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DOI: 10.1017/S1431927606069510

Microsc Microanal 12(Supp 2), 2006

In-situ Fabrication, Manipulation and Property Measurements of Single Nanotubes and Nanowires with Near Atomic Resolution

L.-M. Peng[1,2], Q. Chen[1], J.Y. Wang[1], M.S. Wang[1], Z.Y. Zhang[2], C.H. Jin[2] and X.L. Wei[1]

[1]Key Laboratory for the Physics and Chemistry of Nanodevices and Department of Electronics, Peking University, Beijing 100871, China
[2]Beijing Laboratory of Electron Microscopy, Institute of Physics, Chinese Academy of Sciences, P.O. Box 603, Beijing 100080, China

Carbon nanotube (CNT) and nanowire materials are important building materials for nanotechnology. These materials may be synthesized via a range of physical and chemical methods, and new nanotube and nanowire materials are produced every day. Measurements on individual nanostructures remain, however, difficult and it is even more challenging to control the property of these nanomaterials via structure modification at near atomic resolution. A very promising and perhaps the best method to tackle this problem is to combine the scanning tunnelling microscope (STM) with electron microscope (EM) so that manipulation and structure modification may be made via a highly controllable fashion on individual nanostructure [1-3].

CNT can be cut, manipulated and used to form complicated patterns such as PKU as shown in Fig. 1. This operation requires a correlated manipulation of the CNT by two independent nanomanipulators [1], and in principle complicated CNT circuit may be constructed this way and its electric characteristics may be measured at each step of the pattern construction. While it is very convenient to carry out manipulation and measurement on nanostructure in a scanning electron microscope (SEM) either on or above a substrate, the resolution of the SEM is limited and the vacuum level is typically not as good as in a transmission electron microscope (TEM). The higher resolution and vacuum level in a TEM has been utilized for revealing the importance of the CNT tip structure on its electron field emission characteristics [4] and effects of deformation on the conductance of the CNT [5]. Figure 2 shows a typical bending experiment on a multi-walled CNT (~40nm in diameter) and the corresponding current passing through the CNT while it was under deformation. Experiments of this type show clearly that the conductance of the large diameter multi-walled CNT is not easily affected by deformation etc. and these CNTs may in principle be used in the fabrication of novel nanoelectronic circuit as interconnects [5].

A quantitative analysis of the electric transport property of the semiconducting nanowire also requires the detailed structure of the contact and nanowire. Two terminal I-V characteritics may be measured inside TEM as shown in Fig. 3, and the diameter, length etc. of the nanowire may readily be obtained from TEM imaging and varied during experiments providing valuable input for the quantitative analysis of the transport property of the nanowires[6].

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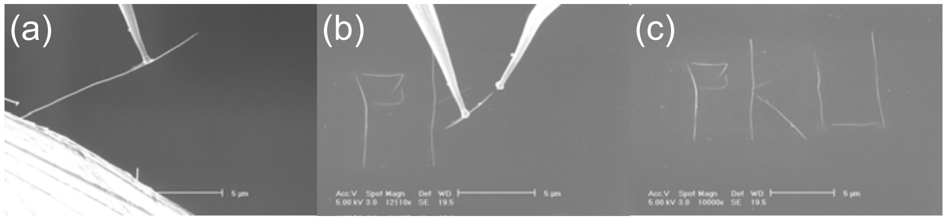

Fig 1. SEM images showing the process of writing the letter of PKU (Peking University) with carbon nanotubes.

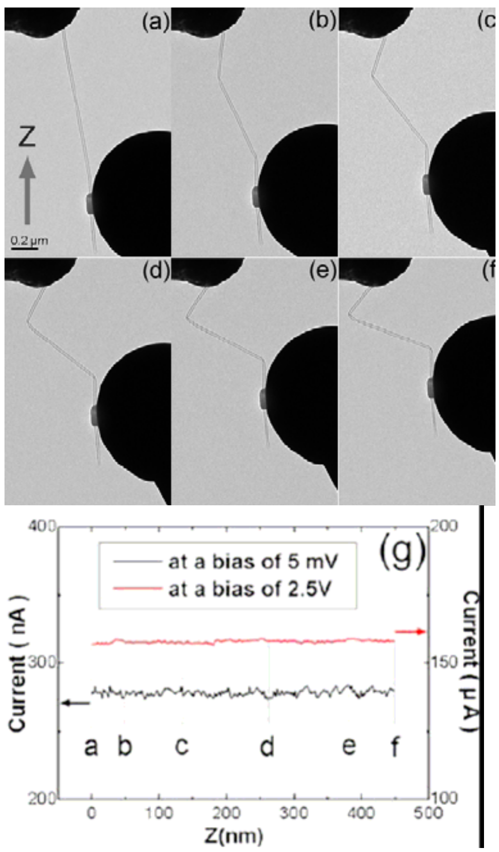

Fig. 2. Electronic conductance for a bending carbon nanotube.Letters a-f in (g) correspond respectively to (a-f).

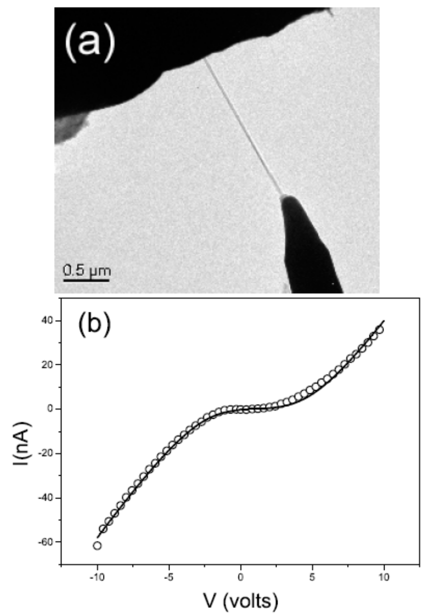

Fig. 3. (a) TEM image showing a typical Metal-Semiconductor (ZnO)-Metal structure and (b) a typical almost symmetric I-V curves. The circles are experiment and solid line is fitted theoretical curve.

https://doi.org/10.1017/S1431927606069510 Published online by Cambridge University Press