deoxycholate is most preferred since it is relatively inexpensive, and it maintains continuous, complete, individualization of the nanotubes under the conditions of the separation. Other surfactants, such as DNA, cost significantly more to achieve the same result, or cannot completely maintain individualization of the dispersed nanotubes in solution at any sort of meaningful concentration. In general, any surfactant can be used if it is used under conditions at which it maintains (complete or acceptably complete) individualization of the SWCNTs, makes them primarily non-interacting, and maintains a density that is primarily concentration independent. Most preferably, DNA and sodium deoxycholate have been demonstrated to meet these requirements, particularly at moderate and high concentrations of SWCNTs.

[0046] A wide array of surfactants, dispersal agents, and other additives can likely be used in the processes of the present invention. For example, it is contemplated that many of the systems and surfactants known in the art may be suitable. For example, the surfactants and systems disclosed in U.S. Pat. No. 7,074,310 may be suitable. In addition, the dispersal agents, emulsifying agents, detergents, surfactants, and other additives disclosed in U.S. Pat. No. 7,166,266 may be appropriate for use in the present invention methods.

[0047] Also, as noted, one or more density adjusting agents are used to form at least some of the various layers in the layered array. Preferably, the liquid or density adjusting agent is iodixanol, which is commercially available in an aqueous solution under the designation Opti-prep™, available from Sigma Chemical. Iodixanol is 5,5'-[(2-hydroxy-1-3 propanediyl)-bis(acetylamino)]bis [N,N'-bis(2,3dihydroxylpropyl-2,4,6-triiodo-1,3-benzenecarboxamide]. Opti-prep™ is a 60% (w/v) solution of iodixanol in water.

[0048] As noted, the density adjusting agent Opti-prep™ is actually an aqueous solution of polymer in water. There is no intrinsic restriction against the use of other dense liquids, aqueous or non-aqueous, as long as several parameters are met. The SWCNTs must be dispersed as individual tubes, and ideally as non-interacting individuals. They must be stable in the solution (non-aggregating). The medium must maintain enough density under centrifugation to allow sufficient time for the separation. The nanotubes must be able to move or translate in the manner dictated by the free particle hydrodynamics (i.e. no gels, as this would change the hydrodynamic scaling). And other non-ideal effects (such as sedimentation potentials and other charging effects) should be minimized.

[0049] To generate length, rather than chirality separation, the race layer(s) must also be dense enough such that the difference in density of different types of nanotubes is relatively small as compared to the difference in densities between the nanotubes (as dispersed) and the bulk liquid. The effective density of the SWCNTs varies in different solutions based upon how the nanotubes have been dispersed, so the absolute required density of the liquid can only be truly set once the dispersion protocol is known.

[0050] A wide variety of other aqueous density media are commercially available. Accordingly, it is contemplated that other media may be useable. The key is to meet the previously noted preferences. As for non-aqueous solutions, there are no intrinsic reasons why the separation would not work, so long as the previously noted preferences were met.

[0051] Referring to FIG. **1**, a schematic illustration of a preferred embodiment array **10** of layers in a vessel **20** is shown. Specifically, the vessel **20** contains one or more underlayers **50** such as a first underlayer **50***a* and a second underlayer **50***b*. The vessel **20** also contains an injection layer **40**. And, the vessel contains one or more race layers **30** such as a first race layer **30***a*, a second race layer **30***b*, a third race layer **30***c*, a fourth race layer **30***d*, and a fifth race layer **30***e*. Although multiple race layers are noted, it is preferred for most applications that a single race layer be used. An optional upper layer **60** may also be utilized. It will be appreciated that the present invention includes arrays having a greater or lesser number of layers than that depicted in FIG. **1**. In addition, it is to be understood that the present invention includes a collection of race layers **30** and underlayers **50** having a greater or lesser number of layers than shown in FIG. **1**. Preferably, the present invention layered array includes a total of four layers—two underlayers, a single injection layer, and a single race layer.

[0052] The injection layer comprises solubilized and preferably, individually dispersed SWCNTs in a medium. Preferably, the SWCNTs are in a medium of iodixanol and water. A representative composition of the medium in the injection layer, using iodixanol is from about 18% to about 22% iodixanol, and about 2% surfactant, and the remainder portion being water.

[0053] As noted, in many applications, it is preferred to use a single race layer. Using iodixanol as the density adjusting agent, typical compositions of the race layer include for example, from about 15% to about 30% iodixanol, from about 0.5% to about 4% surfactant, and from about 65% to about 85% water. Preferably, the concentration of iodixanol in the race layer(s) is from about 15% to about 25%. The concentration of surfactant in the race layer(s) is preferably about 2%. Water is preferably present in a majority proportion in the race layer(s). It will be appreciated that the present invention includes the use of these components in different proportions and in combination with additional or different components. Moreover, as previously noted, the present invention is not limited to the use of iodixanol as the density adjusting agent.

[0054] The underlayer(s) typically comprise amounts of the density adjusting agent used in the race layer(s), surfactant, and water. For systems using iodixanol, the concentration of iodixanol in the underlayer(s) typically ranges from about 30% to about 50% with a preferred concentration of 30% to 40%. Surfactant may also be included in the underlayer(s) in an amount of from about 0.5% to about 4%, and preferably 2%. The underlayer(s) preferably comprise water in remainder amounts.

[0055] The volume amounts of each respective layer type may be expressed relative to the amount of the injection layer. Preferably, the amount of the underlayer(s) is from about 50% to about 200% of the amount of the injection layer. And, the amount of the race layer(s) is preferably from about 100% and more preferably from about 500% to about 1000% of the amount of the injection layer. The race layer should be large enough such that an approximate uniform density is maintained despite the sedimentation of the iodixanol (or other density adjusting agent), and such that there is enough room for the SWCNTs to separate in position within the vessel or centrifuge tube. However, the present invention includes amounts for the underlayer(s) and the race layer(s) greater than or lesser than these indicated amounts. The amount of the upper layer is not critical, however is contemplated to typically be greater than the amount of the injection layer.

[0056] FIG. **2** is a preferred embodiment process **100** for separating a population of carbon nanotubes into various fractions of different lengths, in accordance with the present