Different routes for synthesis of carbon nanotubes through T-CVD: A feasibility study

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Abstract

Carbon nanotubes (CNTs) are leading materials in several technological advancements. Due to improved technology and the increased scale of CNTs production at present their cost has dropped to a level where the application of CNTs could be economically viable in many areas. The large scale production and wide application of CNTs makes the selection of raw materials important. Among the factors which should be considered when selecting a carbon source are the yield and quality of the CNTs produced, the environmental impact and the overall safety of the process. Chemical Vapor Deposition (CVD) is considered by far the most attractive method for synthesis of CNTs, as it offers the capability to scale up and selectively control the process parameters, such as carbon source, catalyst type and reaction temperature. Two approaches of CVD process can be distinguished according to the way the catalyst is engineered: a) floating catalyst and b) fixed catalyst methods group. In the first case, the catalyst is introduced in the gas phase by evaporating the appropriate catalyst precursor, while in the latter the catalyst needs to be loaded to the substrate before placing it inside the reactor.

In this work, synthesis of CNTs was achieved by CVD and performed by the two aforementioned different approaches, as following:

- camphor and ferrocene as carbon source and catalyst (floating method), respectively, and,
- acetylene as carbon source and iron particles supported on Al_2O_3 substrate as catalyst (fixed method).

The morphology of the as-received carbonaceous materials was fully characterized by means of scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Their graphitic crystallographic structure was determined by X-ray powder diffraction (XRD), while their purity and thermal stability by thermogravimetric analysis (TGA). Specifically, for camphor/ferrocene system the results revealed that a vertically aligned (VA) multi-walled CNTs carpet with diameter distribution from 60 to 100 nm was grown on the silicon substrate with thickness in the range of 1-2 mm (Figure 1a), while CNTs were produced in bulk powder form with uniform diameter distribution between 20-40 nm using Fe/Al_2O_3-acetylene system (Figure 1b). Furthermore, high thermal stability in air atmosphere, high purity and uniform graphitized structure were evident in both cases. The effectiveness of these particular approaches is discussed outlining their scalability. In this context, CVD appears to be a versatile process with great potential, capable to produce CNTs in different forms (VA carpet, entangled) with different characteristics (e.g. diameter, length, density) being suitable for commercial uses.

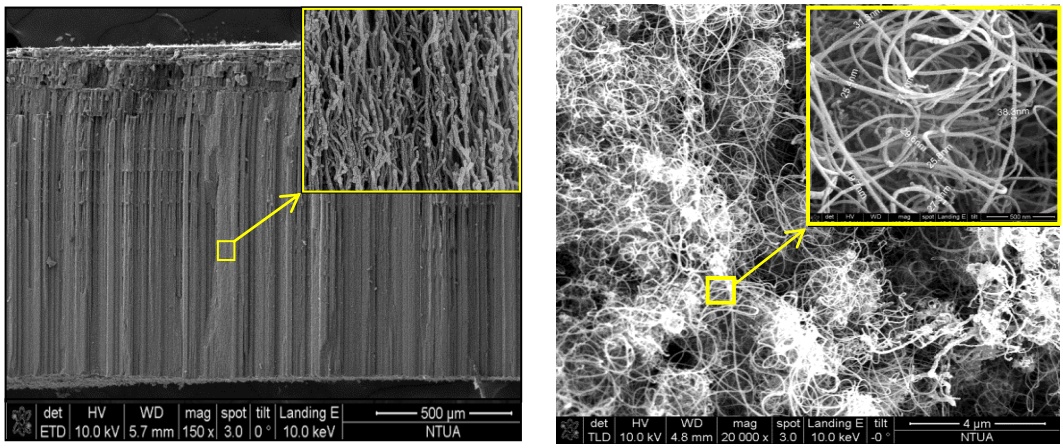

Figure 1. SEM images of CNTs produced from (a) camphor/ferrocene and (b) Fe/Al_2O_3-acetylene system.

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