Effective synthesis of carbon nanofibers at low temperature

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Carbon nanofibers (CNFs) have drawn lots of attention for their potential application as improvement materials for thermal, electrical, optical, frequency shielding, and mechanical properties [1]. They are currently being utilized in different composite formulations thanks to their exceptional properties and low cost. CNFs consist of grapheme layers rolled into cylindrical shape in which carbon atoms are arranged in a hexagonal way. Depending on the degree of coiling and the ordering of the layers, nanofibers of different diameter and different internal geometry are obtained [2].

In this work, CNFs have been synthesized by catalytic chemical vapor deposition (CVD) using alcohol as the source of carbon. Stainless steel plates measuring 50x20x1 mm were used as a catalyst support. Several Fe-, Co- and Ni-based catalyst films were deposited on the metal plates and implemented in a microreactor machined in stainless steel in two differentiated halves. Each reactor halve comprised a 0.5 mm-height rectangular cavity which constituted the flow channel. The catalytic plate was sandwiched between the two halves, except at one of the ends where a window communicated upper and lower flow channels; by these means, the reacting mixture flowed axially along both sides of the plate. The lower part of the reactor comprised distribution and preheating facilities. A gas chamber offered an enhancement of the residence time of the incoming feed to achieve the desired reaction temperature. Six equidistant bores (0.5 mm diameter) were implemented between the preheating chamber and the lower flow channel to assure a uniform distribution of the feed on the channel width. The microreactor was disposed inside an electrical furnace to reach the reaction temperature. A K-type thermocouple (±0.5 K) was placed in contact with the microreactor to control the furnace temperature. Alcohol mixtures were supplied both as vapor mixtures balanced with inert gas or directly with a liquid pump and passed through the reactor at different flow rates. CNFs were grown at atmospheric pressure in the temperature range 673-873 K for 6 hours.

We have studied the effect of catalyst, reaction temperature and alcohol load on the properties of the CNFs synthesized in order to establish a correspondence between these preparation parameters and the geometrical properties of the CNFs. Nanofiber diameters between 10 nm and 0.1 μm have been obtained by choosing the appropriate preparation parameters. Regarding nanofiber length, values between 0.2 and 3 μm have been attained. It is interesting to note that these values are rarely obtained at temperatures lower than 873 K. Figure 1 shows scanning electron microscopy (SEM) images of various CNFs prepared. Catalyst nanoparticles are located at the tip of the nanofibers, as expected from the CVD method. High resolution transmission electron microscopy (HRTEM) revealed that the CNFs synthesized in this work are cylindric nanostructures with graphene layers arranged as poorly-defined plates. Our method constitutes a simple way to prepare CNFs with geometric properties that are easy to tune. Also, the use of alcohol mixtures as a source of carbon at atmospheric pressure and low temperature allows an easy and safe implementation of the method for the preparation of CNFs at large scale.

All this study is performed inside a project named nAUTO (now in the second stage, named nAUTO^2) which purpose was to involve nanotechnology capabilities with the automotive needs.

Acknowledgements:

nAUTO: Centro Técnico SEAT, Plastal Spain S.A., ASCAMM, FICOSA, PEGUFORM and UPC

nAUTO2: Centro Técnico SEAT, LEITAT, FICOSA, PEGUFORM, RAVAGO, IQAP and UPC.

References

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Figures

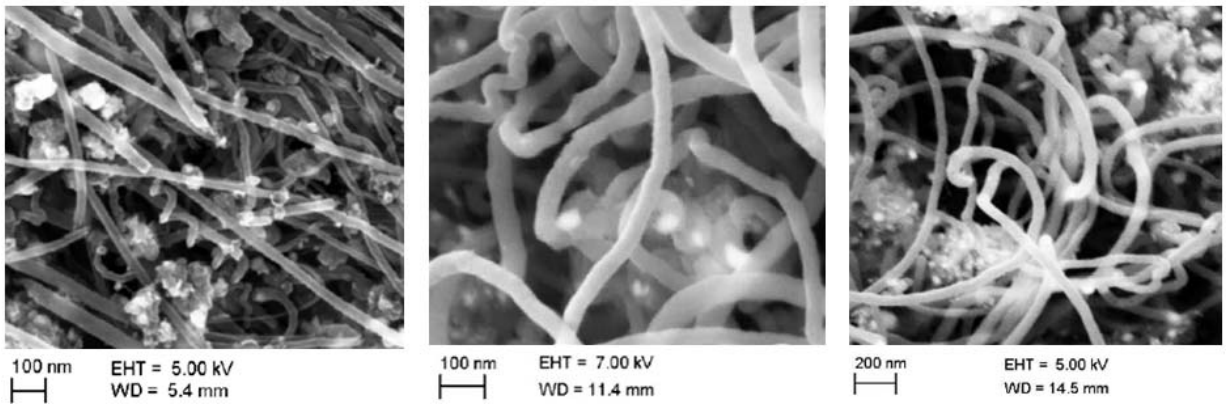

Fig. 1. SEM images of various carbon nanofibers prepared.