PROPERTIES OF POLYPROPYLENE/CARBON FIBER/MULTI-WALLED CARBON NANOTUBE NANOCOMPOSITES

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1. Introduction

Composites of polypropylene (PP) with carbon fiber (CF)[1-5], carbon nanotubes (CNTs)[6-10] or graphene[11] have been widely studied. In particular, carbon fiber and carbon nanotube have good mechanical, thermal, and electrical properties.
During the manufacturing of semiconductors, many failures occur due to dust as well as sparks caused by static electricity. To address these problems, adequate electrostatic discharge (ESD) performance is required at many parts. Fig. 1 shows the electrical properties of various materials with differential volume resistivity.

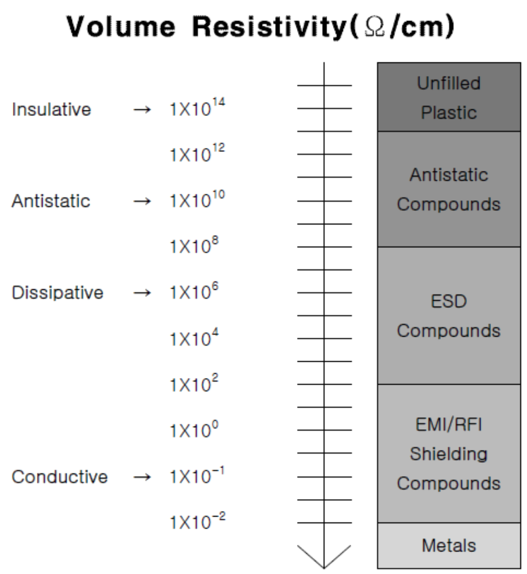

Fig.1. Electrical properties of various materials with differential volume resistivity [12-13]

In this work, the electrical and mechanical properties of melt mixed composites of PP/CF with MWCNTs have been investigated to realize ESD level polymer composites. Melt-mixed PP/CF/MWCNT composites were prepared using a twin screw extruder. From the results of the electrical conductivity of the PP/CF/MWCNT composites, it is found that the high aspect ratio of MWCNTs increases the conductivity of PP/CF composites in a polymer matrix compared to the composites without the MWCNTs. The tensile strength, flexural modulus, and notched-izod impact strength of the PP/CF/MWCNT composites were higher than those of composites without MWCNTs. This is attributed to the reinforcing effect of the well dispersed MWCNTs in the PP matrix. The measured electrical and mechanical properties indicated that the MWCNTs increase the electrical conductivity and mechanical strength of the PP/CF composites.

Table 1. Summary of the exact formulation and notation for each material examined in this study

Notation	PP (wt%)	CF (wt%)	MWCNT (phr)
PP(HJ500)	100	-	-
CFRP10	90	10	-
CFRP15	85	15	-
CFRP20	80	20	-
CFRP10MWCNT0.5	90	10	0.5
CFRP10MWCNT1	90	10	1
CFRP10MWCNT2	90	10	2
CFRP15MWCNT0.5	85	15	0.5
CFRP15MWCNT1	85	15	1
CFRP15MWCNT2	85	15	2
CFRP18MWCNT0.5	82	18	0.5
CFRP20MWCNT0.5	80	20	0.5
PP/MWCNT4	100	-	4

2. Experimental

2.1. Materials

Polypropylene was purchased from Samsung-Total, Korea. (Homo-PP, HJ-500, MI=11(at 230℃, 2.160kg)). Carbon fiber (Toray, Japan, T700SC, d=8um, l=6mm) and MWCNTs (EM-POWER, Korea, SDR-3152M, d=15nm, purity≥95%) were used as conductive filler without pretreatment.

2.2. Preparation

Composites were prepared using a co-rotating twin screw extruder (BAUTEK, Korea, BA-19, L/D=40, 19Φ). The temperature conditions of the extruder were 190-200-210-220-230-240-250-260-260-250℃ (from feeder to barrel) and the screw speed was 150rpm.

Table 1. presents a summary of the exact formulation and notation for each material examined in this study.

