This aggregate or agglomerate formation leads to a reduction of performance in their mechanical and electrical behaviors. Disaggregation of MWCNT has been achieved by mechanical methods such as e.g. shear mixing, shear milling and ultrasonication of MWCNT dispersed in a liquid, organic or aqueous, or by a combination with chemical methods including surface functionalization, and the addition of surfactants, in some cases in combination with centrifugation steps. The disaggregation of SWCNTs requires higher energy levels in comparison to MWCNTs, which can be obtained only by ultrasonication.

Some techniques suggest that after the dispersion and sonication, the CNTs can be dried and re-dispersed. However, with regard to the application of CNTs in electrochemical cells the common techniques change the surface chemistry or introduce additional unwanted foreign material, or damage the CNT structure, any or all of which lower the electrical and/or thermal conductivity and decrease the quality of the electrochemical cells.

There is thus a need for a method of dispersion of small scale materials which is devoid of the above limitations.

SUMMARY

The present disclosure, in examples thereof, relates to a method for the disaggregation and deagglomeration of small-scale materials. Small scale materials are defined herein as materials having particles in the micro- and nano-scale range, and may include, for example, inorganic pigments such as TiO2, Fe2O3, organic fluorescent pigments from rhodamine group, from phtalocyanide group, abrasive powder such as corund, diamond, and carbon nanotubes (CNT). The method of the example is directed to these small-scale materials and their dispersion and formation of a physical network with electrode substrate particles. More particularly the present disclosure relates to the disaggregation and deagglomeration of carbon nanotubes via cavitation. More particularly the present disclosure relates to the disaggregation and deagglomeration of carbon nanotubes based on the application of a cavitator, such as an ultrasound probe, in dense-phase fluids, and more particularly, using ultrasonication in liquid CO_2 or CO_2 under supercritical conditions. More particularly the present disclosure relates to use of particles of electrode materials

prepared with carbon nanotubes for the improved performance of energy storage devices including, but not limited to supercapacitors of either the aqueous or organic solvent electrolyte types, Ni/metal hydride batteries, lead-acid batteries, and Li-ion and lithium-ion polymer batteries. The present disclosure uses a process that creates a 3D-network of carbon nanotubes with substrate particles without the use of surfactants or covalent modification of the carbon nanotubes or substrate particles.

The term electrode substrate particle refers to nano- and micron particles that are used as electrode materials.

The term battery herein refers to batteries or super-capacitors comprised of at least one cell or a plurality of cells, connected in series, parallel or combinations.

There is provided, in accordance with an aspect of the present disclosure, a method for dispersion of small scale materials such as carbon nanotubes. The method includes placing a small scale material powder into a treatment chamber, introducing a treatment substance into the treatment chamber, the treatment substance being capable of undergoing cavitation, wherein the treatment substance comprises carbon dioxide, and and cavitating the treatment substance to cause dispersion of the small scale material.

In accordance with further features in examples of the invention, the small scale material may be TiO2, Fe2O3, organic fluorescent pigment from a rhodamine group, organic fluorescent pigment from a phtalocyanide group, corund powder, diamond powder, or carbon nanotubes, or other suitable materials.

In accordance with further features in examples of the present disclosure, the dry carbon nanotube powder is mixed with an electrode substrate material and placed together into the treatment chamber. The carbon nanotubes have an electrical affinity to the electrode substrate material such that the dispersed carbon nanotubes establish stable contact with the electrode substrate material, thus forming a dispersed CNT/electrode substrate matrix.

In examples of the present disclosure, the treatment substance may be carbon dioxide – in liquid or supercritical form - or mixtures of carbon dioxide with other gases, or other suitable materials. The treatment substance may undergo phase changes before or during treatment. The cavitating may be done by applying ultrasound to the treatment substance at a high pressure (for example, greater than or equal to 74 bar for supercritical CO_2 or 40-60 bar for liquid CO_2 at room

temperature), or may be done by mechanical agitation or by repeatedly increasing and decreasing a pressure in the treatment chamber, or by injection of a jet stream of supercritical CO_2, or by other suitable methods. The method may include increasing a temperature of the treatment chamber during cavitation.

