University of Dayton
Office of Technology Partnerships
937.229.3469

Growth of Carbon Nanotubes, Nanofibers and Whiskers on Fiber Surface, Film and Foam

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Inventor: Khalid Lafdi Ph.D., et al.

DETAILED DESCRIPTION OF THE INVENTION: METHOD FOR GROWING CARBON NANOTUBES, NANOFIBERS, AND WHISKERS ON FIBER SURFACE, FILM, FOAM, AND SURFACES FROM WHICH THE FIBERS CAN BE REMOVED.

Khalid Lafdi

OTHER KEY FACTS:

- **Material must be able to withstand temperatures from 600C to 900C**
- **What makes this new is that 1) it is a water based catalyst, 2) that the density of the nanotubes can be controlled by the flow or surface functionalization, and 3) the preparation of the surface the whiskers will be grown on.**

MATERIALS:

INTENT OF INVENTOR:

To fabricate high thermal conductive adhesive or conductive interface material for guided heat or tailored electrical conductivity.

PROBLEM TO OVERCOME:

Today, there are no thermal conductivity adhesives because of the limitations of increasing the density of the conductive skeleton in a given skeleton. The limitations correlate with the challenges of nanoartifact dispersion and alignment in nanocomposites technology.

BACKGROUND:

To overcome these challenges, a process for growing carbon nanotubes, nanofibers, and whiskers must allow the uniformity and controllability of carbon nanoartifacts to be made in a controlled fashion with selected surface conditions. Currently, carbon materials of different forms, carbon fibers and 2 D fabric, were used for growing carbon nanotubes on them. Uniformity and controllability is primarily achieved by the surface functionalization of the carbon substrates with (1) the proper gas oxidizer treatment and (2) water based catalytic process. Optimal growth and concentration of carbon nanotubes occurs by varying the catalysts and growth temperature, controlling the rate of diffusion of metals onto substrates during carbon growth, and eliminating the Ni, Fe, and Co compositions within the recipes of solutions for the catalysts.

APPLICATION:

Growing carbon nanotubes, nanofibers on fiber tow and fiber fabric has several applications. First, it could overcome all issues related to nanotube dispersion and diffusion during composite processing. Also, carbon nanotubes increase the interlaminar sheer and thermal resistivity of composites. In addition, because of the electrical and thermal conductivity and chemical stability of carbon, the carbon nanotubes could be used on materials in lightening strikes and EMI shielding applications, and thermal management. Lastly, carbon nanotubes could be useful in the biomedical field. By growing carbon nanotubes on a prosthetic device made of a metal, the body's reaction to device will be less adverse because of the body's compatibility with the carbon surface of the prosthetic device. Two possible concerns for the process are: (1) whether high performance can be maintained after scaling up process and (2) whether impurities can be sufficiently removed with the process.

METHOD FOR GROWING CARBON NANOTUBES, NANOFIBERS, AND WHISKERS ON FIBER SURFACE, FILM, AND FOAM:

1. Surface conditioning

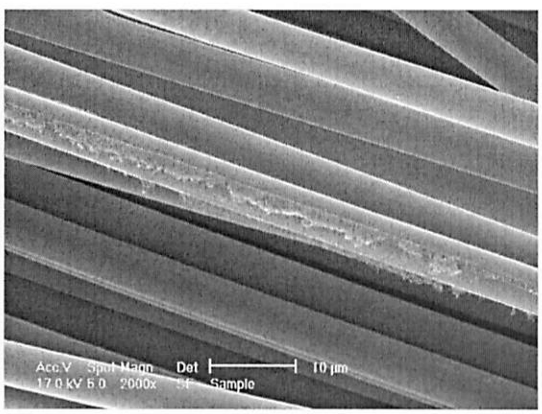
Introducing a gas oxidizer into a container of carbon materials at specific temperature and pressure for time between 5 to 30 minutes causes the surface functionalization of these carbon materials. Then, the carbon materials are immersed in water or alcohol solutions (both which contain soluble salts of nickel, iron and cobalt) for a very short time, and dried by air at room temperature or heated. As soon as the carbon materials dry, the subjects of catalysts spreads to the surface of material and becomes very conducive and fertile for growing carbon nanotubes.

