PROPERTIES OF CARBON NANOTUBE/POLYMER COMPOSITE MATERIALS PREPARED BY DIRECT MIXING METHOD

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Abstract

Carbon nanotube (CNT)/polymer composites are expected as useful new functional materials. In this research, simple and easy physical mixing method, which is direct mixing of the multi-wall CNT (VGCF) with polymers, was studied in order to realize a functional material. The grain size of polymer particle and nano carbon before mixing is greatly different each other. Therefore, direct mixtures of these materials are usually difficult. Here, Granulated polymer and CNTs were mixed by a high speed rotating blade. The electrical conductance of the samples measured by AC impedance meter increased with the increase of CNTs ratio in the polymer. This simple and easy mixing method has possibility to mix up the powders uniformly which have different size and properties.

Introduction

Various composite polymers including distributed carbon nanotube (CNT: single wall and multiwall tube) are expected as useful functional materials. For example, if electrical conductivity is added to characteristics of a polymer, it can apply to various electron devices. In order to realize the new functional materials, it is important to control the dispersion of CNT in the polymer materials. However, the simple and effective distributed method has not been established until now. In this report, we will show a new mixing method (direct mixing method) by which the powders with which the magnitude of grains completely differs mutually are well mixed.

Experimental

Granular or powder of polymer (PMMA, ABS, and PET) and CNT (vapor grown carbon fiber: VGCF) were directly mixed using the grinding mixing apparatus. Moreover, the sample which mixed carbon black for the comparison was also prepared. The rotational frequency of an agitating blade is 25,000 rpm (in a part of experiments, 1,000 to 37,000rpm), and duration time of 120 second. Plate shaped samples, with about 5cm in diameter, and a thickness of about 1mm, were made from this powder by using press apparatus at a temperature of 180℃and under pressure of 40 kN. The alternating current impedance of the obtained plate samples was measured under condition of applying signal at a voltage of 1V and at a frequency between 100Hz and 1MHz using an LCR meter (HP4284A). The specific resistance under the direct-current was measured by the 4-probe method.

Results

Figure 1 shows the optical microscope image of mixed powder of PMMA and VGCF (2wt%) prepared by the direct mixing method. The sample prepared by relatively high rotational frequency speed seems to be mixed uniformly.
On the other hand, unevenness was observed in the sample powder mixed at low rotational frequency (photograph left-hand side). In the preliminary experiment, it was observed that the volume of the whole powder decreased after mixing at high mixing ratio (30wt%) of VGCF. And it was showed that when mixing at the rotational frequency of 25,000rpm or more possibility that uniform mixed state would be obtained. The same results, about the relation between rotational frequency and mixed situation, were obtained also in the cases of the other polymers such as ABS and PET.

Figure 2 shows the scanning electron microscopy (SEM) image of powder particles after mixing. It is seen that CNT's are sprinkled on the surface of the polymer, and some of the VGCF's has pierced into the interior of the particle. After mixing for 120 seconds, powder sample temperature rose to about 70-90 °C, and the velocity of edge of the agitating blade of a grinding mixer at the case of 25,000rpm rotational frequency is equivalent to about 470km/h. It is thought that polymer particles soften by the rising of the temperature and collide mutually by the kinetic energy during mixing.

Figure 3 shows the electrical properties of polymer / VGCF mixed material sample plates measured at 1kHz and 1MHz. The conductivity increased with the increase of mixed ratio of VGCF or carbon black. However, When a 5wt% of VGCF was mixed, the electric conduction rate of the polymer was higher, compared to that of the polymer mixed with the same ratio of carbon black.

As shown in Figure 4, the DC resistivity of the sample with VGCF filler measured by 4probe method is lower than that of the sample with carbon black filler, at the range of mixed ratio up to 5wt%. On the other hand, with the filler mixed ratio range from 5 to 10wt%, the resistivity of the samples with VGCF filler scarcely decreased. One of the reasons why resistivity does not decrease by high ratio mixing of VGCF is considered as follows. When mixing ratio becomes high, it is thought that the impact of a collision is moderated by the large volume of VGCF because of its small density, so insufficient dispersion will be made.