In further features in examples of the present disclosure, the method also includes removing the dispersed small scale particles from the treatment chamber without changing a chemical composition of the nanotube particles. The small scale material may then be used in a battery.

There is provided, in accordance with examples of the present disclosure, a system for disaggregation and deagglomeration of carbon nanotubes. The system includes an AMT vessel having a treatment chamber which is configured to hold therein a CNT/electrode substrate mixture, and is configured to withstand a pressure of at least 40-60 bar, and in some examples at least 70 bar, and in some examples at least 100 bar. The system further includes an external source of a treatment substance capable of undergoing cavitation, and a cavitator for causing cavitation of the treatment substance in the treatment chamber.

In further features in examples of the present disclosure, the AMT vessel includes a bottom portion and a top portion positionable on top of the bottom portion, such that when the top portion is positioned on top of the bottom portion, the top and bottom portion form the treatment chamber. In examples of the present disclosure, the AMT vessel includes a treatment substance feeding pipe through the top portion.

In further features in examples of the present disclosure, the cavitator may be an ultrasound probe, and the top portion includes a probe insert through which at least a portion of the ultrasound probe can be introduced into the treatment chamber. In other examples, the cavitator may be an injector for injecting high speed jet stream of treatment substance into the treatment chamber. The treatment chamber may be, for example, a pipe AMT vessel.

There is provided, in accordance with additional example of the present disclosure, a dispersed CNT/electrode substrate matrix material, including a carbon nanotube material and an electrode substrate material which is configured to have an electrical affinity with the carbon nanotube material, wherein the carbon nanotube material is dispersed on the electrode substrate material in a stable form, thus

CLAIMS

What is claimed is:

1. A method for dispersion of small-scale materials, the method comprising:

placing a small-scale material powder into a treatment chamber;

introducing a treatment substance into the treatment chamber, the treatment substance being capable of undergoing cavitation, wherein the treatment substance comprises carbon dioxide; and

cavitating the treatment substance, wherein said cavitating causes dispersion of the small-scale material.

2. The method of claim 1, wherein the small-scale material comprises carbon nanotubes.

3. The method of claim 1, wherein the small-scale material comprises at least one of: TiO2, Fe2O3, organic fluorescent pigment from a rhodamine group, organic fluorescent pigment from a phtalocyanide group, corund powder, and diamond powder.

4. The method of claim 2, further comprising forming a dispersed CNT/electrode substrate matrix from the dispersed nanotubes, wherein said placing the small-scale material powder comprises placing the dry carbon nanotube powder mixed with an electrode substrate material into the treatment chamber, wherein the dispersed carbon nanotubes are free from added impurities due to a chemical-free mechanical cavitation method of dispersing the carbon nanotubes, the carbon nanotubes having an electrical affinity to the electrode substrate material such that the dispersed carbon nanotubes establish stable contact with the electrode substrate material, thus forming the dispersed CNT/electrode substrate matrix.

5. The method of claim 1, wherein the carbon dioxide is in a non-liquid form.

6. The method of claim 1, wherein the treatment substance is capable of undergoing phase change, and wherein the method further includes inducing a phase change in the treatment substance.

7. The method of claim 1, wherein said introducing a substance comprises introducing supercritical carbon dioxide.

8. The method of claim 1, wherein said cavitating comprises mechanically agitating the supercritical carbon dioxide.

9. The method of claim 8, wherein said mechanically agitating is done by rotating blades or cups.

10. The method of claim 1, wherein said cavitating further comprises repeatedly increasing and decreasing a pressure in the treatment chamber.

11. The method of claim 1, wherein said cavitating comprises injecting a jet stream of the carbon dioxide into the treatment chamber.

12. The method of claim 1, wherein said cavitating comprises ultrasonicating the treatment substance.

13. The method of claim 1, further comprising increasing a temperature of the treatment chamber during said cavitating.

14. The method of claim 1, wherein said cavitation comprises providing a pressure gradient and pulling the small scale material powder into an injector via the pressure gradient.

15. The method of claim 1, further comprising removing the dispersed small-scale material from the treatment chamber without changing a chemical composition of the small scale material powder.

16. The method of claim 1, further comprising using the dispersed small-scale material in a battery.