



Review

Effect of maleic anhydride on dielectric properties of natural fiber composite



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ABSTRACT

The use of short palm tree lignocellulosic fibers as a reinforcing phase in polyester matrix has been reported. In order to improve interfacial adhesion, the esterification of the lignocellulosic filler in alkaline medium was performed using maleic anhydride. The dynamic dielectrical analysis of short palm tree lignocellulosic fibres reinforced polyester composites was carried out. Measurements were performed in the frequency range 1–10⁴ Hz. Two relaxations processes were identified in the case of polyester matrix and non treated fibre composite, which are the α relaxation associated with glass–rubbery transition of the polymer and the relaxation process associated with conductivity occurring as a result of the carriers charges diffusion for high temperature above glass transition and low frequencies.

For the treated fiber composite with anhydride, a new relaxation process due to the molecular motion of amorphous celluloses was identified.

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1. Introduction

Over the past two decades, natural plant fibers have been receiving considerable attention as the substitute for synthetic fiber reinforcement such as glass in plastics [1,2]. The advantages of plant fibers are low cost, low density, acceptable specific strength, good thermal insulation properties, reduced tool wear, reduced dermal and respiratory irritation, renewable resource and recycling possible without affecting the environmental damage, and together with biodegradable ability [3,4].

However, in origin the plant fibers exhibit a high hydrophilic property as they are composed of lignocellulose, which contains strongly polarized hydroxyl groups [5–7]. Therefore, these fibers are inherently incompatible with hydrophobic polymer matrix materials and especially for poor interfacial adhesion between the hydrophilic natural fibers and conventional resin matrices. The matrix materials are popularly used in biodegradable composites including thermoplastics such as a polypropylene and a polyethylene.

The incompatibility may cause problems in the composite processing and material properties. Hydrogen bonds may form between the hydrophilic fibers, and thus the fibers tend to agglomerate into bundles and unevenly distribute throughout the non-polar polymer matrix during compounding processing [8].

There is also insufficient wetting of fibers by the non-polar polymer matrices, resulting in weak interfacial adhesion. As a result, the stress transfer efficiency from the matrix to the reinforcing fibers is reduced.

By this token, treatment of natural fibers is beneficial in order to improve the water resistance of fibers, enhance the wettability of the natural fiber surface by polymers (mainly non-polar polymers) and promote interfacial adhesion. The chemical modification may make the fiber cell walls more dimensionally stable, reduce water sorption [9], or increase resistance against fungal decay, but there may be an associated reduced dynamic strength such as impact strength due to embrittlement. A coupling agent is a chemical that functions at the interface to create a chemical bridge between the reinforcement and matrix [4].

Several methods have been tested to enhance adhesion between the lignocellulosic filler and the polymer matrix. They generally involve fiber and/or matrix modification by physical or chemical methods. In chemical methods, for a polar thermoplastic matrices such as PP, several coupling agents have been used to modify the nature of the interactions at the fiber surface. Among these coupling agents, maleic anhydride graft PP homopolymers or copolymers have been widely used [10–12]. On the other hand, silicon alkoxides such as alkyl triethoxysilanes [13] have been widely used to modify lignocellulosic fibers.

The aim of this paper is to characterize the effects of treatments of natural fibers with maleic anhydride on dielectric properties of the resulting composites (polyester/palm tree fiber).

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2. Experimental

2.1. Materials

The polyester used for the study was an unsaturated polyester resin G154TB (containing 31 wt% of styrene monomer and having a gelation time at 25 °C for 30 min). The lignocellulosic filler was obtained by cutting the palm tree leaves. There are obtained by cutting the palm tree leaves. The filler content was fixed at 7 wt% for all the composite materials.

The composites were prepared using the classical “contact method” which consists in the deposition of the fibers in a rectangular mold and its physical impregnation with the liquid resin. At the end of the stratification the mold was closed and a pressure of 2 bars was applied for 24 h. The modification of fibers was done with maleic anhydride (Aldrich) for 30 min.

The resulting fibers were denoted as modified fibers. The latters were then dried under vacuum at 60 °C for 24 h. The chemical modification of the fiber was checked by FT-IR in a transmission mode. The chemical compositions of the dried palm fibers were determined according to the French Standards (NF T 12-011).

