DOI: 10.1017/S1431927605500497
Microsc Microanal 11(Suppl 2), 2005

Structural Characterization of Carbon Nanotube Arrays Formed in Ultra-Long Nanochannels of Porous Alumina Templates

J. Y. Miao, Y. Cai, Y. F. Chan and N. Wang

Physics Department and the Institute of Nano Science and Technology, the Hong Kong University of Science and Technology, Hong Kong, China

The importance of carbon nanotube (CNT) alignment and size distribution in various potential applications has propelled extensive research on the syntheses of CNT arrays via different techniques. Anodic aluminum oxide (AAO) films are ideal templates for the synthesis of highly-ordered nanostructures because they are thermally and chemically stable, with pore size (hence the diameter of the nanostructures formed in the pores) that can be fully controlled [1]. The growth of CNTs based on AAO templates generally requires a tedious preparation process for metallic catalysts. Therefore, metal catalysts always cause contamination to the CNTs. In our previous papers, we demonstrated novel methods for preparing CNT arrays in AAO [2] and zeolite [3] templates without using any catalysts at low temperatures. Here, we show our current approach to the synthesis of uniform CNT arrays in the nanochannels of AAO templates (up to 100μm in length and 20nm in diameter with or without closed ends) by thermal pyrolysis of polyethylene glycol (Fig.1). Since no catalyst is needed, the resultant CNTs are highly pure. The structures of CNT arrays have been studied by high-resolution transmission electron microscopy (HRTEM).

The CNT sample was carefully prepared by chemically etching away the AAO template in order to maintain the original morphology of CNTs without introducing artifacts. This enabled us to examine an individual CNT (about 100μm long) from its one end to the other end. The CNT arrays have extremely uniform tube wall along the entire length of the CNTs up to 100μm long and 20nm in diameter. It was found that all the open ends of the CNTs joined each other (Fig.2), indicating that a thin carbon film formed on the top surface of the AAO template. The thickness of the thin carbon film equals that of the CNT walls. We have systematically investigated the interface structure between the CNTs and the AAO template by cross-sectioning the CNTs/AAO film. We observed that the CNTs simply replicated the nanochannel shapes even the channels had a complicated morphology, such as “Y” shape nanochannels made in the AAO template (Fig.2 (d) and (e)).

Based on our HRTEM investigation, the formation of CNT arrays is proposed to consist of two steps, in which the molecules of polyethylene glycol were first uniformly deposited on the inner walls of the nanochannels due to their special affinity to the AAO surface. CNTs with uniform tube wall thickness were subsequently molded during the pyrolysis process. In the present approach, the absence of metal catalysts and the uniformity of the fabricated CNTs constitute major advantages in comparison to other CNT fabrication methods involving the AAO templates. These highly aligned CNT arrays have been found to be excellent nanosensors to some toxic gases.

References

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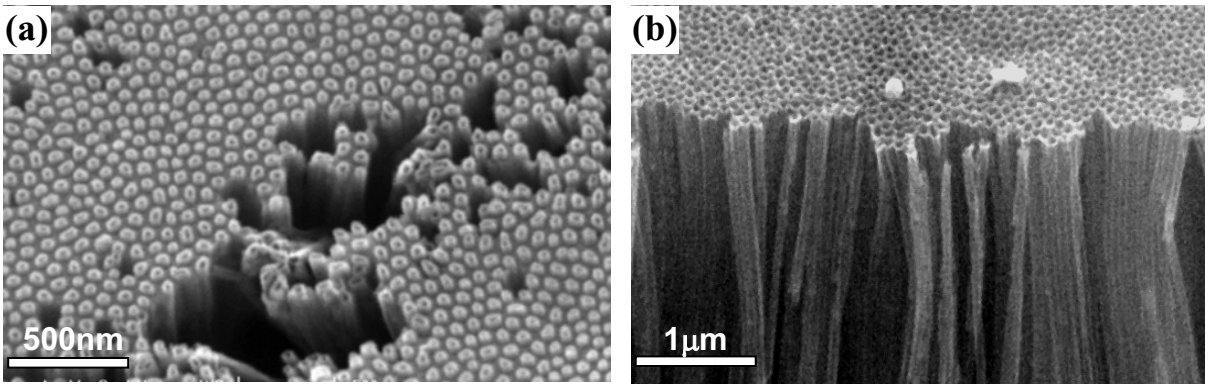

Fig. 1 CNT arrays fabricated by (a) microwave chemical vapor deposition and (b) thermal pyrolysis of polyethylene glycoextracted in AAO templates.

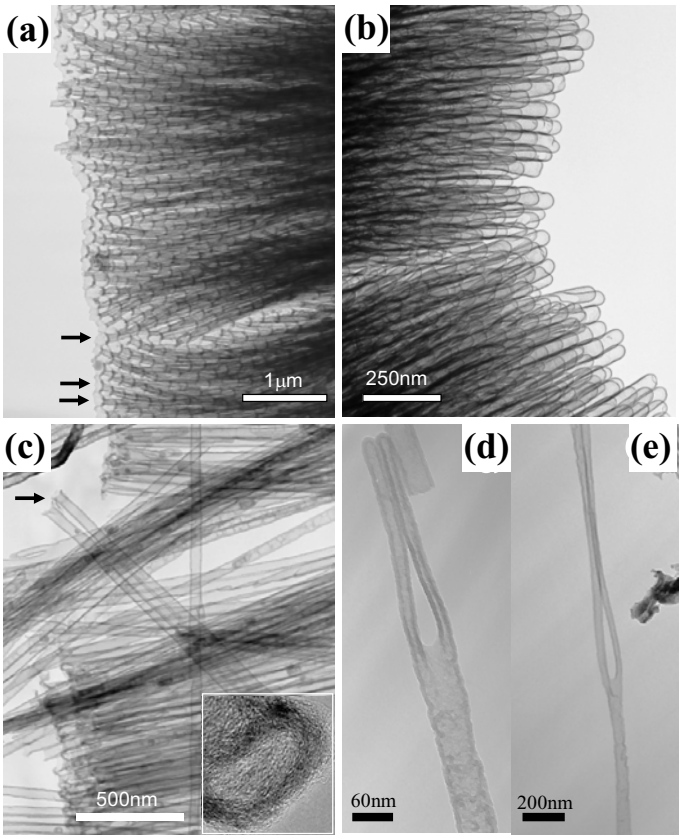

Fig. 2 (a) TEM image showing the open ends (as marked by the arrows) on one side of the CNT arrays. (b) The other side of the CNT arrays consisted of closed ends. (c) CNTs dispersed on a carbon supporting film and the HRTEM picture (inset) of an individual CNT. (d) and (e) Typical "Y" shaped CNTs.

https://doi.org/10.1017/S1431927605500497 Published online by Cambridge University Press