Continuous synthesis of well-crystalline VACNTs using CVD method for engineering applications

Nur Anis Syafiqah, Amin Termeh Yousefi and Nahrizul Adib Kadri

Faculty of Engineering, Department of Biomedical Engineering, University Malaya, Kuala Lumpur, Malaysia

ABSTRACT
The extraordinary properties exhibited by carbon nanotubes (CNTs) make them one of the most active research studies among the researchers. In this paper, the optimum growth conditions for the synthesis of highly crystalline CNTs in order to improve their physical properties were presented. Chemical vapour deposition (CVD) was used to synthesise well-crystalline CNTs with uniform orientation using camphor oil as carbon source and argon gas as a carrier gas in the presence of ferrocene as a metal catalyst. The effects of four critical parameters, namely gas-flow rate, temperature, reaction time and the ratio of catalyst to carbon source on the crystallinity of CNTs, were investigated. The FESEM and TEM images, supported by the plot of Raman spectra emphasised the morphological improvement of the grown CNTs. It was found that crystalline CNTs can be synthesised using CVD method via restriction of the effective parameters.

1. Introduction
Many biomedical devices rely on nanomaterials, especially nanostructures. Nanostructures differ from bulk materials due to their small size and unique structure that exhibits extraordinary physical, chemical and electronic properties [1]. Carbon nanotubes (CNTs) are a type of carbon nanomaterials that have significantly different properties compared to other forms of carbon. Generally, the rolled graphene sheets are known as CNTs with capped ends, which could be single-walled carbon nanotube, double-walled carbon nanotube, or multi-walled carbon nanotubes (MWCNTs) [2]. Although techniques such as arc discharge [3] or laser ablation [4] have been traditionally employed to synthesise CNTs, currently low temperature techniques (<800 °C), such as chemical vapour deposition (CVD) [5], have been developed to produce CNTs which is touted as the most popular synthesising method of CNTs, due to possibility of synthesising CNTs in different length and diameter, uniform orientation, extra high purity and low costs [6]. The decomposition of carbon containing gas over supported catalyst is the basis of this method [7]. The synthesised nanotubes often consist of impurities such as amorphous carbon and metal nanoparticles and growing CNTs with low impurities and high crystallinity is still remains challenging in the synthesis of CNTs using CVD [8]. The amounts of impurities are directly effect on the electrical property of the synthesised CNTs especially when grown CNTs are synthesised by organic precursors.

2. Experimental
Synthesis of CNTs using CVD method is based on the horizontal electronic furnaces. The furnaces were equipped with a quartz tube. The tube with 35 mm outer diameter and 85 cm length acts as a reactor for the