2.2. Dielectric relaxation spectroscopy

In dielectric analysis, the sample is placed between two gold parallel plate electrodes (diameter of 24 mm). The fibres are totally embedded in the matrix, so there is no contact between fibres and electrodes. A sinusoidal voltage is applied, creating an alternating electric field. This produces polarization in the sample, which oscillates at the same frequency as the electric field, but has a phase angle shift. This phase angle shift δ is measured by comparing the applied voltage to the measured current, which is separated into capacitive and conductive components. Measurements of capacitance and conductance are used to calculate

- Permittivity ϵ' which is proportional to capacitance and measures the alignment of dipoles.
- Dielectric loss ϵ'' which is proportional to conductance and represents the energy required to align dipoles and move ions.
- Dielectric loss factor. $\tan \delta = \epsilon''/\epsilon'$

The parallel plate sensors are used to evaluate bulk dielectric properties, and to track molecular relaxations. The lower electrode, positioned on the surface of the furnace, applies the voltage that sets up the electrical field in the sample. A platinum resistance temperature detector (RTD) surrounds the perimeter of the gold electrode and measures the temperature of the sample. The temperature is controlled directly by the RTD. The upper electrode, attached to the face of the ram, measures the generated current, which is then converted to an output voltage and amplified. A guard ring around the perimeter of the upper electrode corrects for electric field fringing and for stray capacitance at the edge of the plates. Signal circuits are connected through pads on the lower sensor, which contact spring probes attached to the ram. The plate spacing (sample thickness 0.3–0.5 mm) recorded at the start of the method is used throughout the experiment in the calculation of ϵ' and ϵ'' .

3. Result and discussion

The dielectric characterisation of the resin polyester matrix was conducted from the room temperature to approximately 150 °C for the following frequencies 1,10, 100,1000 and 10,000 Hz. We show from Fig. 1 the variation of the loss factor ϵ'' as a function of temperature. The spectra can be divided into two temperature regions:

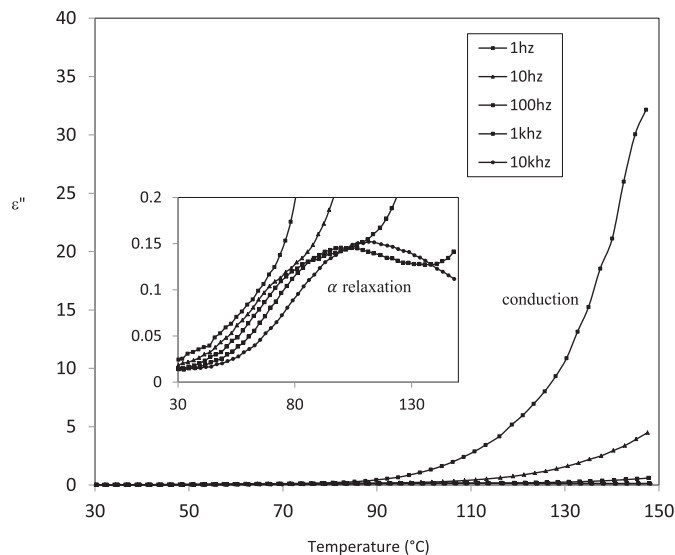


Fig. 1. Isochronal runs of the loss factor ϵ'' versus frequency for the polyester matrix.

The α relaxation associated with the glass–rubbery transition of the polymer at a higher frequency. The relaxation peak maximum, shifts to higher frequencies with temperature, because increased temperature results in faster movement, which leads to decreased relaxation times, consequently shifting the maxima to higher frequencies [14].

The ionic conduction appearing for temperature above glass transition T_g and low frequency range which arise from the increase in the mobility of electric charges in the polymer with temperature thus giving rise to a conduction processes that bring about a large increase in both the real and imaginary part of the dielectric function [15–17].

The loss factor ϵ'' of the non treated fibre composite is shown in Fig. 2. We observe the same phenomena of relaxation associated to the α relaxation and the ionic conduction. Compared to the unfilled matrix we can notice an increase of the permittivity due to an increase of the total polarization arising from dipoles and trapped charge carries [18].

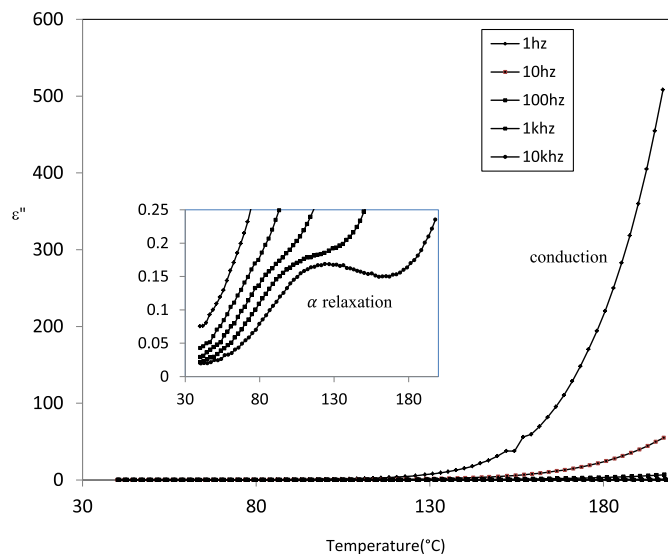


Fig. 2. Isochronal runs of the loss factor ϵ'' versus frequency for the non treated fiber composite.

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