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# Viscoelastic and mechanical properties of multi walled carbon nanotube/epoxy composites with different nanotube content

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ABSTRACT

The viscoelastic and mechanical properties of composites multi walled carbon nanotube (MWNT)/epoxy at different weight fractions (0.1, 0.5, 1 and 2 wt.%) were evaluated by performing tensile and dynamic-mechanical thermal analysis (DMTA) tests. The MWNT/epoxy composite were fabricated by sonication and a cast molding process. The results showed that addition of nanotubes to epoxy had significant effect on the viscoelastic and mechanical properties. However, the use of 0.5 wt.% increased the viscoelastic properties more significantly. Concerning viscoelastic modeling, the COLE–COLE diagram has been plotted by the results of DMTA test. These results show a good agreement between the Perez model and the viscoelastic behavior of the composite.



## 1. Introduction

The discovery of carbon nanotubes (CNT) and carbon nano structured materials has opened new possibilities for a range of potential applications [1–4]. More specifically, the use of carbon nanotubes in polymer/carbon nanotubes composites has attracted much attention in term of exceptional mechanical and electrical properties [5–7].

Thermoset polymers comprise an abroad range of polymers with a large number of industrially relevant application, including coating, encapsulates and matrices for fiber reinforced composites. Thus, the idea of combining CNT with thermosets is very appealing from several perspectives. Among various polymers, epoxy resin is the most common class of thermosetting resin used in various applications due to its high tensile strength, modulus, low curing shrinkage in cure, good chemical and corrosion resistance, high adhesion and dimensional stability. The main drawback of epoxy resins for structural applications may be its inherent brittleness. Thus, several research works have recently been devoted to reinforcement of epoxy matrices with CNT [8–10]. Recently, the use of MWNT as the filler in polymer matrix has attracted considerable interest due its unique mechanical, thermal, and electrical properties. Nanotubes epoxy composites have been fabricated using different purification and dispersion processes [11–16]. In general, the mechanical and viscoelastic properties were found to depend on the degree of dispersion of CNT. Control of the nanotubes dispersion can be facilitated by manipulating the polymer/CNT mixture. It is necessary to understand the effect of CNT dispersion on the various properties of the CNT filled composites. However, quantitative characterization of CNT dispersion is a difficult task. The best indirect method is to perform the dynamic-mechanical thermal analysis (DMTA) test. According to the dispersion state of CNT, different storage modulus ($E'$) and loss modulus ($E''$) behavior are expected [17–22].

The complex modulus components $E'$ and $E''$, depend on loading frequency. These functions are determined in a wide range of temperature and frequency and by drawing $E'' = f(E')$ (COLE–COLE) plots [20].

Various models have been proposed to account for the viscoelastic behavior. These models are mechanical analogies of Maxwell, Kelvin–Voigt, Havriliak–Negami [21] and Perez model, which are usually made from combination of spring and dashpot [22]. Models proposed by Havriliak-Negami and Perez usually give a good fit of COLE–COLE plots. In the case of a good fit with experimental data, their parameters can be identified and eventually can be interpreted in terms of the width of the relaxation spectrum, effect of cross linking, etc. [20].

The main purpose of this research is to study on the mechanical and viscoelastic properties of epoxy composites at different contents of multi walled carbon nanotubes. For this purpose tensile and DMTA tests were applied. The Perez model is used to study on the viscoelastic behavior. The nanotubes dispersion was investigated through scanning electronic microscopy (SEM) and atomic force microscope (AFM).

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