method for CNT (Carbon NanoTubes) nanoelectrode pairs by combining the DEP (Di-electrophoresis) and AFM (Atomic Force Microscope) lithography. The single CNT is driven and electrically connected with the microeletrodes by the DEP force,then cut into nanoeletrode pairs with AFM tip. The fabricated CNT nanoeletrode pairs can be used as probes to detect species in micro-environment and applied in electrochemical sensors.

INTRODUCTION

Since carbon nanotubes (CNTs) were rediscovered by Iijima in 1991 (Iijima, 1991), many scientists have done research on its synthesis, characterization, application in nanoelectronic devices and material field, such as transistors (LeMieux et al., 2008), integrated logic circuit (Chen et al., 2006), controlled growth (Sangwan et al., 2010), and sensors (Hu et al., 2010). At present, there are three methods for synthesis of CNTs:arc discharge (Journet et al., 1997), laser burning (Guo et al., 1995) and chemical vapor deposition (CVD) (Bethune et al., 1993).

Although assembling the CNT to make devices is still a challenge, several groups have made some progress by different methods. Tian successfully assembled the single carbon nanotube (SWCNT)

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into the gap between two microelectrodes (Tian et al., 2009). Martin used patterning catalyst technology to directly grow CNTs in the designed place (Martin-Fernandez et al., 2010). Specially, the muti-walled carbon nanotube (MWCNT) is a prospect material in nanodevices, which can be used as electrical connection (Chien, Yun, & Wei, 2008) due to its metallic property.

Nanoelectrodes are ultramicro- electrodes, (Kleps et al., 2001), which can be used in ultra-sensitive electrochemical sensors, or analytical tools for measuring electron transfer reactions and as probes to detect species in micro-environment (Li et al., 2005). Compared to microelectrodes, nanoelectrodes can break through the conductivity limitation and be directly used in measurement for electroanalysis, while microelectrodes need electrolytes to adjust the conductivity, pH and so on (Amatore et al., 2010). Generally speaking, nanoelectrodes can provide higher mass transferring rate, less time constant, higher signal-to-noise ratio, better operability, higher sensitivity and greater capability (Bond, 1994; Feeney, 2000; Forster, 1994; Zoski, 2002). Due to its perfect properties, nano electrodes can be used in electroanalysis, sensors, nanoelectronics and so on.

So far, there are four methods to make nanoelectrodes, which are template making (Bai, Cheng, & Wang, 2010; Compton, 2008), etching method (Krishnamoorthy & Zoski, 2005), self-assembly (Jeoung et al., 2001) and lithography method (Tu, Ren, & Lin, 2003). As CNTs have good conductivity, electron transfer ability, biocompatibility and good chemical stability, it is the best choice for making nanoelectrodes. Yi Tu and his group fabricated CNT electrodes with lower capacitive current by spin-coating of epoxy resin and used it in detecting ion concentration (Tu et al., 2005). Xiang wei and his group used MWCNT-graphite paste electrodes to detect Pb^{2+} (Xiang et al., 2006). Li Jun detected DNA by nanoelectrodes based on MWCNT with high sensitivity, which could be used for molecular diagnosis due to their well defined nano-scale geometry (Li et al., 2003). While in making nanodevice based on CNT nanoelectrodes, how to accurately control CNT's position and its size is a big problem. And limited by disperation technology of CNT bundles, most studies are on CNT bundles based nanoelectrode, which limit the performance of nanoelectrode and then the nanodevice. Thus, how to fabricate individual CNT-based nanoelectrodes becomes very important and urgent. Shen and his group has successfully fabricated individual nanoelectrode based on MWCNT by SEM, while using a probe to pick up a CNT is not an easy job (Shen, Wang, & Chen, 2009).

To solve the above proposed difficulties, in this article, the authors will assemble the single MWCNT into gaps between electrodes, and then mechanically cut it into pairs by the AFM system. Also the CNT based nanoelectrodes will be characterized by the AFM system.

EXPERIMENTAL MATERIALS AND SYSTEM

A. Materials

MWCNTs, whose average diameter is 5-25nm, and length is 1-4μm, were synthesized by CVD. The 10μm wide electrodes with a 3μm wide gap were made by lithography.

B. Experimental System

The experimental system for assembling CNTs is our custom-built Di-electrophoresis (DEP) system, while imaging and manipulating of CNTs are implemented by Dimension 3100 AFM with a Nanoscope IV a controller.

C. MWCNT Suspension Preparation

To prepare individual MWCNT suspension, the mixed solution of MWCNTs, de-ionized water and sodium dodecyl sulfate surfactants (SDS)

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