Carbon Nanotube-based Supercapacitor

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Abstract

Carbon nanotube supercapacitors are an object of ongoing study. Once perfected, they have the potential to revolutionize electrical energy storage. Production of carbon nanotubes (CNTs) for experimentation has generally required the use of expensive and complex equipment, which has proven to be an obstacle to direct study of CNTs. This research is an attempt to define a simple, economical method of CNT synthesis that produces CNTs of a quality viable for experimental observation. Every attempt was made to utilize materials and equipment commonly available to a material science laboratory.

Background

CNT supercapacitors offer the ability to store and release electrical energy faster than conventional storage devices. They are based on the principle that the surface area of a capacitor is directly proportional to its capacitance. The existence of a CNT "forest", or a mass of vertically aligned CNTs, on each electrode of a double-layer capacitor will increase surface area and thus increase capacitance dramatically.

Methods

In order to promote the growth of carbon nanotubes, several SiO_2 samples were prepared by submersing the samples in a $FeCl_3$/Acetone solution. This would deposit a thin film of $FeCl_3$ on the surface of the sample. The samples were placed in tube furnace (Fig. 1) at varying temperatures and gas flow rates. Nanotube growth occurred when the furnace achieved 900˚C for 10 minutes with Hydrogen and Methane Gases flowing over the samples. The samples were removed from the furnace once room temperature was achieved. SEM was employed to visually verify the growth of both Fe particles and nanotubes. AFM was used to test whether the nanotubes grown were single-walled or multi-walled by measuring the thickness of the carbon nanotubes.

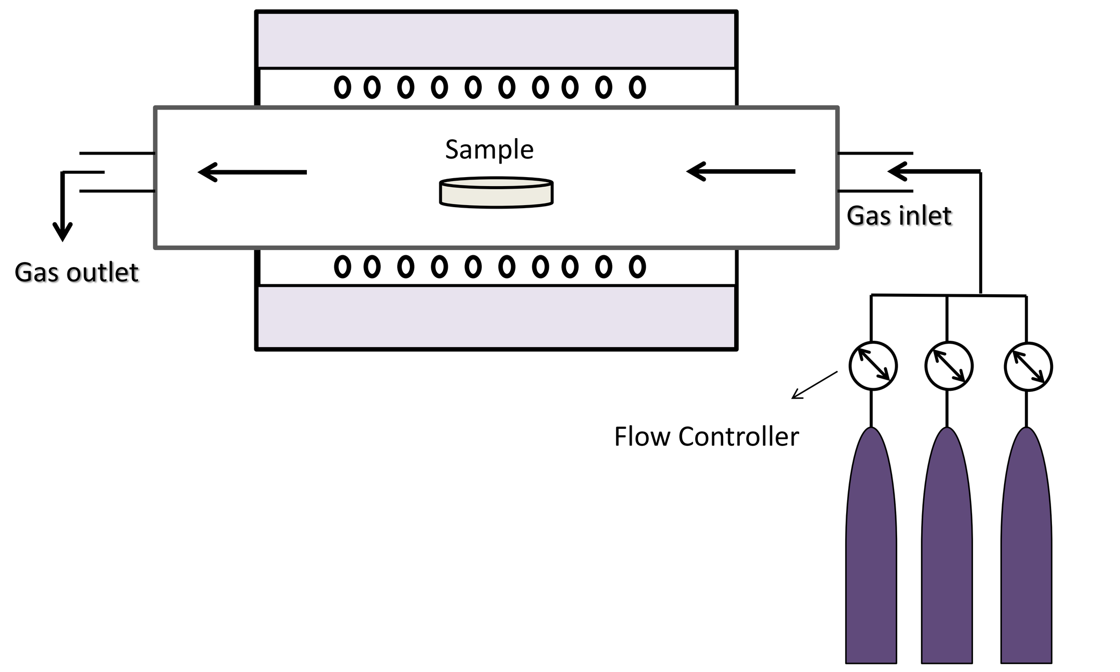

Figure 1. Schematic of the tube furnace showing the gas cylinders and sample of the SiO2 wafer.

SEM Analysis

As shown in Figure 2, Fe particle growth on the samples showed promising bonding sites for the growth of carbon nanotubes. The average size of particles was about 40 nm. In Figure 3, growth of horizontally-aligned carbon nanotubes was successful. Carbon nanotubes formed at varying lengths, with lengths reaching 15 microns.

