Injection moldable electrostatic dissipative composites based on polycarbonate/oxygen-plasma treated graphene nanoplatelet/multi-walled carbon nanotube

Akkachai Poosala[1,a], Kittipong Hrimchum[2,b], Darunee Aussawasathien[2,c]*
and Duanghathai Pentrakoon[3,d*]
[1]Technopreneurship and Innovation Management, Graduate School, Chulalongkorn University
Bangkok 10330, Thailand
[2]Plastics Technology Lab, Polymer Research Unit, National Metal and Materials Technology Center,
Pathumthani 12120, Thailand
[3]Department of Materials Science, Faculty of science, Chulalongkorn University
Bangkok 10330 Thailand
*Corresponding authors: [c]daruneea@mtec.or.th and [d]duanghat@yahoo.com
Present author: [a]akkachai@blt.co.th

Abstract

Electronic components are susceptible to damage from electrostatic discharge (ESD). The annual losses in products containing sensitive electronic components and subassemblies due to ESD during manufacturing, assembly, storage and shipping has been estimated in billions of dollars [1]. In order to reach savings of billions of dollars, an ESD control system should be introduced in production and handling. Electrostatic dissipative materials are often used to slow down the charge removal process and prevent a damaging ESD event during storage and shipping. For many articles in ESD protected environments the optimal surface resistivity is in the range of 10^5-10^9 Ω/sq [2, 3]. Electrostatic dissipating thermoplastic composites have successfully eliminated ESD failures in many applications in the electronics industry. A number of conductive fillers are presently available to material engineers, including carbon black (CB), carbon fibers (CF), metallic powders, flakes or fibers, and glass spheres or glass fibers coated with metals. For a given polymeric composite, electrical conductivity is determined by the amount, type and shape of the conductive fillers [4-6]. Carbon black-loaded static controlling products usually contain 15-20% CB by weight (wt%). This relatively high CB concentration causes local variation of the concentration of the conductive additives resulting in variation of the conductivity with location in the same product. The addition of carbon black at increasing levels has a negative effect on the processability of a composite and its mechanical properties: the melt viscosity increases and the impact resistance decreases. Contamination is also an important issue since, in highly filled CB composites, the carbon powder tends to slough and thus contaminate the environment. There is therefore a challenge in developing cleaner injection moldable composites with consistent and uniform surface resistivity in the static dissipative range.

Carbon nanotube (CNT) with a cylindrical nanostructure and graphene with a two-dimensional sheet of sp^2-hybridized carbon atoms densely packed in a honeycomb network have distinctly different geometry shape; but they have remarkable properties, such as superior thermal and mechanical properties and exceptional electronic transport [3-8], which make them excellent candidates as reinforcing and conducting fillers in composites.

In this research work, we are doing a technology edge which will replace the material of ESD composites from high loading CB to a small amount of conductive fillers using oxygen-plasma treated graphene nanoplatelet (OGNP)/multi-walled carbon nanotube (MWCNT) hybrid system, which will eliminate the contamination problem and provide permanent ESD properties including high mechanical properties. Injection moldable composites with desired resistivities in the ESD range (10^5-10^9 Ω/sq) for conveying in production lines, storage, shipment and for cleanroom applications, having good and balanced mechanical properties can be achieved by combining PC resin with 1.0-2.0 wt% OGNP and 2.0 wt% MWCNT as shown in Table 1. Such PC/OGNP/MWCNT composites will be suitable for making ESD containers (see Fig. 1) generally used in electronic and semiconductor and hard disk drive industries.

References

[1] S.P. Singh, H. El-Khateeb, Packaging Technology Science, Vol. 7 (1994) p.283.
[2] K. Vakiparta, EOS/ESD Symposium, Phonix AZ, (1995) p.229.
[3] R.W. Cambell, W. Tan, EOS/ESD Symposium,Phoenix AZ, (1995) p.218.
[4] M. Narkis, A. Ram, F. Flashner, Journal of Applied Polymer Science, Vol. 22 (1978) p.1163.
[5] M. Narkis, A. Ram, Z. Stein, Journal of Applied Polymer Science, Vol 25 (1980) p.1515.
[6] M. Narkis, A. Vaxman, Journal of Applied Polymer Science, Vol. 29 (1984) p.1639.
[7] P.G. Collins and P. Avouris, Scientific American Magazine, Vol. 283 (2000) p. 62.
[8] J. Nilsson, A.C. Neto, F. Guinea and N. Peres, Physical Review Letters, Vol. 97 (2006) p. 266.
[9] A.A. Balandin, S. Ghosh, W. Bao, I. Calizo, D. Teweldebrhan and F. Miao, Nano Letters, Vol. 8 (2008), p. 902.

