

phous carbon coatings are agitated in an aqueous liquid containing a dispersant with free-flowing grit particles to disassociate the CNTs from the metallic catalysts, remove the amorphous carbon of the amorphous carbon coatings and shorten the CNTs via shearing along the radial axis of the tubes.

[0013] A second aspect of the invention provides a method of harvesting CNTs, in which mixtures of CNTs, residual metallic catalysts and amorphous carbon are subjected to a density gradient, magnetic phase separation in which stratified, resolved layers of the CNTs, the amorphous carbon, and the metallic catalysts are generated that allow for separation.

[0014] A third aspect of the invention provides a method of harvesting carbon nanotubes, in which a liquid containing a dispersant, carbon nanotubes, and amorphous carbon of a coating is subjected to a colloidal electrophoresis operation in a rotating apparatus containing at least one rotating membrane sized to permit the passage of the amorphous carbon, but to intercept and block the passage of the carbon nanotubes.

[0015] Other aspects of the invention, including apparatus, systems, methods, and the like which constitute part of the invention, will become more apparent upon reading the following detailed description of the exemplary embodiments and viewing the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The accompanying drawings are incorporated in and constitute a part of the specification. The drawings, together with the general description given above and the detailed description of the preferred embodiments and methods given below, serve to explain the principles of the invention. In such drawings:

[0017] FIG. 1 is a flow chart of a harvesting process for carrying out an embodiment of the present invention;

[0018] FIG. 1A is a flow chart of a harvesting process according to an alternative embodiment of the present invention;

[0019] FIG. 1B is a flow chart of another harvesting process according to another alternative embodiment of the present invention;

[0020] FIG. 1C is a partial flow chart of a modification that may be applied to the harvesting processes of FIGS. 1, 1A, and 1B;

[0021] FIG. 2 is an overview of a system for carrying out a grit-shearing step according to an embodiment of the invention;

[0022] FIG. 3 is a partially transparent, sectional view of tumbler for carrying out a grit-shearing step according to an embodiment of the invention;

[0023] FIG. 4A is a plan view of a filter for the tumbler of FIG. 3;

[0024] FIG. 4B is an enlarged, fragmented view of a filter according to an alternative embodiment of the invention;

[0025] FIG. 5 is a sectional view of an assembly for carrying out a magnetic phase separation step according to an embodiment of the invention;

[0026] FIG. 6 is a side-sectional view of an apparatus for carrying out an electrophoresis step according to an embodiment of the invention;

[0027] FIG. 7A is an end view of a filter cassette for the electrophoresis apparatus of FIG. 6;

[0028] FIG. 7B is a fragmented, side-sectional view of the filter cassette of FIG. 7A; and

[0029] FIG. 8 is a side-sectional view of an apparatus for carrying out a dialysis step according to an embodiment of the invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS OF THE INVENTION

[0030] Reference will now be made in detail to exemplary embodiments and methods of the invention as illustrated in the accompanying drawings, in which like reference characters designate like or corresponding parts throughout the drawings. It should be noted, however, that the invention in its broader aspects is not limited to the specific details, representative devices and methods, and illustrative examples shown and described in this section in connection with the exemplary embodiments and methods. The invention according to its various aspects is particularly pointed out and distinctly claimed in the attached claims read in view of this specification, and appropriate equivalents.

[0031] It is to be noted that, as used in the specification and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise.

[0032] FIG. 1 depicts a flowchart including steps for harvesting (CNTs) according to an embodiment of the invention. These steps and alternatives will be described below in great detail. Generally, the steps include a grit-shearing stage **10** for debundling, decoating, and shortening the CNTs, a magnetic phase separation stage **12**, an electrophoretically driven filtration stage **14**, and a dialysis stage **16**. It should be understood that the scope of the present invention may include additional or fewer steps to those shown in FIG. 1. For example, as shown in FIGS. 1A and 1B, respectively, the dialysis stage **16** or the electrophoretically driven filtration stage **14** may be omitted. As shown in FIG. 1C, additional stages may be added to the embodied processes, such as an osmotic pressure driven filtration stage **11**, discussed below. Additional, alternative and known procedures and operations can be substituted for or supplement the stages shown in FIGS. 1, 1A, 1B, and 1C.

[0033] FIG. 2 provides an overall general view a system for carrying out the grit-shearing stage **10**. The system of FIG. 2 is generally designated by reference numeral **30**, and includes a tumbler **32**, a rotating mechanism **34** for imparting rotational movement to the tumbler **32** about its longitudinal axis, and a pump assembly **36**.

[0034] Referring more particularly to FIG. 3, the tumbler **32** has an upstream end **32a** and a downstream end **32b**. The tumbler **32** may comprise a plurality of cylindrical segments **40**, **42**, **44**. In the illustrated embodiment, first cylindrical segment **40** is proximal the upstream end **32a**, and third cylindrical segment **44** is proximal the downstream end **32b**. The second cylindrical segment **42** is interposed between the first and third cylindrical segments **40**, **44**. The cylindrical segments **40**, **42**, **44** may be attachable and detachable from one another using, for example, known fasteners, such as screws or bolts inserted into aligned apertures in adjacent flanges of the cylindrical segments. Alternatively, the cylindrical segments **40**, **42**, **44** may be permanently joined or formed together as a unitary structure.

[0035] The cylindrical segments **40**, **42**, **44** each comprise an annular outer wall having an interior surface defining a compartment (or zone) **40b**, **42b**, **44b**. The outer walls of the cylindrical segments **40**, **42**, **44** may be formed of relatively thick walls of plastic, glass, ceramic, or other material. Plastic