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Synthesis and characterization of starch/Na$^+$-montmorillonite clay nanocomposites

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Abstract

Native corn starch and montmorillonite caly nanocomposites were prepared using the glycerol as the plasticizer. These were characterized by mechanical analysis, X-ray diffraction, infrared spectroscopy, differential scanning calorimetry, and scanning electron microscopy. The tensile strength increased with the clay content to a maximum point and then decreased due to gapping between the two phases. Dispersion of the layered silicate within the starch was verified using X-ray diffraction pattern. Examination of these materials by scanning electron showed that intercalates have good wetting to the starch surface.

Introduction

Nanocomposites are a relatively new class of materials. The introduction of inorganic fillers to a polymer matrix increases its strength, modulus and stiffness and heat resistance [1,2].

In order to improve mechanical properties and water resistance, starch has been modified by blending with synthetic or natural polymers. Among these natural polymers, inorganic materials applied to a polymer matrix lead to enormous interest in studying its uses. But few studies are reported on starch/clay nanocomposites. In the present study, Na$^+$-montmorillonite clay is added to starch and from this mixture starch/clay nanocomposite is obtained. The dispersion of clay into the starch matrix, mechanical, thermal and morphological properties with different weight percents of clay is investigated.

Experimental

Materials and preparation

Regular cornstarch (30% amylose), supplied by Samyang Co.(Korea), and reagent grade glycerin are used. The clay used in this study is an organophilic MMT from Southern clay products, Inc. (Gonzales, Texas) under the trade name of claytone.

Starch and glycerin, 30% w/w of glycerin to starch are pre-mixed in polyethylene bags until a powder is obtained. The starch/clay ratios are 100/0, 95/5, 90/10, 80/20, 70/30, and 60/40 (w/w), relative to dry starch. The different amount of starch/clay ratio and glycerin aqueous suspensions are casted and maintained at 40-50℃.

Characterization

A Minimat opetating at a crosshead speed of 5 mm/min at room temperature is used to determine tensile properties of the nanocomposites.

X-ray diffraction

The extent of clay exfoliation in the nanocomposites is determined by X-ray diffraction (CuKα radiation λ=1.5406 Å). Samples are scanned in 2θ ranges from 0.5 to 50° at a rate of 1°/min.

Thermal analysis

Differential scanning calorimetry (DSC) is carried out using a TA Instrument. Samples are heated from 30 to 400℃ at a rate of 10℃/min under a nitrogen atmosphere.

Infrared spectroscopy

Infrared spectroscopy are recorded using a M series Midac apparatus. Transmittance spectra are obtained by accumulation of 64 scans and a 4 cm^{-1} resolution.

Scanning electron microscopy

SEM micrographs of the fractured surfaces of the nanocomposites are studied on a JEOL scanning electron microscope (JSM-5410LV) operating with an accelerating voltage of 10kV.

Results

Mechanical properties

The modulus of the nanocomposites are shown in Figure 1. With increasing clay content, the nanocomposites show a substantial improvement in modulus compared to the non-containing clay material, that is, only neat starch 100% material.

DSC analysis

The DSC thermal traces for starch/clay

nanocomposites with different amount of clay are shown in Figure 2. It can be seen that three endothermic transitions associated with the soft segments of the clay phase are observed at 146-165°C, 283-301°C and 288-310°C. The transition temperature is increased with clay content due to increased hard segment concentration. However, for the first transition temperature, the peak decreases with clay content.

X-ray diffraction

The X-ray diffraction patterns of starch/clay nanocomposites are shown in Figure 3. The XRD patterns of pure clay contained a peak at $2\theta=2.75°$, while a peak at this degree in the pure starch is not observed in the XRD pattern. In this case, This peak at $2\theta=2.75°$ is shifted with increasing starch content in the nanocomposite films.

Morphology

The SEM microphotographs show the cleavage fracture implying that the toughness of the starch increased with the addition of clay.

Conclusions

Tensile strength and yield strength of the content of clay 5 wt% is higher than that of neat starch material. In the DSC thermograms, there are three endothermic transitions. A peak at $2\theta=2.75°$ is shifted with increasing starch content in the nanocomposite films in the XRD. In the FT-IR analysis, the intensity changes in the peak below 800 cm^{-1} are observed. From the SEM, when the starch contents are decreased, the toughness is increased with the addition of clay.

References

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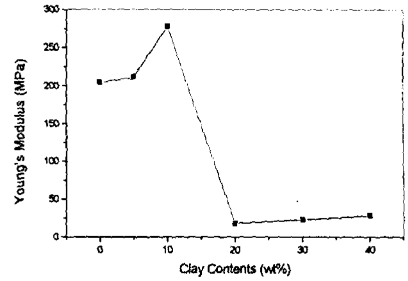


Figure 1. Young's modulus as a function of clay content for the starch/clay nanocomposites.

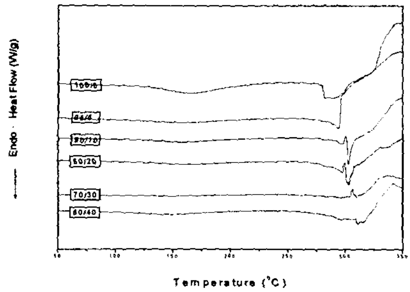


Figure 2. DSC scans for the starch/clay nano-composites.

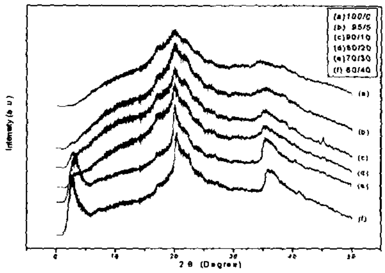
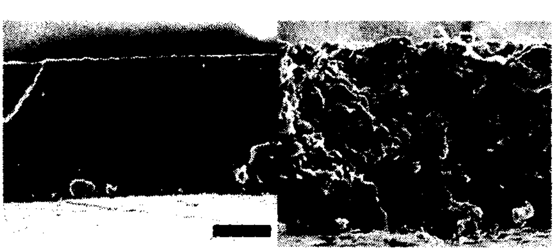


Figure 3. XRD patterns of starch/clay nano-compsites.



(a) (b)

Figure 4. Morphology of starch/clay nano-composites. (a) 100/0 (b) 60/40