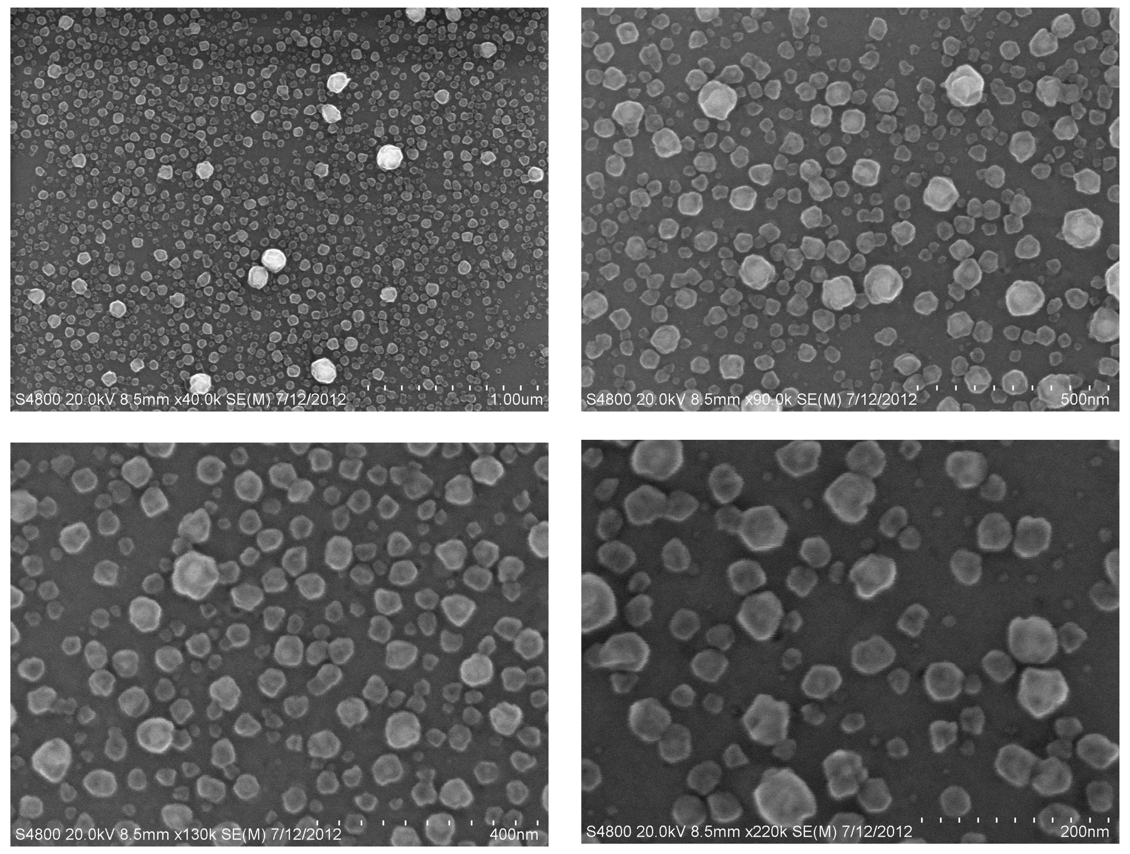

Figure 2. SEM images of Fe particles.

