Anisotropic electromagnetic interference shielding properties of polymer-based composites with magnetically-responsive aligned Fe$_3$O$_4$ decorated reduced graphene oxide

Sung Yong Hong$^a$, Ye Chan Kim$^b$, Mei Wang$^c$, Jae-Do Nam$^{a,e}$, Jonghwan Suhr$^{a,d,*}$

$^a$ Department of Polymer Science and Engineering, Sungkyunkwan University, 2066, Seobu-ro, Jangan-gu, Gyeonggi-do, Republic of Korea
$^b$ Corporate R&D Group, LG Hausys, LG Science Park, 30, Magok-dong 10-to, Gangseo-gu, Seoul, Republic of Korea
$^c$ State Key Laboratory of Quantum Optics and Quantum Optics Devices, Institute of Laser Spectroscopy, Collaborative Innovation Center of Extreme Optics, Shanxi University, Taiyuan, Shanxi 030006, China
$^d$ School of Mechanical Engineering, Sungkyunkwan University, 2066, Seobu-ro, Jangan-gu, Gyeonggi-do, Republic of Korea
$^e$ Department of Energy Science, Sungkyunkwan University, 2066, Seobu-ro, Jangan-gu, Gyeonggi-do, Republic of Korea

ABSTRACT

Recently, polymer-based composites for electromagnetic interference (EMI) shielding materials have received considerable attention since the autonomous vehicle market is increasingly growing. However, the strategies for enhancing EMI shielding effectiveness (EMI SE) are limited to the increase of filler loading. Only few studies have been conducted on controlling fillers owing to the technical challenges. In this study, anisotropic EMI shielding properties of polymer-based composites were demonstrated and investigated. In order to control the orientation of reduced graphene oxide (RGO) in thermoplastic polyurethane (TPU), magnetic responsive RGO (Fe$_3$O$_4$@RGO) was synthesized for filler material. The orientation of Fe$_3$O$_4$@RGO was controlled in in-plane and out-of-plane direction by applying the magnetic field. For comparison with the aligned Fe$_3$O$_4$@RGO/TPU composites, random Fe$_3$O$_4$@RGO/TPU and random RGO/TPU composites were synthesized and characterized. The random Fe$_3$O$_4$@RGO/TPU composites showed 224% increased EMI SE over random RGO/TPU composites. The highest EMI SE, 250% improvement over random RGO/TPU composite, was observed in in-plane aligned Fe$_3$O$_4$@RGO composite among the four different composites. This could be attributed to improved electromagnetic wave (EM) loss by introducing magnetic nanoparticles, as well as enlarged effective reflection area of the aligned Fe$_3$O$_4$@RGO. Our results confirm that the orientation of fillers can play a key role in determining EMI SE in the composites. It can indicate that, if optimized, magnetically-responsive aligned polymer composites could significantly improve EMI SE of the composites by controlling the orientation of fillers, and also be a new solution to create anisotropic composites toward desirable properties.

1. Introduction

Recently, electromagnetic pollution has become a serious concern owing to the rapid development of various electronic devices. This is particularly true since the autonomous vehicle market is increasingly growing in our society. This type of pollution usually occurs in the form of electromagnetic interference (EMI) with other electronic devices, which causes malfunction and electromagnetic radiation, and poses potential risks to human health [1,2]. To address the aforementioned issues, novel and high-performance EMI shielding materials have drawn considerable attention in the relevant fields. Polymer-based composites containing electrically conductive nanofillers appear to become more attractive than traditional metal-based EMI shielding materials because of their light weight, applicability, good processability, and corrosion resistance. In particular, polymer-based graphene composites have been extensively investigated as EMI shielding materials due to their high specific surface area and excellent electronic conductivity [3–6].

In polymer-based graphene composites for EMI shielding, high nanofiller loading is required to attain desirable EMI shielding effectiveness (EMI SE). Increasing nanofiller loading in composites would be a simple and easy strategy to enhance the EMI SE of composites. However, it is well-known that higher loadings of nanofillers would...