2.3. Property measurements

Measurements of the electrical surface resistance were conducted using a SRM-130(ORIONTEK, Korea). For electrical surface resistance, 5 points were measured randomly and averaged. The morphology of the cross-sectional surfaces of the CFRP/CNT composites was studied via field emission scanning electron microscopy (FE-SEM, JSM-7500F) at 15.0kV accelerating voltage after platinum deposition. The fractured surface of the composites was prepared by cryogenic fracturing. The tensile and flexural properties were studied using a universal testing machine (UTM, Tinius, H5KT) under the conditions of ASTM D638 and D790. The notched-izod impact strength test was performed with a SJTm-131 (Sejin, Korea) according to the ASTM D256.

3. Results and Discussion

3.1. Electrical property

MWCNTs improved the electrical properties of the PP/CF/MWCNT composites in the overall composition as compared to the case without MWCNTs. This is a result of the well dispersed MWCNT. In particular, the well dispersed MWCNTs serve as a pathway of current between CFs.[2]

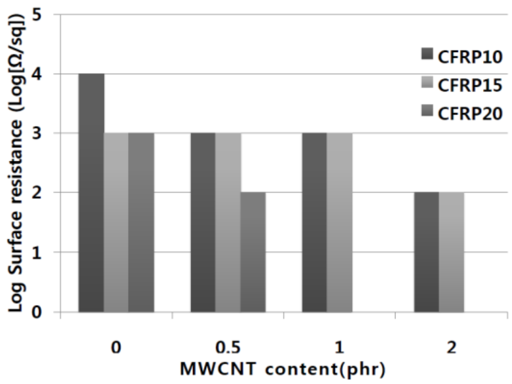

Fig.2. Surface resistance of CFRP/MWCNT with variation of MWCNT content

At 10wt% CF, the electrical surface resistance of the PP/CF/MWCNT composites was found to improve from 10^4 to $10^2\Omega$/sq with an increase from 0 to 2wt% of MWCNT content. From the above results, it is suggested that the higher aspect ratio of the MWCNTs facilitate a more productive network of the CFRP composites in the polymer matrix relative to the case of the composites without MWCNTs.

3.2. Morphology of CFRP/MWCNT composites

Fig. 3 shows scanning electron micrographs of CFRP15CNT composites with MWCNT content of 0, 0.5, 1phr and PP/MWCNT4. As seen in Fig. 3, the CFs are oriented to the flow direction. Fig. 3 d) shows the MWCNT dispersion morphology. It is suggested that the MWCNTs can disperse between the CFs.

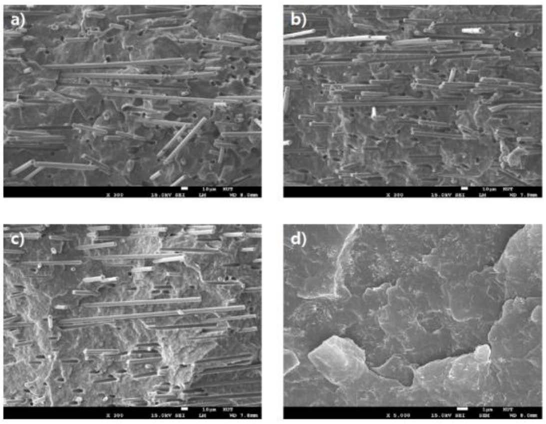

Fig.3. FE-SEM images of CFPR/MWCNT composites. a)CFRP15, b)CFRP15MWCNT0.5, c)CFRP15MWCNT1(X300) d)PP/MWCNT4(X5,000)

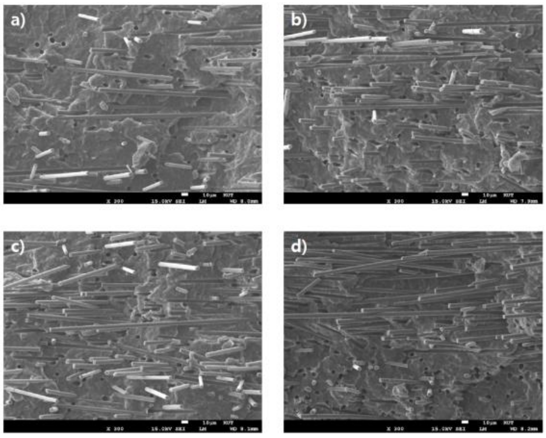

Fig.4. FE-SEM images of CFPR/MWCNT composites a)CFRP10MWCNT0.5, b)CFRP15MWCNT0.5, c)CFRP18MWCNT0.5, d)CFRP20MWCNT0.5 (X300)

From the results of Fig. 2, it is considered that the MWCNTs and CF create a conductive network. Improvement of the surface resistance of the CFRP composites with the addition of MWCNTs can perhaps be explained by an increased degree of connectivity between the fillers, that is the CF and MWCNTs.

