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Thermally Activated Energy Dissipation in Semi-crystalline Polymer Nanocomposites

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Abstract

In this manuscript, we demonstrate the concept of active damping in semi-crystalline thermoplastics which are reinforced with a percolated network of CNTs, where the damping of the composite was augmented considerably, controllably and reversibly via Joule heating. The Joule heating triggered relaxation mechanisms in the amorphous phase of the matrix. To this end, semi-crystalline poly ether ether ketone (PEEK) polymer and PEEK/carbon nanotube (CNT) composites were fabricated and their viscoelastic properties studied. The damping capability was experimentally tested by dynamic mechanical analysis. The polymer relaxation resulting from an increase in temperature, triggered by the Joule heating of the nanoparticles, demonstrated the potential for damping enhancement in the composite. A considerable enhancement in damping (by as much as 400%) was achieved at a significantly lower relative loss in storage modulus (40%), both caused by relaxation mechanisms in Joule heated samples. This enhancement in damping corresponds to a 150% improvement in the figure of merit for damping materials. The non-uniform temperature distribution in the sample was measured experimentally at the macroscale and estimated via continuum models at the microscale. It was concluded that non-uniform temperature distribution in the composite, especially at the microscale, had a large effect on the overall damping enhancement. Based on the microscale models, potential mechanisms by which the active damping can be enhanced are discussed.

Keywords: Active damping, viscoelastic damping, nanocomposites, PEEK

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1. Introduction

The ratio of loss to storage modulus, also known as *tan* δ, in polymers is strongly dependent on temperature, especially near the glass transition temperature, T_g. [1]. The remarkable temperature sensitivity of viscoelastic properties of a polymer can be utilized to dissipate undesired mechanical energy input to polymer-based composites in the form of vibration. This concept can in principle enable the development of advanced concepts such as active rotor vibration reduction leading to reduced operating