CARBON NANOTUBES GROWN FROM GAS PHASE PREPARED IRON CATALYST PARTICLES

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An innovative technique which successfully grows carbon nanotubes (CNT) by chemical vapor deposition (CVD) using cyclohexane will be introduced. The novelty of the technique lies in the separately generated catalytic nanoparticles which are synthesized via a gas aggregation technique of the type conceived by Haberland et al. [1]. The particles grow from a supersaturated metal vapor obtained by sputtering from an iron target at pressures of 1 mbar. After nucleation and subsequent growth of the particles within an aggregation volume, they are ejected into high vacuum (10^{-5} mbar) through a double aperture system. As a consequence and in contrast to other gas phase techniques [2], further agglomeration of the particles is suppressed (Fig. 1).

If deposited onto appropriate substrates (e.g. Si with a 10 nm Al_2O_3 layer), these particles can act as individual nucleation sites for the growth of CNT. While the size of the particles templates the diameter and defines the type of the resulting CNT, their spatial distribution controls their density. The use of separately generated particles provides the advantage to control and characterize their size, morphology, spatial distribution and mutual separation. In addition size fractionation of the particles via quadrupole mass filtering (for masses as high as $4*10^6$ amu) can be employed [3]. The spatial distribution is conveniently controlled by the deposition time.

Thus far, we show that this technique can successfully grow both single wall and multi wall CNT of high quality (Fig. 2-3). Further, the technique offers significant control over the catalyst particle size and hence the type and diameter of the resulting CNT.

References:

[1] H. Haberland et al., J. Vac. Sci. Technol. A **12** (1994) 2925.
[2] S. Stappert et al., J. Cryst. Growth **252** (2003) 440.
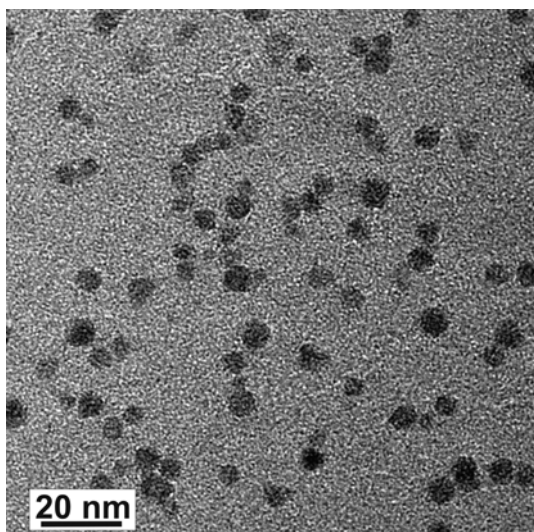[3] S. H. Baker et al., Rev. Sci. Inst. **68** (1997) 1853

Figures:

Fig. 1: TEM micrograph of the gas phase prepared catalyst nanoparticles
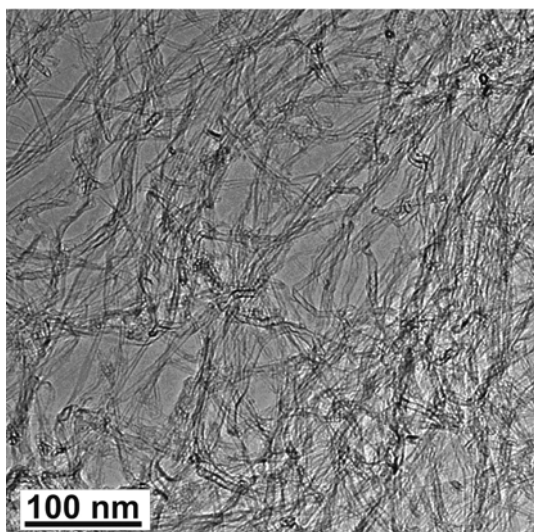

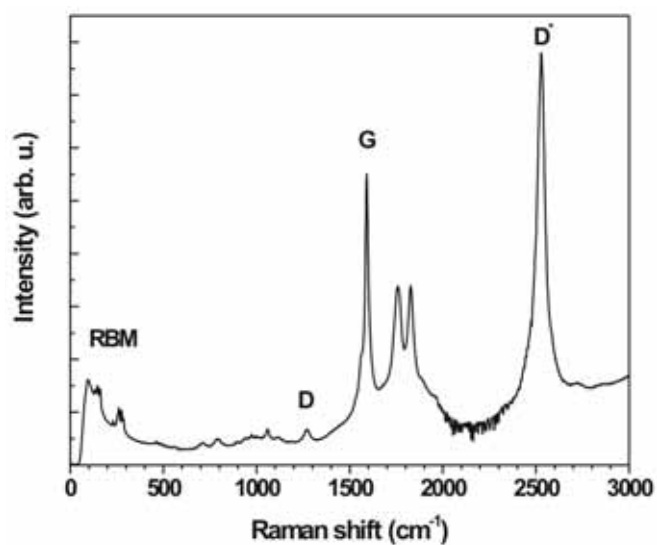**Fig. 2:** Large scale overview TEM micrograph of the as grown CNT network

Fig. 3: Fourier Raman spectrum (1064 nm) of high quality CNT.