an appropriate density with respect to the solubilized nanotubes. The method also comprises forming an array of liquid layers in a vessel including a first layer comprising the first liquid and a second layer disposed above the first layer, the second layer comprising the second liquid. And, the method comprises centrifuging the vessel and array of layers for a time period sufficient for at least a portion of the nanotubes in the first layer to migrate into the second layer and form a plurality of fractions in the second layer, wherein each fraction includes carbon nanotubes having an average length different than that of other fractions in the vessel.

[0012] In another aspect, the present invention provides a method for separating carbon nanotubes by length. The method comprises obtaining carbon nanotubes having a range of different lengths. The method also comprises dispersing the carbon nanotubes in a first liquid to thereby form a dispersed sample of carbon nanotubes. The method further comprises selecting a second liquid having a density such that the difference between (i) the density of the second liquid and (ii) the average density of the carbon nanotubes in the dispersed sample, is greater than the difference between (ii) and (iii) the density of any species of carbon nanotubes in the dispersed sample. The method further comprises in a vessel adapted for centrifugation, forming a first layer comprising at least a portion of the dispersed sample and forming a second layer comprising at least a portion of the second liquid, wherein the second layer is disposed above the first layer. And, the method comprises centrifuging the vessel and first and second layers for a time period sufficient for a plurality of fractions to form within the second layer, wherein each fraction includes carbon nanotubes having an average length different than that of other fractions in the vessel.

[0013] In yet another aspect, the present invention provides a method for separating carbon nanotubes by length. The method comprises providing carbon nanotubes having different lengths and dispersing the carbon nanotubes in water to form an aqueous mixture of the nanotubes and water. The method also comprises forming a liquid having a density such that the difference between (i) the density of the liquid and (ii) the average density of the carbon nanotubes in the aqueous mixture, is greater than the difference between (ii) and (iii) the density of any species of carbon nanotubes in the aqueous mixture. The method further comprises forming an array of layers in a vessel including a first layer comprising at least a portion of the aqueous mixture; a second layer disposed above the first layer, the second layer comprising at least a portion of the liquid and having a density less than that of the first layer; and a third layer disposed below the first layer, the third layer having a density greater than that of the first layer. The method additionally comprises centrifuging the vessel and first, second, and third layers for a time period sufficient for a plurality of fractions to form within the second layer, wherein each fraction includes carbon nanotubes having an average length different than that of other fractions in the vessel.

[0014] As will be realized, the invention is capable of other and different embodiments and its several details are capable of modifications in various respects, all without departing from the invention. Accordingly, the drawings and description are to be regarded as illustrative and not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. **1** is a schematic illustration of a vessel containing a preferred embodiment layered array that includes a layer of carbon nanotubes to be separated by length.

[0016] FIG. **2** is a schematic flowchart depicting a preferred embodiment process for separating a population of carbon nanotubes by length.

[0017] FIG. **3** includes a schematic diagram, photographs, and related graphs of the initial and final location of carbon nanotubes, and UV-vis-NIR spectra for various indicated fractionation locations associated with a preferred embodiment process of the present invention.

[0018] FIG. **4** is a graph illustrating apparent length versus fraction number at 4 hours, 9 hours and 19 hours of centrifugation in accordance with a preferred embodiment process.

[0019] FIG. **5** shows the spectra of various separated carbon nanotubes.

[0020] FIG. **6** is a graph of theoretical nanotube displacement calculated as a function of the nanotube length.

[0021] FIG. **7** includes schematic illustrations and photographs of a preferred embodiment length separation by centrifugation process for carbon nanotubes.

[0022] FIG. **8** is a graph of carbon nanotube length for various fractions.

[0023] FIG. **9** is a collection of images for two fractions after a preferred embodiment separation process.

[0024] FIG. **10**A is a graph of absorbance and wavelength for various fractions after a preferred embodiment separation process.

[0025] FIG. **10**B is a contour plot of emission energy and excitation wavelength.

[0026] FIG. **10**C is a contour plot of emission energy and excitation wavelength.

[0027] FIG. **11** is a graph of Raman scattering of a fraction of collected nanotubes.

[0028] FIG. **12** is a graph of absorbance and wavelength for certain fractions.

[0029] FIG. **13** are photographs of various SWCNTs in vials prior to undergoing a preferred embodiment separation process.

[0030] FIG. **14**A are photographs of various samples after a preferred embodiment separation.

[0031] FIG. **14**B is a graph of projected length and distance traveled of carbon nanotubes subjected to various centrifugation speeds.

[0032] FIG. **15** is a graph of projected length of carbon nanotubes per fraction number.

[0033] FIG. **16** are photographs of various samples and a corresponding graph of projected length and fraction number associated with certain carbon nanotubes described herein.

[0034] FIG. **17** are photographs of samples and a corresponding graph of length and fraction number associated with separating carbon nanotubes at different temperatures.

[0035] FIG. **18** is a graph of projected length and distance traveled of carbon nanotubes centrifuged at various rotational speeds.

[0036] FIG. **19** is a graph of length and distance traveled for certain carbon nanotubes.

[0037] FIG. **20** is a graph illustrating redistribution of a density adjusting agent during centrifugation.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0038] The present invention is based upon a discovery that the transient, i.e. rate dependent, motion of carbon nanotubes, and preferably SWCNTs, in response to an applied centripetal acceleration field can be utilized to achieve length separation. That is, carbon nanotubes can be separated according