The tensile strength of the polymer plank which contains VGCFT as the filler was measured [Nagasaka, 2006]. When the mixed ratio became large, there was a tendency for intensity to fall. On the other hand, the tensile strength of a wire with a diameter of 0.5mm prepared by extrusion fabrication was higher than that of a plank. It is thought that one of the reasons is the orintation of dispersed VGCFs to a direction by the extrusion fabrication

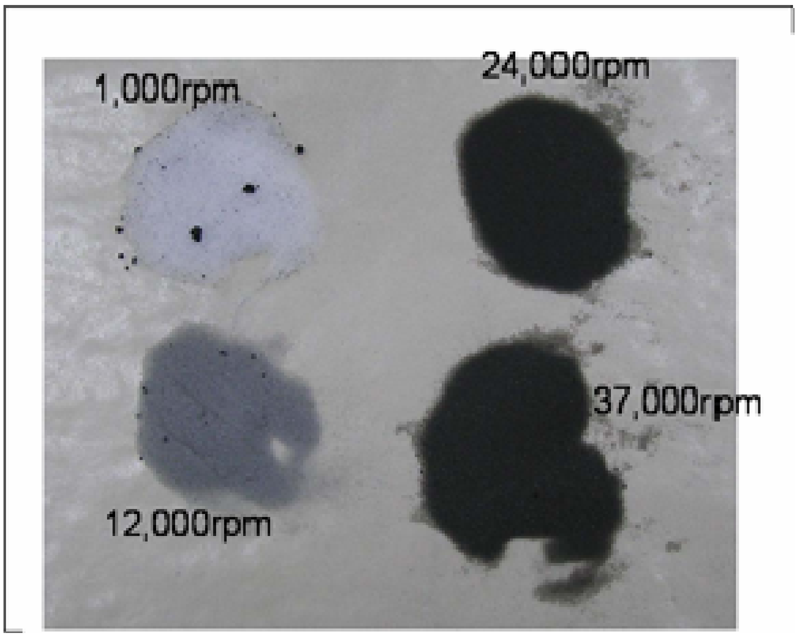

Figure 1. Optical microscope images of mixed powders (PMMA+VGCF) mixing at various rotation rate (1,000-37,000 rpm) in 120sec.

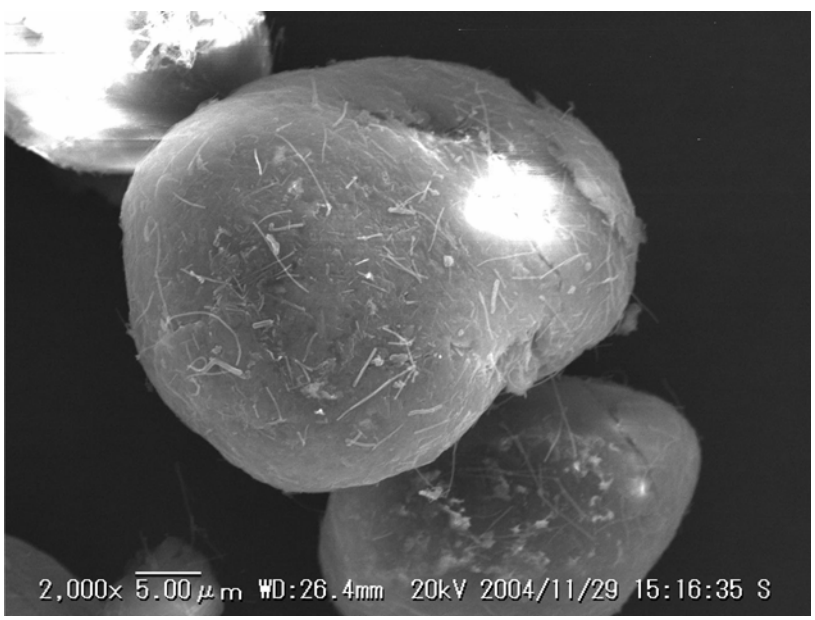

Figure 2. SEM image of direct mixed polymer/VGCF powder.

