Proceedings of the 1st IEEE International
Conference on Nano/Micro Engineered and Molecular Systems
January 18 - 21, 2006, Zhuhai, China

Precise Assembly and Electrical Contact of MWCNT Based on AC Dielectrophoresis and Robotic Nanomanipulation Technology

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Abstract **Nowadays research on single CNT based nanoeletronic device arises much interest among researchers, but in the fabrication of CNT based nanoeletronic device, one of the key technical problems is to realize precise assembly and electrical contact between CNT and microelectrode. For solving the problem, first AC dieletrophoresis (DEP) method is used to coarsely position batch of CNTs near the microelectrode, then AFM based robotic nanomanipulation method is used to precisely position, assembly and make electric contact of the selected CNT. MWCNT assembly and electric contact experiments verify the effectiveness of these two methods' integration.**

Keywords- Precise assembly, electrical contact, MWCNT, AC DEP, Robotic nanomanipulation

I. INTRODUCTION

As carbon nanotube (CNT) has many unique properties, such as special strength properties [1][2], heat properties [3], especially it has special electrical properties to be conduct or semi-conduct with different diameter and helix angle [4~6], and also due to its nanometer size and one-dimension shape, it becomes a kind of promising material to substitute silicon material in fabricating micro/nano electronic device, and currently it is used to fabricate various kinds of nanoelctric device such as CNT-based nano transistor [7][8], nano chemical gas sensor [9], etc.

However, it is one of the key technical problems to realize precise assembly and electrical contact between CNT and microelectrode in nanoelectric device's fabrication, and several methods were proposed for solving it. Dispersed CNTs solution is directly spread and deposited randomly on the surface of microelctrode and thus the assembly and electric contact is realized [10], obviously its success ratio is very low. Dispersed CNTs solution is deposited on substrate and CNTs are actuated to microelectrode only by AC dieletrophoresis (DEP) technology [11], for always batch of CNTs or even bundles are absorbed to the microelectrode, it is difficult to make assembly and electric contact of predefined single CNT. CNT is grown at the predefined position of two microelectrodes [12], but it is in itself very difficult to accurately position the catalyst and control the CNT growth process. Dispersed CNTs solution is firstly deposited on the substrate, and then focused ion beam (FIB) lithography technology is used to make microelectrode with CNT and thus electric contact is formed [13], although the electric contact is reliable, CNT is prone to be destroyed by high energy FIB. And in these methods described above, there also exists a common shortcomings, that is, the position of predefined CNT cannot be precisely controlled and adjusted, which impeded the research of CNT based nanoelectric device.

A new method to solve the problem is proposed with the integration of AC DEP method and AFM based robotic nanomanipulation method in this paper, that is, firstly batch of CNTs are coarsely actuated to microelectrode by AC DEP force, then the selected CNT is accurately pushed and assembled to the microelectrode, and additional CNTs are pushed outside the operation area with AFM probe. In this way, precise assembly and electrical contact of single CNT can be realized and experiments will be performed to verify the effectiveness of the method.

II. AFM BASED ROBOTIC NANOMANIPULATION SYSTEM

Recently AFM based nanomanipulation has been researched and various kinds of manipulation methods have been proposed [14~16]. However, these AFM based nanomanipulation methods can be cataloged into 'scan-design-manipulation-scan' mode, its main problem is the lack of real-time sensory feedback for the operator, the manipulation result can only be verified by another new scan for every manipulation step. Obviously, this manipulation mode is inefficient and inflexible, the probe is also prone to be broken without force information feedback, and all these shortcomings hamper the development and application of AFM based nanomanipulation.

For solving the problem, an AFM based robotic nanomanipulation system was built up as shown in Fig. 1 [17][18].

