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Characteristics of Single-Walled Carbon Nanotube-Reinforced Polycaprolactam Nanocomposites

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ABSTRACT

The material characteristics, configuration, and phase geometry of each individual component were examined in order to determine the impact of carbon nanotube loading and aspect ratio on the thermal expansion characteristics of polymer nano composites. The goal of this study is to develop techniques for making carbon nanotube reinforced polymer nanocomposites with extremely low thermal expansion coefficients. To further understand the morphology-property correlations, the thermal expansion characteristics of polycaprolactam nanocomposites synthesised with various levels of thermal histories were examined. On the thermal expansion behaviour of the polymer nanocomposites, the impacts of carbon nanotube loading and aspect ratio were assessed. The findings showed that carbon nanotube loading and aspect ratio significantly affect the thermal expansion characteristics of the High aspect ratio polymer nanocomposite materials with heavy filler loading are recommended.

Keywords: Nanotube; Nanocomposite; Correlations; Configuration

INTRODUCTION

To effectively reduce the features of thermal expansion, the issue of carbon nanotube dispersion is essential. In order to create polymer nanocomposites with a very low coefficient of linear thermal expansion in the required direction, it is also preferable to obtain a high degree of alignment of carbon nanotubes in the matrix along the desired direction. Additionally, the thermal expansion characteristics of the polymer nanocomposite are decreased as a result of flow-induced alignment of carbon nanotubes in the matrix along the direction of flow. The relative Young's modulus, the relative thermal expansion of the nanocomposite, and the matrix all exhibit excellent linear correlations [1].

MATERIALS AND METHOD

Due to their potential uses in numerous industries, there is a growing interest in creating composite materials with enhanced mechanical and physical qualities. The creation of improved polymer matrix composites has been the main focus of study. Due to their superior characteristics, particulate-filled polymer composites are frequently used. The polymer matrix is frequently supplemented with nanoparticles to increase its yield strength and elastic modulus. In all branches of materials research, there is still great interest in polymer nanocomposites, which are made by combining polymers with organic or inorganic nanoparticles [2]. Because of their numerous desirable performance characteristics that are strongly related to mechanical and physical qualities, polymer nanocomposites have generated interest. Such nanocomposites offer high specific stiffness, great strength, and outstanding durability along with low weight. Significant focus has been devoted to developing polymer nanocomposites with distinctive characteristics. Many of these nanocomposites have been made available for purchase, and numerous processing techniques have also been created. In automotive applications, the melt mixing technique assumes special significance. For a specific application where sufficiently low coefficients of thermal expansion are more important than high mechanical performance, there is growing interest in polymer nanocomposites [3]. Unfortunately, the high coefficients of thermal expansion of typical polymer nanocomposites sometimes limit their ability to achieve desired performance characteristics. Therefore, it is very important to investigate a practical means of lowering the coefficients of thermal expansion for polymer nanocomposites. There is a demand for polymer nanocomposites with extremely low thermal expansion coefficients. The coefficients of thermal expansion for polymer nanocomposites at low filler concentrations have been significantly reduced [4]. Recent research has shown that high aspect ratio fibres are very promising as fillers for lowering the thermal expansion characteristics of polymer composites. Additionally, there has been a growing interest in the utilisation of Utilizing polymer nanocomposites reinforced with

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such a nanoscale filler is one of the potential strategies to generate materials with lower thermal expansion properties. A variety of polymers can be filled with carbon nanotubes. In order to lessen the dimensional changes caused by thermal absorption for polymers, it has been discovered that carbon nanotubes exhibit a negative coefficient of thermal expansion at ambient temperature. Polymer materials with regulated thermal expansion properties have a unique opportunity to be used in certain applications because of the negative thermal expansion capabilities of carbon nanotubes. In a variety of applications, including the packaging of electronic and optoelectronic components, polymer composites with very low thermal expansion are valuable as dielectric materials. There has been some theoretical research into the thermal expansion behaviour of carbon nanotube-reinforced polymer nanocomposites recently [Figure1]. The adhesion between the phases should be clarified by thermal expansion, which entails the passage of stresses across the interface between carbon nanotubes and the surrounding polymer matrix [5]. The elastic characteristics of the phases are also closely related to the thermal expansion behaviour.

RESULT

The possible benefits of carbon nanotubes' extremely high aspect ratio include to drastically lowering the thermal expansion coefficient of polymer nanocomposites. It is yet unclear how carbon nanotube aspect ratio affects the thermal expansion characteristics of polymer nanocomposites. The development of carbon nanotube reinforced polymer nanocomposites with extremely low coefficients of thermal expansion would also be desirable. Understanding the thermal expansion behaviour of polymer nanocomposites reinforced with single-walled carbon nanotubes is the main goal of this study [6]. The effects of single-walled carbon nanotube loading and aspect ratio on the thermal expansion characteristics of polymer nanocomposites are highlighted. The thermal expansion behaviour of polymer nanocomposites is predicted here using the theoretical model created by Chow, taking into account the material characteristics, component configurations, and phase geometries of each individual component. Here, the model is specifically used to determine the thermal expansion coefficients of polymer nanocomposites. It differs from previous models of thermal expansion found in the literature in that the effect of filler aspect ratio is taken into account. As well as being known as Since nylon 6, or polyamide 6, is one of the most important construction materials utilised in various industries, such as the automotive, apparel, electronics, and electrotechnical, as well as the aerospace industries, it is used here as the matrix for a polymer nanocomposite. This study aims to develop techniques for making polymer nanocomposites with extremely low thermal expansion coefficients [7].

