Several methods have been used to make carbon nanotubes (CNTs) more dispersible, including oxidation processes, the use of surfactants, covalent functionalization with solubilizing groups, and non-covalent functionalization. Of these methods, non-covalent functionalization has the least effect on the electronic properties of the carbon nanotubes. Covalent functionalization creates defects in the pi network of the CNTs, which adversely affects their conductivity. Similarly, oxidation of the nanotubes will negatively affect the electronic characteristics of the CNTs, as the oxidation damages the tubes and could decrease their size. The addition of additives to the solution, such as surfactants, can also disrupt the electronic properties of the final ink-printed CNT films. To reduce this effect, post-applications treatments, including repeated washings, of the printed CNT films are necessary, which creates extra steps, yield lost, and large amounts of waste, and still may not restore the conductivity of the original CNTs.

Several methods of non-covalently functionalizing carbon nanotubes have been published. If the functional group is a liquid, then simply stirring at a raised temperature can be effective. Some solids can be melted with the carbon nanotubes but many solids decompose before melting, which is particularly the case for many polyaromatic hydrocarbons. Sonication can also be used to temporarily disperse CNTs in a solvent. Sonication can be used in conjunction with another functionalizing method, since it temporarily breaks up the carbon nanotube bundles and allows the functionalizing groups to get between the CNTs. However, strong or prolonged sonication has a tendency to damage carbon nanotubes, which likely results in less than desirable electronic properties.

There is a need for improved methods of solubilizing carbon nanotubes while preserving, and even enhancing, their conductivity.

SUMMARY OF THE INVENTION

In one aspect, t~~T~~he present ~~invention~~disclosure overcomes the problems of the prior art by providing a method of preparing a carbon nanotube dispersion with improved carbon nanotube solubilities and conductivities. The method comprises providing a mixture of carbon nanotubes, a compound comprising at least one polyaromatic moiety, and an acid. The compound comprising at least one polyaromatic moiety is noncovalently bonded with the carbon nanotubes, and the acid is reacted

with the at least one polyaromatic moiety. The ~~invention~~disclosure is also directed towards the dispersion formed by this method.

In another ~~embodiment~~aspect, the ~~invention~~disclosure provides a dispersion comprising carbon nanotubes noncovalently bonded to compounds comprising respective polyaromatic moieties. At least some of the polyaromatic moieties are reacted with an acid. The dispersion, being free of surfactants, has a carbon nanotube concentration of at least about 0.05% by weight, based upon the total weight of the dispersion taken as 100% by weight. The dispersion is also formable into a film having a sheet resistance of less than about 7,000 Ω/sq.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graph depicting the D/G ratio of the sample prepared in Example 1;

Fig. 2 is a graph showing the TGA analysis of the sample prepared in Example 1;

Fig. 3 is a graph of the TGA analysis of raw CG200 carbon nanotubes;

Fig. 4 is a graph depicting the D/G ratio of the sample prepared in Example 2;

Fig. 5 is a graph showing the D/G ratio of raw CG200 carbon nanotubes;

Fig. 6 is a graph illustrating the Raman spectrum of the sample prepared in Example 2;

Fig. 7 is a graph depicting the Raman spectrum of raw CG200 carbon nanotubes;

Fig. 8 is a graph depicting the D/G ratio of the sample prepared in Example 3;

Fig. 9 is a graph showing the D/G ratio of raw SG65 carbon nanotubes;

Fig. 10 is a graph illustrating the Raman spectrum of the sample prepared in Example 3;

Fig. 11 is a graph depicting the D/G ratio of the sample prepared in Example 4;

Fig. 12 is a graph illustrating the Raman spectrum of the sample prepared in Example 4;

Fig. 13 is a graph depicting the D/G ratios of the sample prepared in Example 5 and of XBC3350 carbon nanotubes (for readability, the spectrum for the XBC3350 was multiplied by a factor of 0.473);

Fig. 14 is a graph depicting the Raman spectra of the sample prepared in Example 5 and of XBC3350 carbon nanotubes (for readability, the spectrum for the XBC3350 was multiplied by a factor of 0.473);

Fig. 15 is a graph showing the D/G ratios of the second sample prepared in Example 6 and of CG200 carbon nanotubes (for readability, the spectrum for the CG200 was multiplied by a factor of 4.212);

15. A dispersion comprising carbon nanotubes noncovalently bonded to compounds comprising respective polyaromatic moieties, at least some of said polyaromatic moieties being reacted with an acid, said dispersion:

being free of surfactants;

having a carbon nanotube concentration of at least about 0.05% by weight, based upon the total weight of the dispersion taken as 100% by weight; and

being formable into a film having a sheet resistance of less than about 7,000 Ω/sq.

16. The dispersion of claim 15, wherein said carbon nanotubes are selected from the group consisting of single-walled, double-walled, and multi-walled carbon nanotubes.

17. The dispersion of claim 15, wherein said compound comprising at least one aromatic moiety is selected from the group consisting of substituted and unsubstituted compounds selected from the group consisting of naphthalene, anthracene, phenanthracene, pyrene, tetracene, tetraphene, chrysene, triphenylene, pentacene, pentaphene, perylene, benzo[a]pyrene, coronene, antanthrene, corannulene, ovalene, graphene, fullerene, cycloparaphenylene, polyparaphenylene, cyclophene, and compounds containing moieties of the foregoing.

18. The dispersion of claim 15, wherein said acid has a pKa of less than about -1.

19. The dispersion of claim 15, wherein said acid is selected from the group consisting of sulfuric acid, chlorosulfonic acid, triflic acid, p-toluenesulfonic acid, and mixtures thereof.

20. The dispersion of claim 15, wherein said carbon nanotubes and compounds comprising at least one polyaromatic moiety are provided in quantities such that the molar ratio of carbon nanotubes to polyaromatic moieties is from about 25:75 to about 75:25.

21. The dispersion of claim 15, wherein the carbon nanotube concentration in the dispersion is at least about 0.05% by weight, based upon the total weight of the dispersion taken as 100% by weight.