In the system, a sample-scanning AFM (model CSPM-2000wet, Ben Yuan Ltd., China) was used, where a scanner is equipped in the AFM head with XY scan range 50um and Z range 5um, and AFM nano-probe (model NSC15-F5, MickoMasch Inc., USA) with calibrated force

This project was funded by the Chinese National 863 Plan (Project code: 2003AA404070) and the Chinese NSF (Project code: 60575060)
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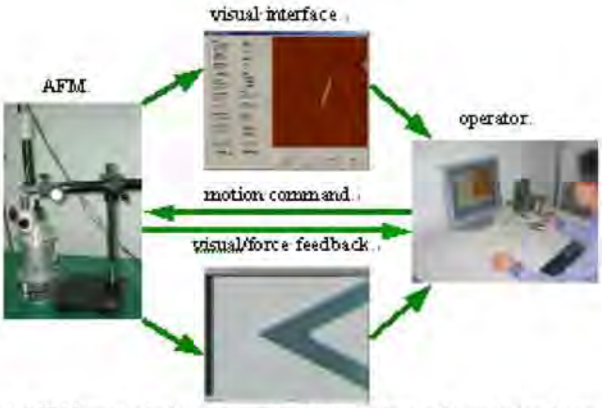

Fig. 1 AFM based robotic nanomanipulation system with real-time force and visual information feedback

constant is also equipped in AFM head. A haptic device (Sensable Co., USA) is used for 3D nano forces feeling and motion commands input, that is, the forces are felt by operator from the haptic joystick and the scanner motion command produced by joystick is sent into the AFM control computer to control the scanner's motion. The visual interface provides the operator with real-time visual feedback information of nano environment. The optical microscope and CCD camera help the operator to adjust the laser to focus on cantilever end and search for interesting area on sample.

During nanomanipulation, real-time 3D nano forces and visual information can be obtained, and several manipulation steps can be continued without break, and this kind of manipulation with various information feedback makes the nanomanipulation more efficient, intuitional and flexible [15].

III. MICROELECTRODE FABRICATION

The microelectrode is fabricated after the design of electrode material, geometric shape and size, and the fabrication process is shown in Fig. 2.

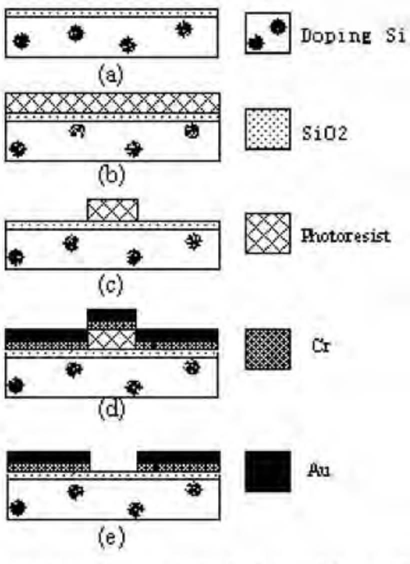

Fig. 2 Fabrication process of micro-electrode: (a) oxidation on Si surface, (b) photo resist deposition, (c) photo resist lithography, (d) Cr/Au deposition, (e) photo resist removed by acetone erosion

Firstly the doped silicon substrate is oxidated and the surface will be covered with a thin SiO2 film, then a thin photo resist film is deposited and photo-lithographed to get the microelectrode shape and size, then Cr/Au thin film is deposited and additional photo resist is removed by acetone, thus the microelectrode is obtained as shown in Fig. 3.

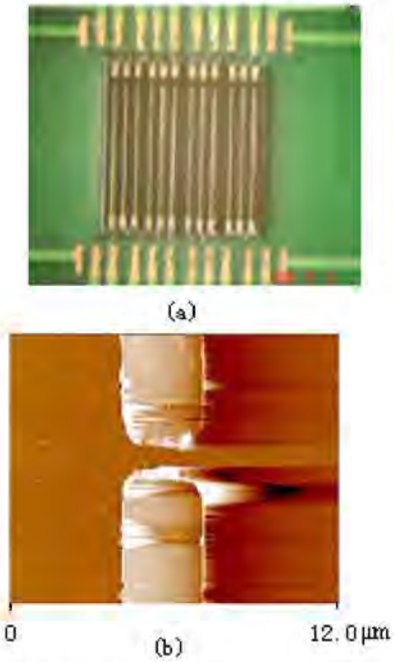

Fig. 3 Microelectrode (a) microelectrode group, (b) AFM image of single microelectrode

IV. MWCNT ASSEMBLY AND ELECTRIC CONTACT

AC DEP technology makes use of electric field force to actuate micro particles as shown in Fig. 4, it is widely used for coarsely actuating and separating batch of particles especially in biology research field.

