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Dispersibility Evaluation of Carbon Nanotubes Using Bead Mill

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Abstract

Carbon nanotubes (CNTs) possess various qualities such as outstanding brightness, strength, conductivity, heat conduction, and the ability to emit electrons. In general, such characteristics can be expressed by dispersing a CNT material into a solvent. However, CNTs cannot be dispersed easily because their aggregates are very hard. In the experiment described in this study, we used a bead mill and an ultrasonic homogenizer to mechanically disperse CNTs into a solvent. The devices were used to disperse multi-wall carbon nanotubes (MWCNT) into a solvent. To evaluate the dispersion efficiency of the bead mill, we examined the relation among dispersion time, specific energy, and median diameter (X_{50}) of MWCNTs obtained through dispersion under different conditions. The results indicated that the dispersion efficiency of MWCNTs varies, depending on the operating conditions. In addition, by using a specific energy, it was demonstrated that the diameter of the beads exerts a great effect on dispersion efficiency. A comparison of the bead mill and ultrasonic homogenizer showed that the shape and hardness of the initial MWCNT's aggregates have an effect on the dispersion efficiency.

Key-words: *Carbon nanotube, Dispersion, Bead mill, Specific energy, Ultrasonic homogenizer*

1. Introduction

A carbon nanotube (CNT) is a carbon material with a cylindrical structure comprised of a single layer or multilayers of graphite. A CNT is a few nanometers in diameter and a few micrometers in length and has an aspect ratio >1000. Depending on the structure, a CNT is classified as a single-wall carbon nanotube (SWCNT) or a multi-wall carbon nanotube (MWCNT).

CNTs exhibit outstanding brightness, strength, conductivity, heat conduction, and electron emission characteristics. They are used in a wide variety of fields, and their applications include use as electron emitters in field emission displays (FEDs), illuminants, and as electrode materials for power generating or storage devices such as fuel cells, lithium-ion batteries, solar cells, and electrical double-layer capacitors. They can also be used as additives in conductive resins and probes for scanning probe microscopes (SPMs)[1)]. However, while we can confirm their superiority in the nano-size domain, it is difficult to bring out those characteristics.

In general, CNTs are dispersed into resin before use. However, they cannot be readily dissolved into water and solvents, and they are also difficult to blend with binder resins. Therefore, it is necessary to develop dispersion techniques that suit the intended application[2)]. In general, materials consisting of carbon cannot be dispersed when they are simply added to water because of their water-repellent properties. Therefore, a dispersant is usually added to a slurry of carbon materials and water. Even so, CNTs cannot be dispersed easily because their aggregates are very hard. An additional problem is that a low concentration of CNT slurry may decrease the utility value, while a high concentration may decrease the dispersion stability[3)]. The development of applications for CNTs depends on the development of techniques for the dispersing, mixing, and coating methods used to arrange dispersed and stabilized CNTs into a specified position under the desired conditions[4)].

Ultrasonic homogenizers, high-pressure homogenizers, mixers, and media mills are all used to disperse CNTs mechanically into a solvent. These devices are used in a number of ways to disperse SWCNTs. For example, ultrasonic waves can be used to produce a stable slurry that remains free of sedimentation for more than 30 days[3)]. There are also devices that employ a manufacturing method in which the slurry is wet-ball milled in an ethanol solvent, dried, and then ground[5)]. When dispersing MWCNTs, if a bead mill and an ultrasonic homogenizer are used, the lengths of the MWCNTs decrease but the number of contact points increase, indicating that there is an increase in contact resistance[6)]. A high-pressure homogenizer can disperse a high-concentration slurry without decreasing the length[7)]. Additives such as CMC and CMC-Na can be effectively dispersed into water, but liquid phase dispersion using a bead mill depends on the diameter of the beads[8)]. A bus-type ultrasonic homogenizer is effective for cup stack carbon nanotubes (CSCNT) that contain hard massive initial particles of approximately 10 μm[9)].