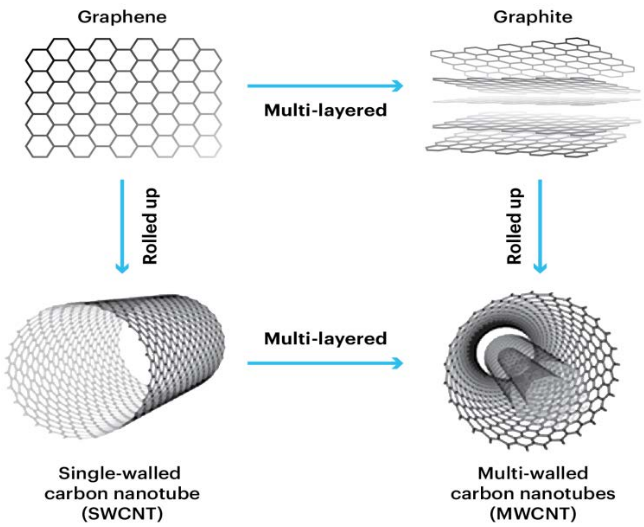

Figure 1: Single-Walled Carbon Nanotube-Reinforced.

DISCUSSION

The potential connection between Young's modulus and thermal expansion is particularly intriguing. A polymer chain's inherent characteristics are highly directionally dependent. In particular, the orientation of polymer chains with regard to the direction of flow during processing, such as in injection moulding and film or fibre extrusion, affects the physical properties of a thermoplastic polymer. In a three-dimensional orthogonal coordinate system, the orientation can be determined by the flow direction, transverse direction, and normal direction. Particularly in a polymer matrix, the flow-induced alignment of filler particles has attracted a lot of interest [8]. The orientation of the filler with regard to the direction of flow will have a significant impact on the effective thermal expansion coefficient of a polymer nanocomposite. For filler particles with a high surface area, the thermal effect is more noticeable [9].

The effective coefficient of linear thermal expansion can be significantly decreased in the longitudinal direction, leading to a significant improvement in the thermal property, when carbon nanotubes are randomly distributed in the matrix with their corresponding axes being well-aligned along the direction of flow. Here, the theoretical model created by Chow is applied to forecast the actual coefficients of thermal expansion of nanocomposites made of polycaprolactam.

The thermal expansion coefficients of polycaprolactam and single-walled carbon nanotubes are positive and negative, respectively. The model assumes that the filler has uniform dimensions and is fully aligned, and treats the distributed carbon nanotubes as aligned ellipsoids. In situations when the presumption of uniform dimensions is no longer true, it gets fairly complex. The model's modifications in diameter are not taken into account. In a Cartesian coordinate system, the ellipsoid's implicit equation has the conventional form, where and c are the minor and major axes' respective half-lengths. The principal axis of the ellipsoids is assumed by the model to be parallel to the flow direction. As a result, the entire polymer nanocomposite assumes a transverse isotropic orientation about this axis [10].

CONCLUSION

The aspect ratio of the filler, which is defined as the ratio of the main axis to the minor axis, determines the morphology of anisotropic carbon nanotubes. Transverse isotropy of single-walled carbon nanotubes about the x3 axis. The polymer nanocomposite's effective coefficient of volumetric thermal expansion is connected in relation to the transverse and longitudinal effective coefficients of linear thermal expansion, The effective coefficient of linear thermal expansion in the longitudinal direction, when carbon nanotubes are randomly arranged in the matrix with their corresponding axes aligned, can be written as, and the effective coefficient of linear thermal expansion in the transverse direction, where k is the bulk modulus and is the volume concentration of filler. The filler and matrix are identified by subscripts 1 and 2, respectively. The shear modulus is used to define the Ki and Gi functions, and I and I can be represented. The following are the mechanical and physical presumptions made for the filler and matrix. one particular single-walled carbon nanotube's elastic modulus Two molecular weight grades of the polymer matrix are taken into consideration in the current work, The low molecular weight polycaprolactam and the high molecular weight polycaprolactam have the following elastic moduli, respectively. Additionally, the filler and matrix both have a Poisson's ratio of 0.48 and 0.33 [11]. In the relevant temperature range, single-walled carbon nanotubes have a coefficient of thermal expansion of 1.0 105 (1/K). The matrix's glass transition temperature is 320 K. Finally, the low and high molecular weight polycaprolactam have coefficients of linear thermal expansion of 8.30 105 (1/K) and 6.75 105, respectively. Specifically, they are 1.49 104 (1/K) and 1.40 104 (1/K), respectively, at temperatures below the glass transition temperature and at temperatures above the glass transition temperature [12]. In the current study, in order to assess the impact of carbon nanotube aspect ratio, the thermal expansion characteristics of polymer nanocomposites created with two distinct degrees of thermal histories, under injection moulding and annealing circumstances, are thoroughly explored. It may be possible to determine the ideal thermal expansion characteristics of polymer nanocomposites using the aspect ratio of carbon nanotubes. The ideal filler geometry, however, might not be the greatest for another physical or mechanical property [13].

Acknowledgement

None

Conflict of Interest

None

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