

# Growth of vertically aligned carbon nanotubes on aluminium substrate through a one-step thermal CVD process

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The aim is to grow vertically aligned carbon nanotubes (VACNT) on aluminium by a single-step process, namely the thermal aerosol assisted CCVD, in order to get a scalable process to fabricate ultracapacitor electrodes. The one-step synthesis of VACNT on such substrates requires a significant reduction in the growth temperature as compared to conventional substrates [1-3]. According to previous work, our process is based on the adjunction of hydrogen in the gas phase to promote the decomposition of the catalyst precursor at low temperature [2], and of acetylene, easy to decompose at low temperature [4]. Our approach is first to identify the most relevant synthesis parameters to reach VACNT growth on aluminium substrates by subsequently analysing the product features. This optimization study enabled to obtain clean, long and dense VACNTs at 580°C or 620°C with a growth rate (ca. 5µm/min) at the best level of the state of the art. Attention is paid on the study of VACNT thickness variation versus synthesis duration showing a limitation of CNT length from a certain time of synthesis. In order to understand this phenomenon, the trend in CNT length is examined according to different models reported in the literature, which gives evidence of a catalyst deactivation phenomenon occurring during the one step-CVD process performed at low temperature due to the additional formation of disordered carbon. In addition, the CNT/Al interface was analysed, enabling to clearly identify catalytic particles located at the CNT base and on the surface of a well-defined oxide interface layer suggesting the availability of catalyst nanoparticles for VACNT growth.

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[2] C. Castro et al, *Carbon*, 2013, **61**, 585

[3] M. Delmas et al, *Nanotechnology*, 2012, **23**

[4] M. R. Arcila-Velez et al, *Nano Energy*, 2014, **8**, 9–16