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CNTs by CVD: Control of Diameters and Lenghts

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Carbon nanotubes (CNTs) were synthesized by chemical vapor deposition (CVD). The CVD system used for the synthesis of CNTs has two heating zones. The first one, at low temperature (~450 K), has the function of evaporating the precursor solution, that was injected by a carrier gas (Argon), to the second heating zone, at high temperature (870 K), where the reaction takes place. The solution was introduced into the first heating zone by a peristaltic pump.

The formation and characteristics of CNTs were studied modifying several parameters such as: flow rate, deposition time, heating zone temperature, type of substrate, concentration of ferrocene in the precursor solution. Web-like arrays and bundles arrays of ultralong CNTs [1] were obtained. The microstructural characterization was carried out by scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

The Fig. 1 shows SEM micrographs of the CNTs produced using a ferrocene-toluene solution on a Si substrate. It is observed the effect of synthesis time over the morphology and the diameter of the nanotubes. CNTs with diameters of 7.5 nm after 15 s of synthesis are presented in Fig. 1a. Fig. 1b to 1d the effect of synthesis time (30 s, 5 min and 60 min respectively), on geometrical characteristics of CNTs, is presented. However, it is observed that from 5 minutes of the solution deposition, bundles arrays are formed. Nanotubes with diameters of ~80 nm are obtained after 1 h of synthesis (Fig. 1d). For this time of synthesis (1h) we were able to produced CNTs with ~2 mm of lengths as it can be observed in Fig. 1e.

The growth of CNTs using a ferrocene-ethanol [2] and a ferrocene-toluene solution on different substrates was also studied. For these series of experiments it was observed that CNTs produced using ethanol are a promising way to the synthesis of SWCNTs. Their grown on Nickel and Inconel sheets are presented in Figure 2 (a,b). The growing of CNTs using toluene over the same substrates is also presented in Figure 2 (c,d).

From the results presented above is clearly observed that an effective way to produced ultralong carbon nanotubes is through the use of ferrocene-toluene as precursor. However the production of single wall nanotubes must be studied by the use of ethanol as precursor.

References

[1] Chien-Chao Chiu et al., *Surface & Coatings Technology*, 200 (2006) 3215-3219
[2] S. Chaisitsak et al., *Diamond and Related Materials*, 16 (2007) 1958-1966.
[3] Thanks to E. Torres-Moye and J. Lugo-Cuevas for their technical assistance.

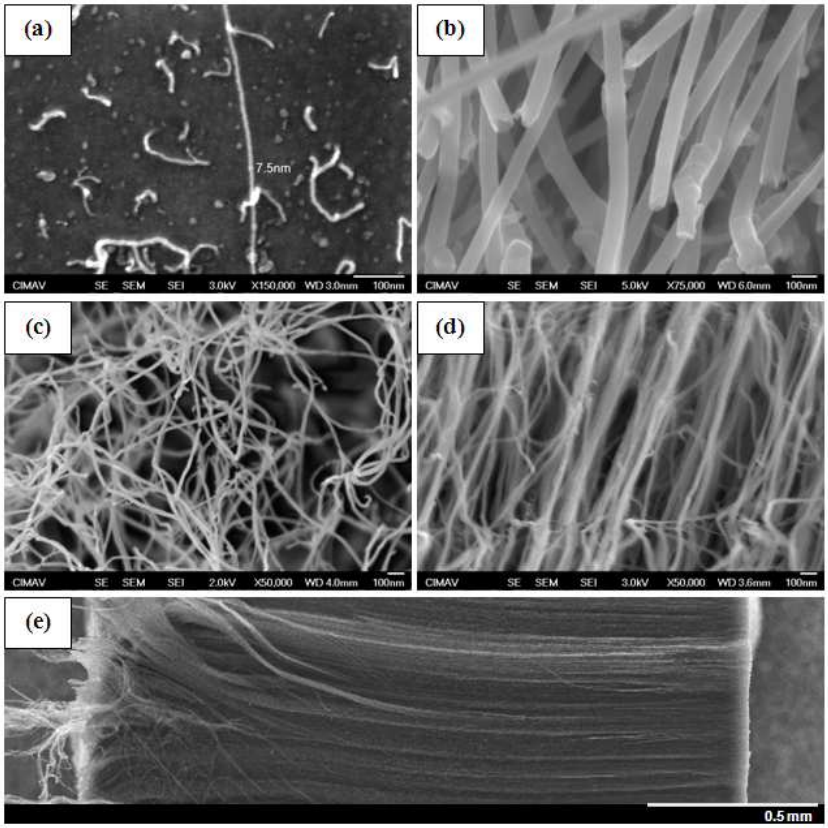

FIG. 1. SEM micrographs of CNTs growth with different time of synthesis (a) 15s, (b) 30 s, (c) 5 min and (d) 30 min. (e) Very long CNTs obtained by CVD.

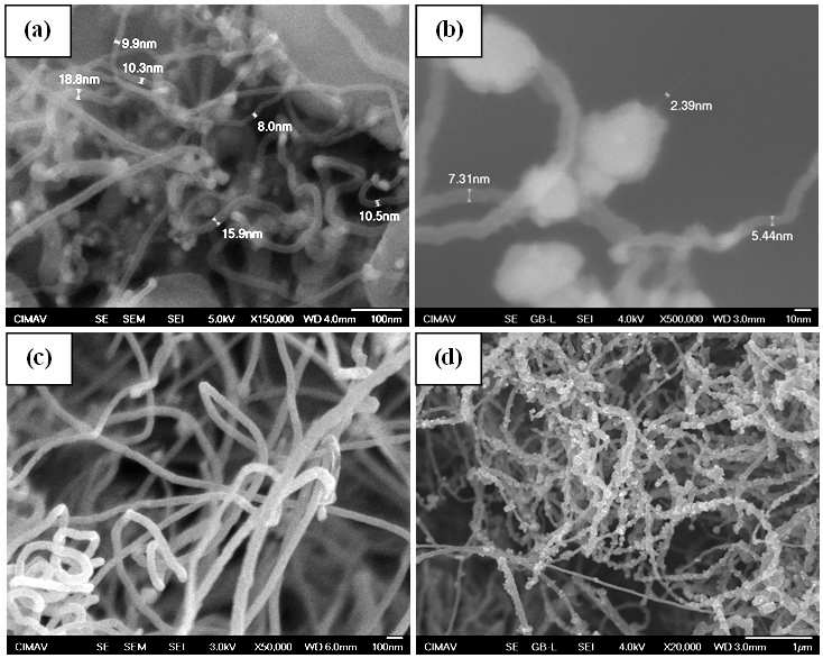

FIG. 1. Ferrocene-ethanol solution for the growth of CNTs on (a) Nickel and (b) Inconel. Ferrocene-toluene solution for the growth of CNTs on (c) Nickel and (b) Inconel.