Electron Beam Irradiation-Assisted Preparation of High-Concentration CNTs/Organic Solvent Dispersion for CNT-Composite Synthesis

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1. Introduction

Carbon nanotubes (CNTs) are recognized for their excellent mechanical, electronic, and thermal properties. Consequently, extensive research has been conducted on composites using CNTs. However, the van der Waals force of CNTs makes it challenging to develop composites using CNTs. To address this issue, many researchers are utilizing functionalized CNTs or surfactants. [1, 2] Despite these efforts, these methods fail to fully demonstrate the great advantages of pure CNTs. In this work, CNTs were dispersed in organic solvents at high concentration and then irradiated with electron beam to achieve well-dispersion while maintaining their inherent characteristics.

2. Methods and Results

2.1 Materials

The CNTs used in this study were single-walled CNTs (TUBALL) and thin-walled CNTs (JENO TUBE 6A, JEIO). And N,N-Dimethylformamide (DMF) and m-Cresol were used as organic solvents. We prepared SWCNTs/DMF and TWCNTs/m-Cresol dispersions, respectively.

2.2 CNTs dispersion

As a pre-irradiation treatment process, 0.45 g of CNTs were dispersed in a 90 mL organic solvent. The dispersion was then subjected to tip sonication for 2 minutes and stirred for 30 minutes, and this process was repeated 1, 8, and 15 times to accumulate 2, 16, and 30 minutes of tip sonication, respectively. After electron beam irradiation with 0 and 150 kGy, homogenization was performed for 0, 1, and 2 hours, respectively, as a post-irradiation treatment. In addition, sampling was performed with a doctor blade method to confirm the dispersion state, and the resulting samples were then observed visually and with an optical microscope.

2.3 Visual observation

On the SWCNTs/DMF dispersion, it couldn't be seen that the sampling through the doctor blade did not work well because the dispersion was not homogeneously dispersed. In the case of the dispersion subjected to tip sonication for a long time, when the electron beam was irradiated, it showed a relatively homogeneous dispersion state, and the doctor blade sampling was successful.

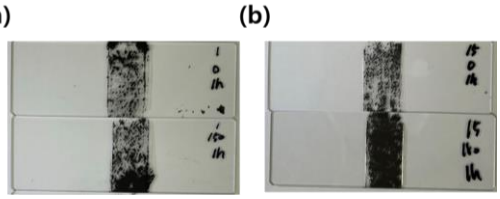

Fig. 1. SWCNTs/ DMF (a) tip sonicated 2 min (from above 0 kGy, 150 kGy), (b) tip sonicated 30 min (from above 0 kGy, 150 kGy).

However, the TWCNTs/m-Cresol dispersion showed a good dispersion state with little tip sonication. And the irradiated sample looked the evenly applied doctor blade.

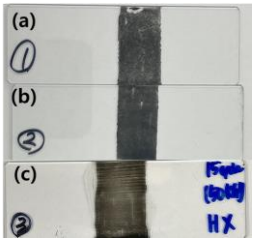

Fig. 2. TWCNTs/m-Cresol tip sonicated 2 min (a) 0 kGy, (b) 150 kGy, (c) tip sonicated 30 min, 150 kGy.

2.4 Optical microscopy

On optical microscopy images of SWCNTs/DMF, the condition which made a large difference was the tip sonication time. When sonication is performed for a long time, we saw that the CNTs were severed clearly. In addition, no significant differences were found under the optical microscope. It is assumed that this is because the SWCNTs/DMF was not homogeneous, and because the sample was dried in the doctor blade method, it was different from the dispersion state.

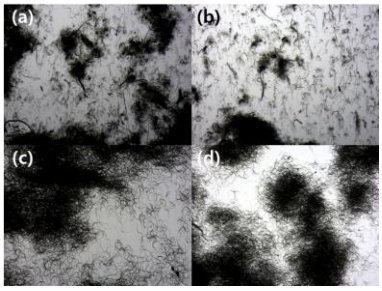

Fig. 3. Optical microscopy of SWCNTs/DMF tip sonicated (a) 2 min, 0 kGy, (b) 2 min, 150 kGy, (c) 30 min, 0 kGy, (d) 30

min, 150 kGy.

Similar to the visual observation, the TWCNTs/m-Cresol showed a well-sampled state through the optical microscope. And it was seen that the dispersibility is increased by the tip sonication time and the electron beam irradiation.

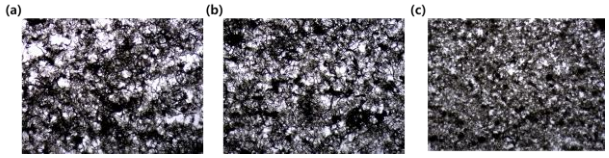

Fig. 4. Optical microscopy of TWCNTs/m-Cresol tip sonicated (a) 2 min, 0 kGy, (b) 2 min, 150 kGy, (c) 30 min, 150 kGy.

3. Conclusions and Future work

This study demonstrates that sufficient tip sonication treatment prior to electron beam irradiation can greatly improve the dispersion of CNTs in organic solvents. Notably, while DMF requires extensive sonication to achieve homogeneous dispersion, m-Cresol can achieve better dispersion characteristics even with minimal sonication, thus reducing damage to the CNTs during the dispersion process. However, the use of CNTs/DMF requires more advanced pre-processing, and the doctor blade sampling method employed in this study causes the solvent to dry, thereby making it difficult to evaluate the dispersion state of the CNTs.

Therefore, in subsequent experiments, we will optimize the irradiation pretreatment process for both DMF and m-Cresol dispersions and apply an appropriate sampling method to analyze dispersions.

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