[10] M. Poot and H.S. Van der Zant: Applied Physics Letters, Vol. 92 (2008), p. 111.
[11] M. Dresselhaus, G. Dresselhaus, J. Charlier and E. Hernandez: Philos. T. Roy. Journal of the Chemical Society A, Vol. 362 (2004), p. 2065.
[12] R.S. Ruoff and D.C. Lorents: Carbon, Vol. 33 (1995), p. 925.

Table 1 Properties of PC/OGNP/MWCNT composites

Samples / Properties	A	B
Tensile strength (psi)	8554	8608
Tensile modulus (psi)	$0.33x10^6$	$0.36x10^6$
Tensile elongation (%)	10.00	10.00
Flexural Strength (psi)	11178	12541
Flexural modulus (psi)	$0.29x10^6$	$0.32x10^6$
Izod notched (ft.lb/in)	1.24	1.27
Izod unnotched (ft.lb/in)	40.35 N	37.34 N
Shrinkage (in/in)	0.0070	0.0057
Specific gravity	1.18	1.19
Melt index	7.60	19.69
Volume resistivity (Ohm·cm)	$5.28x10^7$	$9.04x10^5$
Surface resistivity Point to Point (Ohm/sq)	$1.05\ x10^8$	$1.10x10^6$
Surface resistivity Point to Ground (Ohm/sq)	$1.6\ x10^5$	$1.15x10^5$
Graphene dosage (wt%)	2	1
MWCNT dosage (wt%)	2	2
Type of compatibilizer	Methyl methacrylate butadiene styrene (MBS)	Methyl methacrylate butadiene styrene (MBS)
Compatibilizer dosage (wt%)	0.5	0.5

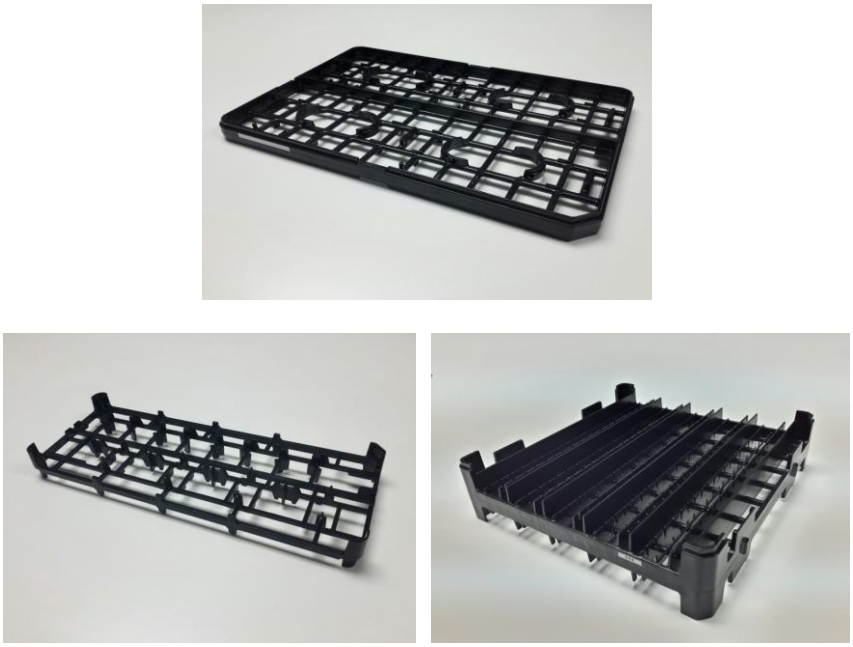

Fig. 1 ESD trays used in semiconductor and hard disk drive industries.