2. Growth of Carbon Nanotubes

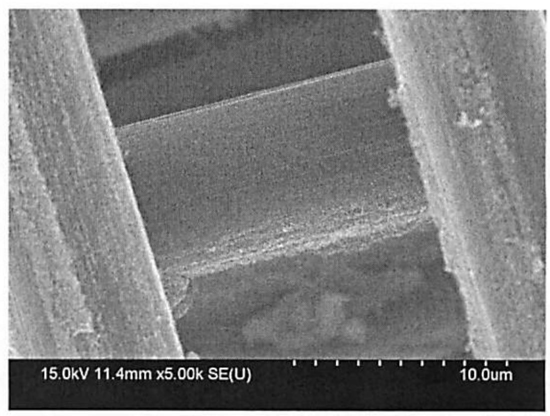
After conditioning the surface, the carbon materials are put into furnace (temperature range between 600 °C and 900 °C). The chemical vapor deposition through the use of various gas phase carbon sources (typically hydrocarbon gases including acetylene and ethylene) causes growth of carbon nanotubes. The growth is controlled for the time ranging from 3 min to 15 min.

ANALYSIS:

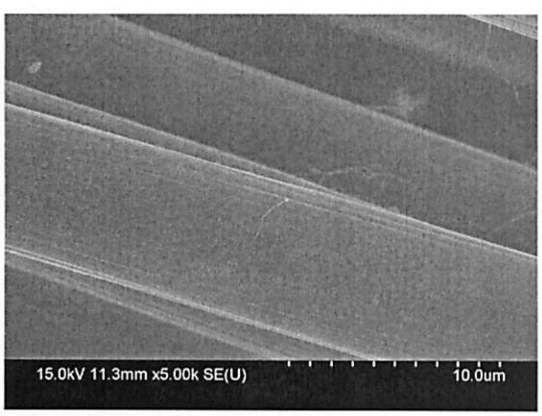
The most critical feature for growth of carbon nanotubes on carbon was the surface functionalization of the carbon substrates. Without the proper gas oxidizer treatment, carbon nanotubes were found unable to grow on most of the surface area of the carbon fibers, even though they could be found at some local areas. Figures 1a to 1d show SEM images of the carbon fibers after growth at 800 C and 900 C.



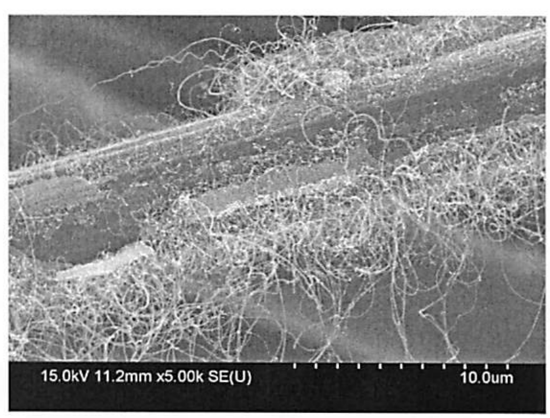
a)



b)