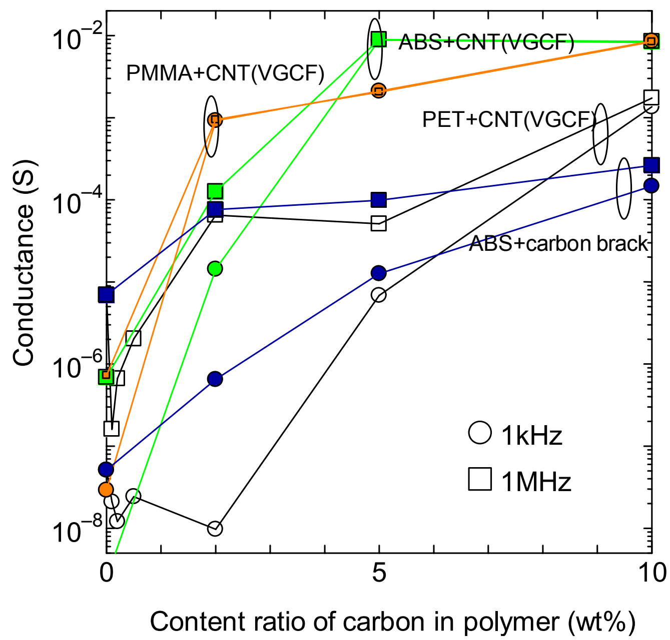

Figure 3. AC conductance of the samples measured at 1kHz and 1MHz.

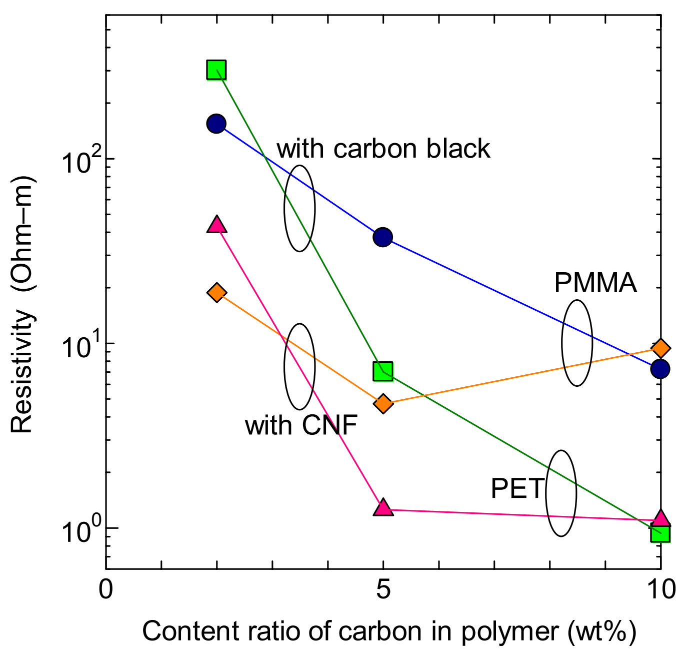

Figure 4. DC resistivity of the samples measured by 4-probe method.

Conclusions

It was shown that the polymer and VGCF which differs in size and a property, can be mixed by the direct mixture dispersion method in a short time using a high velocity revolution. Especially when the mixed ratio of VGCF was less than 5wt%, the uniform mixed powder was obtained. This method is expected to apply to mixing also the powder materials and the nano material other than carbon. The direct current resistivity values of the prepared CNT/polymer composite materials were on the order of 10ohm-m at VGCF mixing ratio of 2wt% and 1ohm-m at 5wt%. The obtained characteristics are considered applicable enough to antistatic materials for membrane structure etc.

Acknowledgement

The authors would like to thank the financial support of the "CLUSTER" of Ministry of Education, Sports, Culture, Science and Technology of Japan.

References

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