Fig. 4 presents FE-SEM images of specimens with various contents of CF at 0.5phr MWCNT content. CF content was increased from 10wt% to 20wt%, resulting in better formation of a conductive network.

3.3. Mechanical properties

The effects of MWCNT and CF content on the mechanical properties of the composites are shown in Fig. 5. At 10wt% CF, the flexural modulus initially increased with the addition of MWCNT content and then was maintained with 1-2wt% of MWCNTs. At 15wt% CF, the flexural modulus increased to 5000MPa.

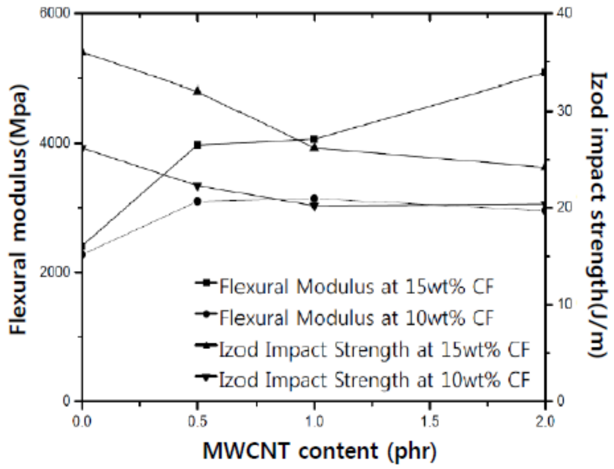

Fig.5. Flexural modulus and notched izod-impact strength of CFRP/MWCNT composites

In terms of impact strength, the CFRP15CNT composites are superior to the CFRP10CNT composites. It is suggested that the impact energy is dispersed according to the oriented CF. CF can slow down the cracking transfer rate. The fracture surface of the CF can be observed in Fig.6. Interfacial separation between the matrix and CF leads to high energy absorption.[14] The wave marks seen in the figure were produced by the effects of a discontinuous fracture phenomenon.[5]

Impact strength decreased with increasing MWCNT content, because the length of the CF was shortened. This is due to increased torque caused by the MWCNTs, during preparation with the extruder. This phenomenon can be observed in Fig. 3 a) – c).

4. Conclusion

In this study, we prepared PP/CF/MWCNT composites and measured their morphological, electrical and mechanical properties. MWCNTs led to decreased electrical surface resistance of the PP/CF/MWCNT composite. It is suggested that the MWCNTs and CF can make a conductive network in the polymer matrix.

From images of the fracture surface, separation of the interface between the matrix and CF resulted in improved mechanical properties. However, the impact strength decreased with increasing MWCNT content. The torque in the extruder was increased by the MWCNTs and the shortened length of the CFs.

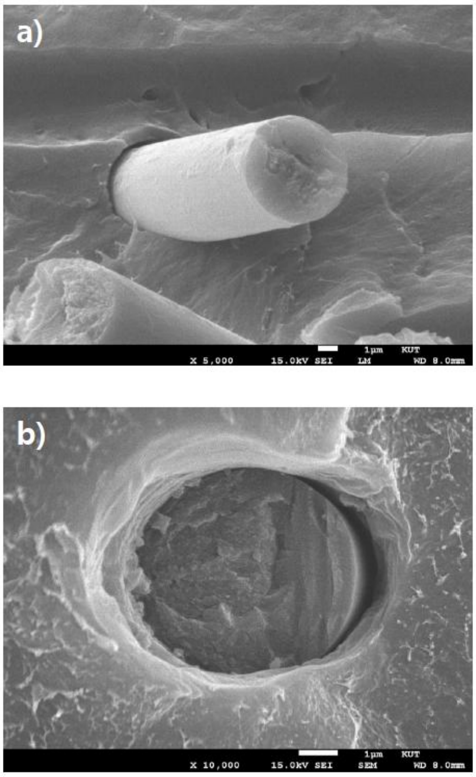

Fig.6. FE-SEM images of the fractured surface of CFPR/MWCNT composites a)(X5,000), b)(X10,000)

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