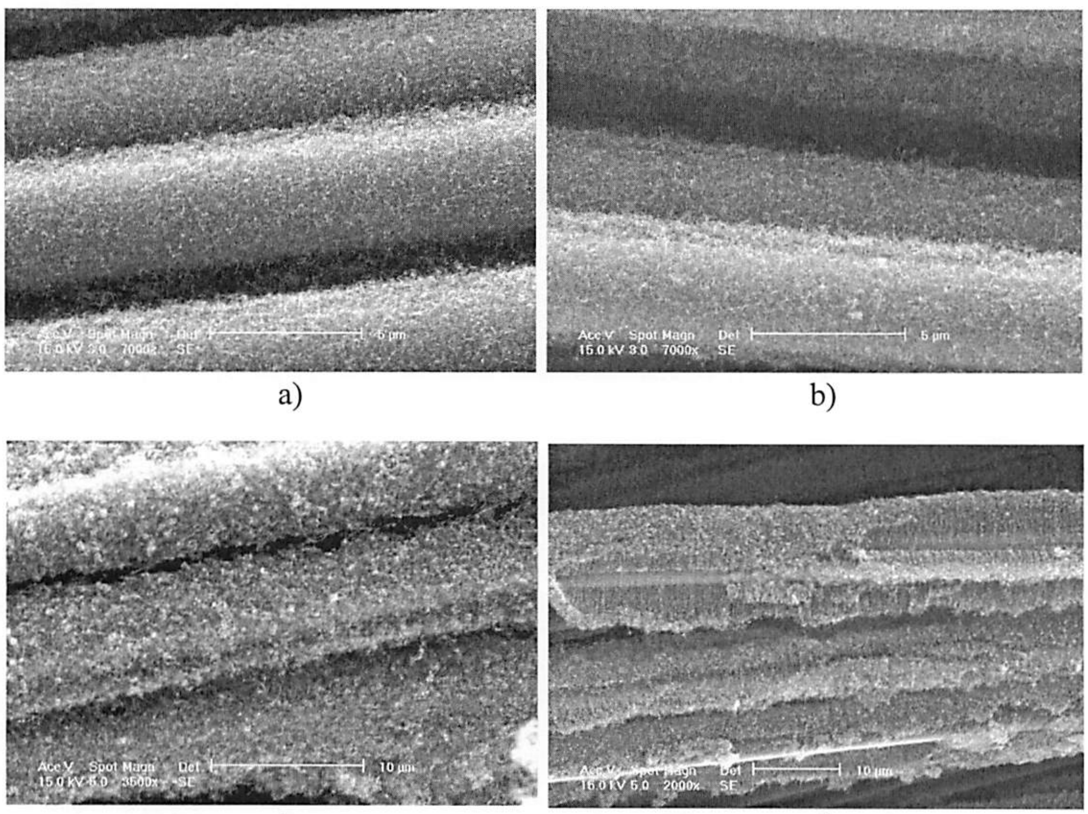
c)



d)

Figure 1: Unmodified carbon fibers after growth of carbon nanotubes at 800 °C (a and b) and 900 °C (c and d).

In contrast, under the same growth conditions (gas type, gas flow, temperature, and growth time) much more carbon nanotubes grew uniformly on the carbon fibers that were surface treated with gas phase process. Figures 2a to 2d show the corresponding SEM images of the carbon fibers after their carbon nanotube growth.



a) b) c) d)

Figure 2. Surface functionalized carbon fibers after growth of carbon nanotubes at 800 °C (a and b) and 900 °C (c and d).

As can be seen from figure 2d, thick and aligned structures on the carbon nanotubes are even observed at some locations of the carbon fibers. The results of XPS and IGC analysis showed a substantial increase in surface concentration of oxygen and change of surface energy after the surface treatment. Consequently, applying the catalysts on the surfaces of carbon is desirable.

Limitations on Carbon

Because carbon nanotube growth is a substrate-related process, metals (Ni, Fe and Co) could also diffuse onto substrate and coalesce into larger particles. Accordingly, diffusion that is too fast may lead to form large metal particles and reduce catalytic particle density and activity for carbon nanotube growth.

Another problem associated with carbon nanotube growth on carbon is the easy diffuse of catalysts into carbon substrate. To overcome these problems, it was essentially imperative that the recipes of solutions for the catalysts were developed with the absence of Ni, Fe, and Co compositions. Even if keeping the same concentration of the catalytic metals, carbon nanotubes may not grow at all or uniformly on the functionalized carbon in the absence of other solution components.

Additionally, the surface shape of the carbon substrates, i.e., if the carbon surface is convex, flat or concave, impacted the carbon nanotube growth on carbon. Growth on convex surfaces, carbon fibers, 2D carbon fabric, and graphite wool, appeared to be similar. Although alignment could be seen at local areas, the formation of entangled carbon nanotubes appeared on most of the surface area of the carbon substrates. Lastly, thickness of the aligned carbon nanotubes could be tailored from 20 nm to 20 micrometers, which have not yet been seen in any open publication and report on carbon nanotube growth on carbon.