ADVANCED MATERIALS

Supporting Information

for

Advanced Materials, adma.200600885

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A New Technique for Controllably Producing Branched or Encapsulating Nanostructures in a Vapor–Liquid–Solid Process

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1. Supplementary Figure

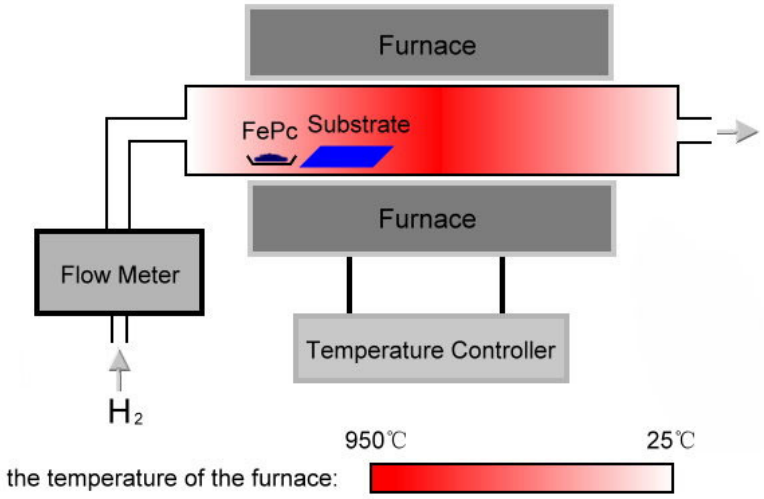

Figure S1. The experimental setup.

2. Detailed Description of Flow Fluctuation

When the flux is steady and small without fluctuations, a vertical array of carbon nanotubes (CNTs) without branch junctions can be synthesized;[1–3] if the flux is much higher, the products are well-aligned CNT arrays oriented along the gas flow.[4,5] However, only when we introduce sequential flow fluctuation to the growth can branched[1] or iron-encapsulating CNTs (Fig. 1) be synthesized. Therefore the flow fluctuation plays a pivotal role in the branching or encapsulating process.

In a steady flow with small flux, the flow field is a stable laminar flow, in which only a tiny, oriented and steady force acts on the CNTs, so CNTs usually grow vertically on the substrate.[1–3] In a steady flow with much larger flux, a large, uniform and oriented force causes the CNTs to orient along the flow while growing. However, if we cause the gas flow to fluctuate by randomly turning the flow meter up and down, the stable laminar flow will break down and the flow will become disordered, randomly unsteady and apparently impossible to analyze exactly. This unsteady flow

can transmit randomly fluctuating pressures, variable viscidity movements and velocity gradients to the surface of CNTs and catalyst particles, applying large disordered forces on them, causing random vibration of the CNT array and catalyst particles. This unsteady flow-induced vibration of tube arrays has already been reported.[6] Moreover, this unsteady flow can trigger vortex shedding or oscillating flow,[7] which are two other important causes of flow-induced vibration. This disordered vibration and movement can provide CNTs and catalyst particles with large driving forces to break down the relatively stable state. Therefore, flow fluctuation can cause the formation of new nanostructures in the VLS process that are not present in the steady state.

References

[1] D. C. Wei, Y. Q. Liu, L. C. Cao, L. Fu, X.. L. Li, Y. Wang, G. Yu, D. B. Zhu, A new method to synthesize complicated multibranched carbon nanotubes with controlled architecture and composition. *Nano Lett.* **2006**, *6*, 186.

[2] S. Fan, M. G. Chapline, N. R. Franklin, T. W. Tombler, A. M. Cassell, H. J. Dai, Self-oriented regular arrays of carbon nanotubes and their field emission properties. *Science* **1999**, *283*, 512.

[3] W. Z. Li, S. S. Xie, L. X. Qian, B. H. Chang, B. S. Zou, W. Y. Zhou, R. A. Zhao, G. Wang, Large-scale synthesis of aligned carbon nanotubes. *Science* **1996**, *274*, 1701.

[4] H. Xin, A. T. Woolley, Directional orientation of carbon nanotubes on surfaces using a gas flow cell. *Nano Lett.* **2004**, *4*, 1481.

[5] S. Huang, X. Cai, C. Du, J. Liu, Oriented long single walled carbon nanotubes on substrates from floating catalysts. *J. Phys. Chem. B* **2003**, *107*, 13251.

[6] P. R. Owen, Buffeting excitation of boiler tube vibration. *J. Mech. Eng. Sci.* **1965**, *7*, 431.

[7] R. D. Blevins, *Flow-Induced Vibration*, Van Nostrand Reinhold, New York **1990**.