CVD ROUTES TO CARBON NANOTUBE SYSTEMS WITH HIGHLY ANISOTROPIC NANOMAGNETS

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The preparation of nanoparticles in the gas phase through inert gas condensation is a very versatile method to fabricate catalyst particles that act as catalytic templates for carbon nanotube (CNT) synthesis since the method allows for easy control of the catalysts' elemental composition and their morphology. Chemical vapour deposition (CVD) as a synthesis route for CNT is by far the most popular synthesis mode to its potential for up-scaling. Various CVD systems exist and two of the more popular are thermal CVD [1,2] and plasma enhanced CVD [3,4].

In this contribution we report on the synthesis of carbon nanotubes via two distinct chemical vapour deposition routes, thermal and plasma enhanced chemical vapour deposition, using such gas phase prepared elemental Fe catalyst particles as well as binary FePt nanoparticles. The gas phase preparation of nanoparticles is very versatile when it comes to the preparation of predefined nanoparticles. The particle material is simply changed through variation of the sputtering target thus enabling to synthesize not only elemental particles, but also alloy particles such as the binary FePt particles shown in this contribution. This alloy, which has so far rarely been used for CNT synthesis, was applied to a thermally activated CVD process. Homogenous and clean CNT were grown. Further gas phase prepared elemental FePt particles were also applied to a plasma-enhanced CVD process. Here CNT with a bamboo-like structure and a conical particle at each tip were grown.

Although FePt is rarely used as a binary catalyst it is of great interest due to the special character of the chemically ordered $L1_0$ phase of FePt. The super structure reflex (001) of the FePt-$L1_0$ phase exhibits a very high magnetic anisotropy. This makes such FePt nanoparticles interesting in terms of their potential for storage media. The combination of such nano-magnets with carbon nanotubes also open up exciting possibilities. For example, the tailored growth of CNT with a hard magnetic particle at their tip is very promising for the realization of functional devices, for example magnetically actuated nanoelectronic systems. Hence, we conducted systematic studies on the synthesis of CNT via FePt catalysts using both thermal and plasma CVD routes to explore their potential in the controlled synthesis of carbon nanotube systems with highly anisotropic nanomagnets. The studies not only exploit the potential for CVD for the single step synthesis of CNT-nanomagnet systems but also open up the opportunity to gain deeper understanding of CNT growth mechanisms.This is important if CNT are to fulfil their promise in CNT based molecular electronics. While efforts are undertaken to reach this goal, optimised device architectures are still emerging and the basic understanding of the physics of CNT-FETs is steadily expanding. However, one of the key weaknesses is the lack of understanding of CNT growth, particularly via supported catalyst routes, which are anticipated to provide easier access for CNT based molecular electronics into current microelectronics systems.

Our systematic studies provide deeper insight into the growth mechanisms at play within thermal and plasma CVD and show new and interesting in roles of the catalyst particles. In thermal CVD we show the supported catalyst is key to nucleate the growth of CNT, however continued growth takes place from the oxide support [5]. In plasma CVD we show the so called "tip-growth" mode dominates and is suited to the formation of chemically ordered $L1_0$ phase of FePt.

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