ARTICLE IN PRESS

J Materiomics xxx (2018) 1–7

Contents lists available at ScienceDirect

J Materiomics

journal homepage: www.journals.elsevier.com/journal-of-materiomics/

High-damping and conducting epoxy nanocomposite using both zinc oxide particles and carbon nanofibers

Jae-Soon Jang [a], Gyo Woo Lee [b, *], Hyung-ick Kim [c], Sung Yong Hong [d], Lijie Ci [e], Jae-Do Nam [d, g], Jonghwan Suhr [d, f, g, **]

[a] Simulation Group, Battery R&D Center, SAMSUNG SDI CO.,LTD, Samsung-Ro, Yeongtong-Gu, Suwon-Si, Gyeonggi-Do, South Korea
[b] Division of Mechanical Design Engineering, Chonbuk National University, Jeonju, 561-756, South Korea
[c] Dongnam Regional Division, Korea Institute of Industrial Technology, Jinju 52845, South Korea
[d] Department of Polymer Science and Engineering, Sungkyunkwan University, 2066, Seoburo, Jangan-gu, Gyeonggi-do, South Korea
[e] School of Materials Science & Engineering, Shandong University, China
[f] School of Mechanical Engineering, Sungkyunkwan University, 2066, Seoburo, Jangan-gu, Gyeonggi-do, South Korea
[g] Department of Energy Science, Sungkyunkwan University, 2066, Seoburo, Jangan-gu, Gyeonggi-do, South Korea

A R T I C L E I N F O

Article history:
Received 11 January 2018
Received in revised form
25 April 2018
Accepted 15 May 2018
Available online xxx

Keywords:
Damping
Piezoelectric materials
Impedance
Poling treatment
Loss factor

A B S T R A C T

In this study, high-damping and conducting epoxy nanocomposites were developed with carbon nanofibers as conducting materials, and zinc oxide particles as piezoelectric materials. The mechanical and electrical properties, electrical impedance, and loss factors were investigated by uniaxial tensile tests, voltage measurement, impedance measurement, and 3-point bending tests. Two percolation thresholds were found: the percolation threshold of resistivity due to the carbon nanofibers forming conductive networks in the matrix; and the impedance threshold due to the zinc oxide particles acting like electric barriers. A poling treatment of the high-damping and conducting epoxy nanocomposite was considered, and we found that poling treatment helped to make the networks more conductive and to generate voltage from ZnO particles. A high-damping and conducting epoxy nanocomposite with 3 wt% CNF and 10 wt% ZnO exhibited higher loss factor than those of others tested.

1. Introduction

With the growth in demands for energy efficiency in structural applications and for high strength and stiffness-to-weight ratios, fiber composite materials are used in fields requiring high-performance structural applications such as aerospace, shipbuilding, and automobiles. Composite structures, however, are often subjected to dynamic loadings and exposed to undesirable environmental vibrations. The consequential trade-off for such high specific strength/stiffness ratios includes poor acoustic and vibration damping capacities, which leads to issues with structural vibrations, noise attenuations, and fatigue for composite structures [1,2]. Therefore, damping is a crucial material property for the noise and vibration mitigation of structures. Damping materials with embedded nano-fillers have been proposed, including carbon nanotubes (CNTs) in their matrix, in order to improve the energy dissipation capabilities in composites. It has successfully been demonstrated by many studies that the energy dissipation capabilities of the composites can be improved by the combination of the CNTs' high surface area and stick-slip friction [3–5].

Recently, some studies [6–12] have suggested piezo-damping materials using both conducting and piezo materials. The concept of the piezo-damping materials is to transmit the mechanical vibrating energy into the piezoelectric materials first, and then to convert the vibrating energy into alternating electrical potential energy by applying the piezoelectric effect. After that, the electrical potential energy is converted into heat, which goes through the conducting filler materials in the polymeric matrix [7–12].

