Synthesis and Characterization of Carbon Based One-Dimensional Structures; Tuning Physical and Chemical Properties

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Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt försvar i MIT Huset MA121, Onsdag den 28 Januari, kl. 13:00. Avhandlingen kommer att försvaras på engelska.

Abstract
Carbon nanostructures have been extensively used in different application; ranging from electronic and optoelectronic devices to energy conversion. The interest stem from the fact that covalently bonded carbon atoms can form wide variety of structures with zero-, one- and two-dimensional configuration with different physical properties. For instance, while fullerene molecules (zero-dimensional carbon structures) realize semiconductor behavior, two-dimensional graphene shows metallic behavior with exceptional electron mobility. Moreover the possibility to even further tune these fascinating properties by means of doping, chemical modification and combining carbon based sub-classes into new hybrid structures make the carbon nanostructure even more interesting for practical application.

This thesis focuses on synthesizing SWCNT and different C_60 one-dimensional structures as well as tuning their properties by means of different chemical and structural modification. The purpose of the study is to have better understanding of the synthesis and modification techniques, which opens for better control over the properties of the product for desired applications.

Carbon nanotubes (CNTs) are grown by chemical vapor deposition (CVD) on iron/cobalt catalyst particles. The effect of catalyst particle size on the diameter of the grown CNTs is systematically studied and in the case of SWCNTs it is shown that the chirality distribution of the grown SWCNTs can be tuned by altering the catalyst particle composition. In further experiments, incorporation of the nitrogen atoms in SWCNTs structures is examined. A correlation between experimental characterization techniques and theoretical calculation enable for precise analysis of different types of nitrogen configuration in SWCNTs structure and in particular their effect on growth termination and electronic properties of SWCNTs.

C_60 one-dimensional structures are grown through a solution based method known as Liquid-liquid interfacial precipitation (LLIP). By controlling the crystal seed formation at the early stage of the growth the morphology and size of the grown C_60 one-dimensional structures where tuned from nanorods to large diameter rod and tubes. We further introduce a facile solution-based method to photo-polymerize the as-grown C_60 nanorods, and show that such a method crates a polymeric C_60 shell around the nanorods. The polymeric C_60 shell exhibits high stability against common hydrophobic C_60 solvents, which makes the photo-polymerized nanorods ideal for further solution-based processing. This is practically shown by decoration of both as grown and photo-polymerized nanorods by palladium nanoparticles and comparison between their electrochemical activities. The electrical properties of the C_60 nanorods are also examined by utilizing a field effect transistor geometry comprising different C_60 nanorods.

In the last part of the study a variant of CNT is synthesized in which large diameter, few-walled CNTs spontaneously transform to a collapsed ribbon shape structure, the so called collapsed carbon nanotube (CCNT). By inserting C_60 molecules into the duct edges of CCNT a new hybrid structure comprising C_60 molecules and CCNT is synthesized and characterized. A further C_60 insertion lead to reinflation of CCNTs, which eventually form few-walled CNT completely filled with C_60 molecules.

Keywords
Carbon Nanotube, single-walled carbon nanotube, nitrogen doped, chemical vapor deposition, fullerene, hybrid structures.