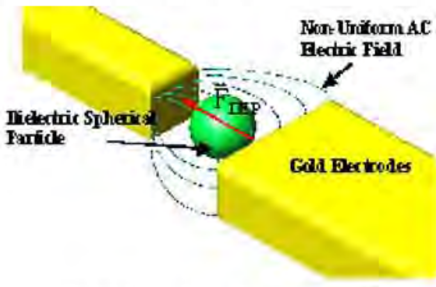

Fig. 4 AC dielectrophoresis principle

Here AC DEP technology will be used for actuating and coarsely positioning batch of MWCNTs to the microelectrode gap. Firstly MWCNTs with diameter 0.1~0.2μm are dispersed in ethanol and dropped near the gap of the microelectrode with the help of optical microscope, then AC signal is applied to the microelctrode with 6V ptp voltage and 5kHz frequency until the solution evaporates within several seconds, and several MWCNTs are actuated to the gap of the microelectrode as shown in Fig. 5.

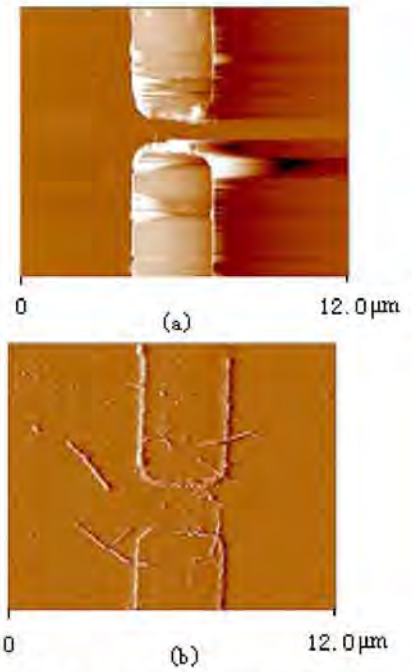

Fig. 5 Several CNTs absorbed near the gap of microelectrode using AC dieletrophoresis technology: (a) scan image before AC DEP, (b) scan image after AC DEP (note that the image is edge-sharpened, and ball-like particles are carbon particles)

After that, by means of the AFM based nanomanipulation system with the assistance of force and visual feedback, the selected MWCNT is accurately pushed and assembled to the gap as shown in Fig. 6, and several pushing operations are continued without stop in the assembly process.

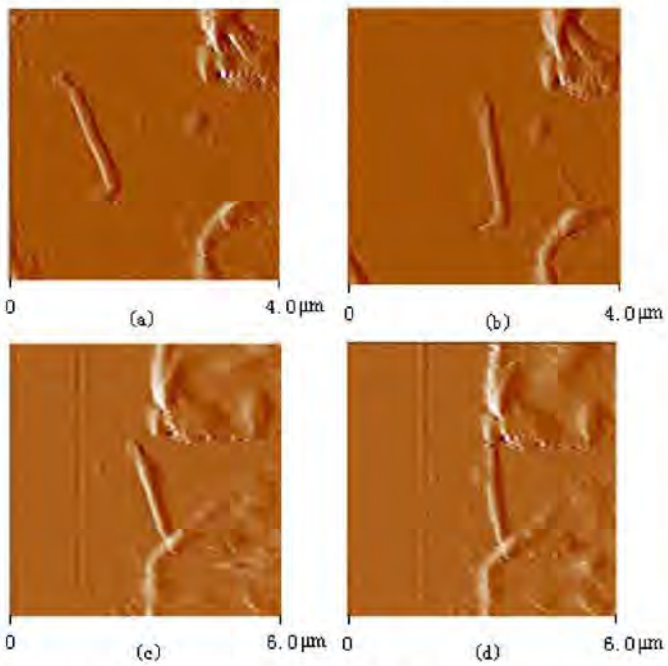

Fig. 6 MWCNT assembled at the gap of microelectrode using robotic nanomanipulation technology: (a) MWCNT deposited near microelectrode by AC DEP technology, (b) scan result after several pushing, (c) one end of MWCNT contacts microelectrode, (d) the other end contacts microelectrode (note that additional MWCNTs are pushed outside the operation area)

Several similar experiments are also done to verify the reliability and effectiveness of the two methods' integration as shown in Fig. 7.

