TAILORING THE DIAMETER, DENSITY AND NUMBER OF WALLS OF CARBON NANOTUBES THROUGH PREDEFINED CATALYST PARTICLES

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Owing to their excellent mechanical and electronic properties, carbon nanotubes (CNTs) are promising candidates for the integration into nanoelectromechanical systems such as nanorelays and actuators or transistors. Effective control of the CNT growth, orientation and positioning is still considered to be a mayor challenge within the scientific community. Progress has been made by using catalyst thin films prepared and patterned by lithography [1] or shadow masking [2]. Yet, such thin film techniques do not offer concurrent control of the catalyst size with a narrow size distribution and the areal density of the catalyst particles. Novel routes that allow for an independent control of both the diameter and the density of catalyst nanoparticles are beginning to emerge. These approaches demonstrate that the preparation of the catalyst material is a crucial step in carbon nanotube synthesis. A notable work is for example the use of block-copolymer micellar thin films [3]. An alternative and advantageous method is to prepare individual nanoparticles in the gas phase that then act as nucleation sites for CNTs [4]. Gas phase preparation techniques allow for the production of nanoparticles with a higher degree of purity as compared to processes where the preparation of catalyst particles requires a series of chemical procedures (see, e.g. [3]).
In this contribution, we show that gas phase prepared catalyst particles for CNT growth allow for independent and simultaneous control over the CNT diameter and the CNT density on substrates. While the size of the catalyst particles can be adjusted by varying the sputtering power, the gas pressure, and/or the gas mixture, their density is conveniently controlled by the deposition time. Thus the whole ranges from thick multi-wall to narrow single-wall CNTs and from individual CNTs to dense mats of CNTs become accessible. Figures 1 a-c show TEM micrographs of (oxidized) iron particles with different mean diameters of 3 nm, 10 nm, and 18 nm as deposited on TEM “witness” grids. The corresponding TEM micrographs of CNTs grown from these particles are shown in Figures 1 f-d. The mean outer CNT diameters have been found to be 4 nm, 9 nm, and 17 nm, respectively. This indicates that the diameter of the catalyst particles determines that of the resultant CNTs which is in agreement with other studies on single wall CNTs [5]. Further, an intimate correlation between the catalyst particle size and the number of walls in the obtained CNTs is observed. This confirms other studies [6] where a correlation between different catalyst film thicknesses and both the obtained diameter and number of walls of the CNT was shown; the authors had attributed this finding to changes in the catalyst particle size. The separate preparation of the catalyst particles and the use of TEM “witness” grids in our approach enables us to reveal a clear link between the catalyst size on the one side and the CNT diameter as well as the number of walls on the other side.

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Figures:

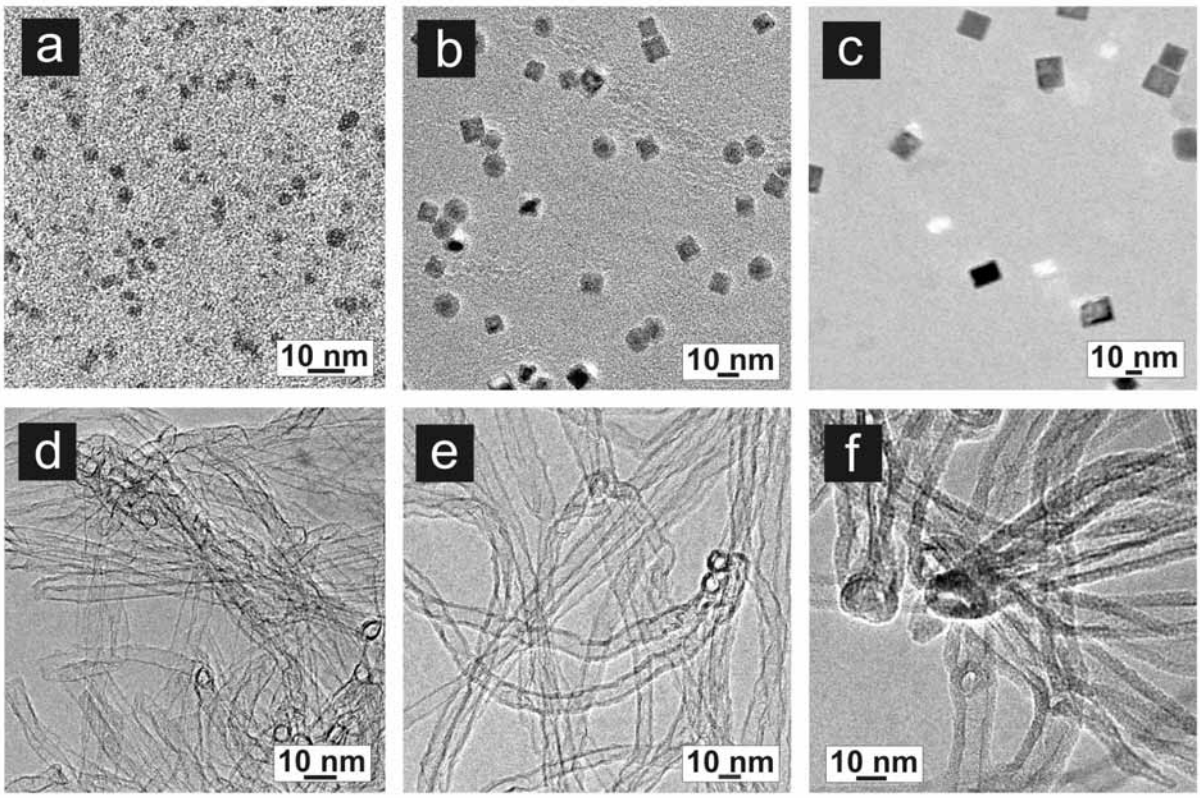

Figure 1: a-c) TEM micrographs of (oxidized) Fe nanoparticles deposited on TEM “witness” grids. d-f) Corresponding TEM micrographs of CNTs grown from these particles.