# Comparative study of the growth of CNTs on stainless steel with and without the external catalyst

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Carbon nanotubes have been the subject of attention of a many researchers due to their superior performance in a wide range of applications. Electrodes for energy applications such as supercapacitor, fuel cells and batteries, water treatment, sensor technology and field emission probes are just a few examples [1-6].

Different synthesis methods have been proposed for carbon nanotubes amongst which, various types of chemical vapor deposition have attracted the utmost attention [7]. In this work, chemical vapor deposition was used to grow multi-walled carbon nanotubes on as-received 316 stainless steel by two different methods.

Firstly, a direct growth method based on catalytic decomposition of ethylene as the carbon precursor on the surface of stainless steel under controlled atmosphere was followed without application of any external catalyst. In this method, iron, as the main element of the stainless steel played the catalyst role. Fig. 1 shows the SEM micrograph of CNTs synthesized by the first method.

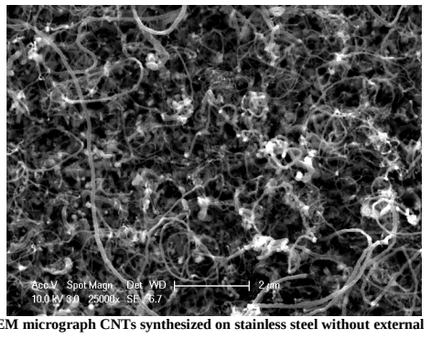


**Fig.1. SEM micrograph CNTs synthesized on stainless steel without external catalyst.**

Secondly, a toluene-ferrocene solution was used as the carbon-catalyst source, without presence of a carbonaceous gas. Ferrocene decomposition provided the iron nanoparticles as the catalyst and toluene evaporation prepared the carbon precursor which subsequently, by catalytic decomposition on iron nanoparticles, resulted in carbon nanotube growth. Fig. 2 shows the SEM micrograph of CNTs synthesized by the second method.

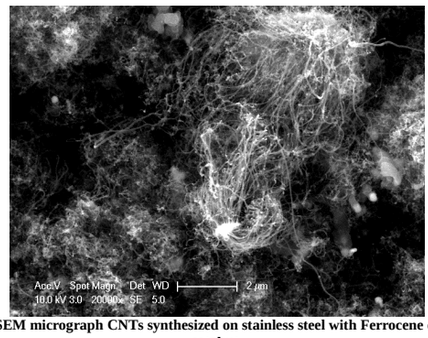


**Fig.2. SEM micrograph CNTs synthesized on stainless steel with Ferrocene external catalyst.**

In the first method, surface nano-features formed under the synthesis thermal and atmospheric conditions were recognized to be responsible for the morphological characteristics of the grown carbon nanotubes. In the second method, characteristics of the iron nanoparticles formed by the decomposition of ferrocene dictated the carbon nanostructures. However, even in this case, catalytic activity of the substrate material contributed in the carbon nanotube growth.

In both cases, carbon nanofibers formed a fraction of the products which were originating from the large surface nano-features or large external catalyst particles. Based on Scanning and transmission electron microscopy observations, both base and tip growth modes were found to be active in carbon nanotube synthesis.

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