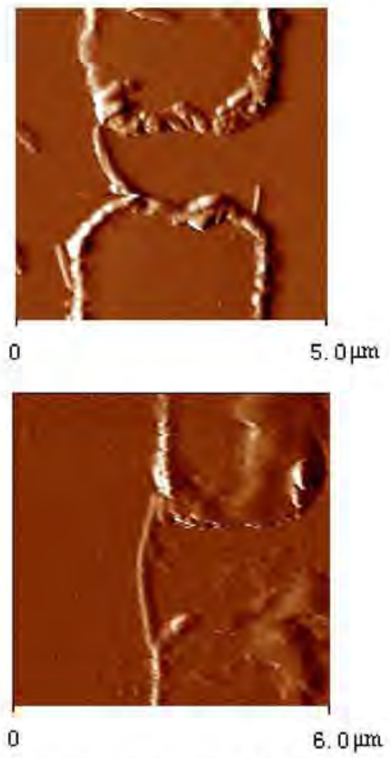

Fig. 7 MWCNT accurately assembled at the gap of microelectrode

To verify whether the electrical contact is built or not, the I/V electric property of the MWCNT is measured before and after assembly by means of semi-conduct parameter analyzer (Agilent 4155C). As to the MWCNT shown in Fig. 6, the measured I/V property is shown in Fig .8

In Fig. 8(a), before assembly the measured current is about -4pA~4pA, and it is obviously caused by signal interrupt. After assembly the current flowing through the MWCNT reaches 650nA when the voltage applied on the microelectrode reaches 5V, obviously the electric contact is built up.

In addition, under the assistance of the AFM based nanomanipulation system, the assembled MWCNT can also be pushed off the microelectrode and other MWCNT can be pushed to the micro electrode, thus the micro electrode can be used to measure the electric property of different MWCNT and thus used to select the suitable MWCNT.

V. CONCLUSION

For realizing CNT's accurate assembly and electric contact in the fabrication of CNT based nanoelectric device, first AC dieletrophoresis (DEP) method is used to coarsely position batch of CNTs near the microelectrode, then AFM based robotic nanomanipulation method is used to precisely position, assembly and make electric contact of the selected

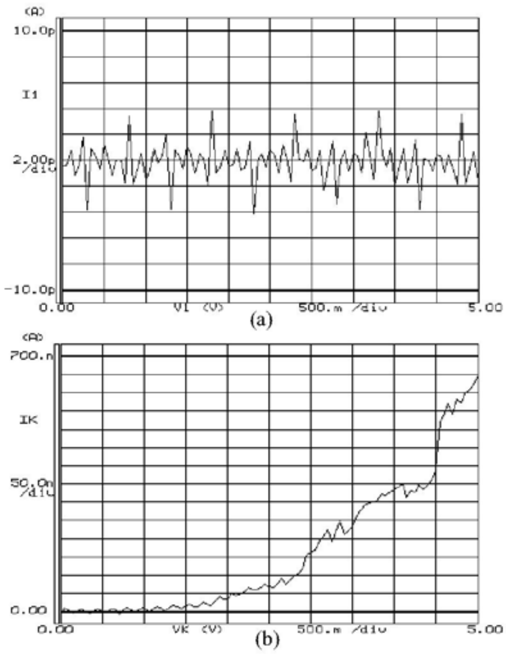

Fig. 8 I/V electrical property of the MWCNT shown in Fig. 6. (a) before assembly and (b) after assembly

CNT. MWCNT assembly and electric properties measurement experiments verify the effectiveness of these two kinds of technology's integration, and it provides an effective strategy for assembling and fabricating nanoelectronic devices based on various nanotubes, nanowires etc.

ACKNOWLEDGMENT

We acknowledge the help from Institute of Metal Research, CAS, China. And we also acknowledge the fund from the Shun Hing Institute of Advanced Engineering, The Chinese University of Hong Kong, HKSAR, China.

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