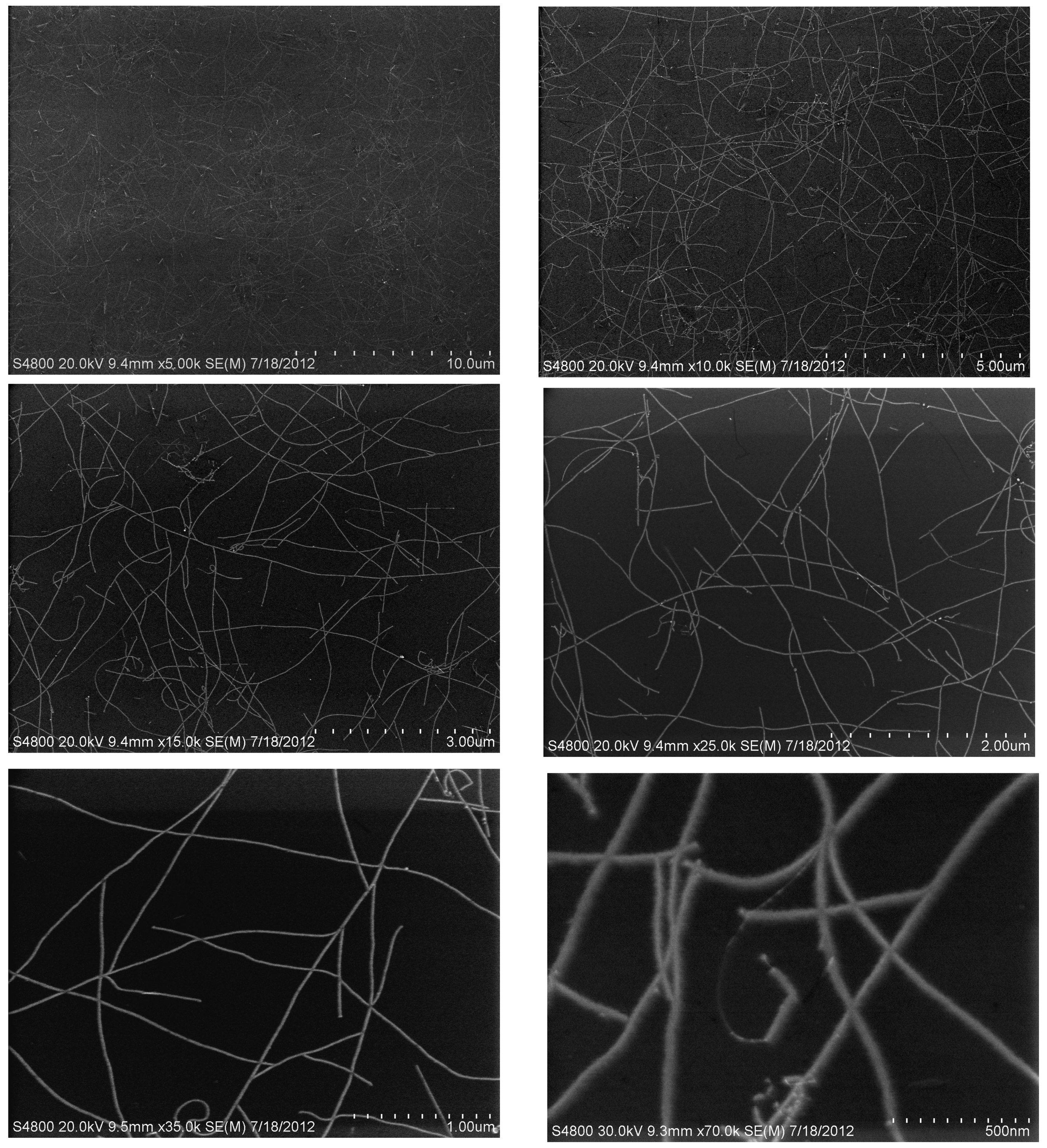

Figure 3. SEM images of CNT growth.

AFM Topography Analysis

AFM was used to determine the thickness of the carbon nanotubes. These measurements indicate that the CNTs have diameters reaching 15-20 nm, indicating that these are multi-walled CNTs. (See Figures 4 and 5)

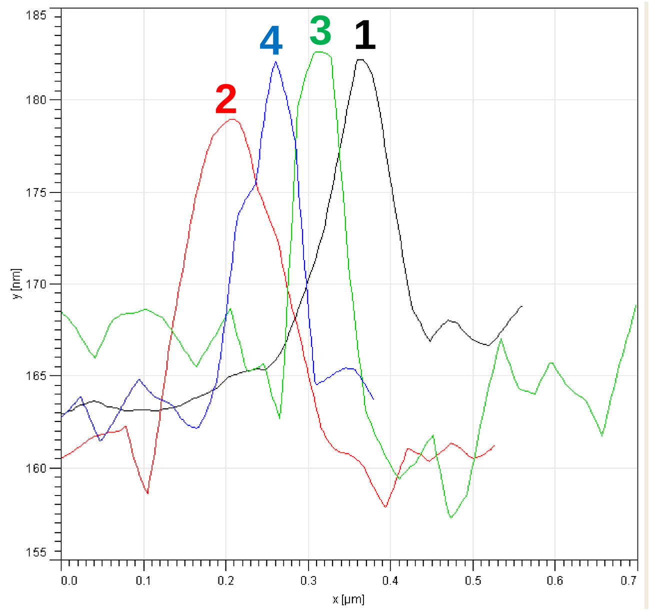

Figure 4. Graph representing the cross section thickness of the nanotubes at several points in Figure 5. The colored numbers represent the colored lines.

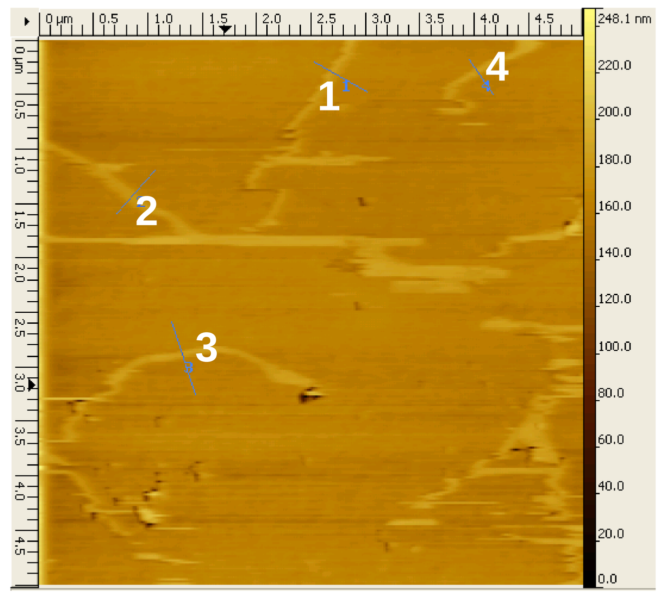

Figure 5. AFM topography image. The numbers correspond to the graph in Figure 4, and the areas where the cross section thickness of the nanotubes were measured.

Conclusions

Nanotube growth was successful. Lengths in excess of 15 microns were observed, which is particularly important with regard to supercapacitors, as the increased surface area is beneficial for increased capacitance. Further work on this synthesis method is needed. With a longer soak time for the deposition process, it is possible that a denser distribution of catalyst particles may be achieved. This would hopefully cause the nanotubes to align themselves vertically rather than horizontally - a key aspect for their use in supercapacitors.

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