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

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ABSTRACT

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.

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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].