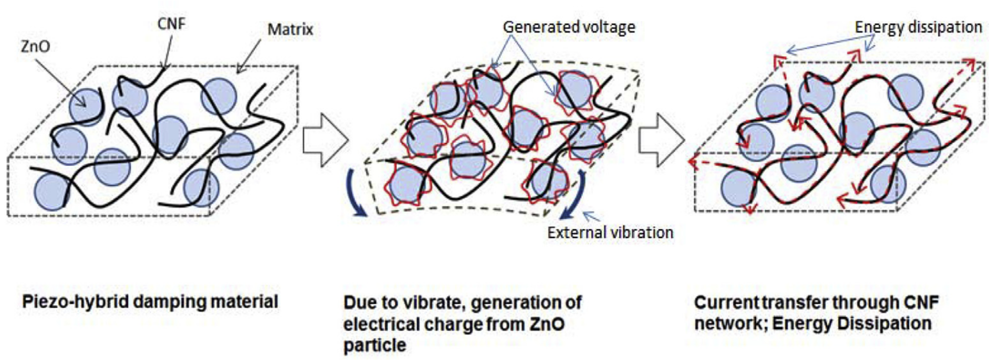
* Corresponding author.
** Corresponding author. Department of Polymer Science and Engineering, Sungkyunkwan University, 2066, Seoburo, Jangan-gu, Gyeonggi-do, South Korea.
E-mail addresses: gwlee@jbnu.ac.kr (G.W. Lee), suhr@udel.edu (J. Suhr).
Peer review under responsibility of The Chinese Ceramic Society.

https://doi.org/10.1016/j.jmat.2018.05.007

However, these studies have not clearly shown whether damping properties were generated by the piezo-damping or the filler material stick-slip mechanism, or a coupling of the two phenomena. For example, Banerjee and Cook-Chennault [11] studied the loss factor and piezoelectric coefficient in the composites with filler materials such as aluminum and PZT. However, they did not consider the combination of the stick-slip friction effect with high-aspect-ratio filler materials. Tian et al. [12] showed the improvement of damping properties of a composite containing PZT and CNT filler materials, but they only used filler materials without any consideration of the characterization of mechanical properties and the poling treatment of PZT.

In this study, a high-damping and conducting epoxy nanocomposite with CNF for the conducting network and ZnO particles for piezo-electricity was developed. Fig. 1 (a) shows the concept of the high-damping and conducting epoxy nanocomposites, and Fig. 1 (b) shows an SEM image of the fabricated high-damping and conducting epoxy nanocomposites. The concept of the high-damping and conducting epoxy nanocomposite is as follows: 1) Using the minimum amount of CNF as a high-aspect-ratio filler material, the conducting network is developed in the epoxy matrix. 2) During the mechanical vibration of the specimen, heat is generated due to the stick-slip friction at the interface of the CNFs and matrix. 3) Simultaneously, electric charges are generated by the compressed ZnO particles in the specimen due to piezoelectric effect. 4) Both the generated heat and electric charges are transferred and dissipated through the conducting network of the CNF in the matrix. 5) This means that the external mechanical energy acting on the composite specimen could be dissipated through the heat generated from the interfacial friction between the matrix and the fillers, and the electric energy due to the piezoelectric effect of the ZnO filler. Therefore, the coupled effect of the damping and conducting is investigated in this study. The minimum amount of CNF is investigated for the conducting paths. In order to clearly understand the piezo-damping effect, an abnormally large amount of ZnO particles is used. Young's modulus, the impedance, the poling treatment effect, and the generated voltage and loss factor of the high-damping and conducting epoxy nanocomposite are determined. The results of this study will be helpful in the design of high damping and conducting composite materials.

(a)



(b)

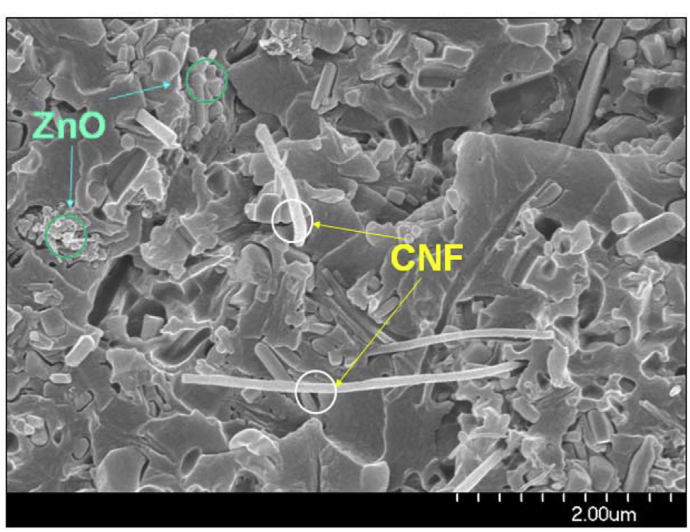


Fig. 1. (a) Schematic of high-damping and conducting epoxy nanocomposite with CNF network and ZnO. (b) SEM image of the fabricated high-damping and conducting epoxy nanocomposite containing 3 wt% CNF and 100 wt% ZnO (compared with the total weight of matrix).

Please cite this article in press as: Jang J-S, et al., High-damping and conducting epoxy nanocomposite using both zinc oxide particles and carbon nanofibers, J Materiomics (2018), https://doi.org/10.1016/j.jmat.2018.05.007