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ORIGINAL RESEARCH

THE EFFECT OF MOLECULAR WEIGHT ON THE THERMAL STABILITY OF CELLULOSE ACETATE

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ABSTRACT. An organic ester with good mechanical characteristics (such as a high Young's modulus and tensile strength) is cellulose acetate (CA), a biobased polymer. Over the past few decades, the thermal characteristics of CA have been extensively studied. This study looked at the morphology and thermal characteristics of plasticized CA, particularly its mass loss according to thermogravimetric analysis. The analysis and comparison of the overall thermal behavior with theoretical models was done. The results of this study may have particular significance as certain polymers have a recognized dependence on β-relaxation for their mechanical attributes; this may also apply to CA.

Keywords: cellulose acetate, thermal properties, TGA, SEM

INTRODUCTION

Cellulose acetate (CA) is a biobased polymer that is classified as an organic ester with excellent mechanical properties (e.g., high Young's modulus and tensile strength). It is biodegradable and abundantly available in the world. The biopolymer has a broad application such as biomedicine, bioplastic, membrane, and other industrial applications. Based on the number of acetyls attached to the structure of CA, it is categorized into three classes namely monoacetate, diacetate, and triacetate. In recent decades, different types of plasticizers have been incorporated in CA, based on glycols [1], phthalates [2], acetates [3], and citrates [4]. The compatibility, mechanical, and thermal properties of CA have been studied with their compatible plasticizer.

Between its degradation temperature (Td) and glass transition temperature (Tg), CA itself has a small temperature range [5]. Plasticizers are used to soften the material and extend this processing window. Although this technique is cutting-edge, it has a drawback in that the lower glass transition temperature lowers the product service temperature. Two distinct molecular weights of CA were employed in this investigation. They underwent analysis and comparison with extant theoretical models, including the Fox, Kelley–Bueche, and Couchman–Karasz models, to see how effective they were at lowering the glass transition temperature of CA [6]. Moreover, the α- and β-relaxations of CA were investigated, along with its interactions with the plasticizers employed in the study. Since β-relaxations are known to have a significant influence on the mechanical properties of different polymers, this survey concentrated on the β-relaxation temperature and its shifts, and how they affect the product service temperature of

CA. The relaxation intensities and shifts in tan δ of CA were highly dependent on the type and concentration of plasticizer. The β- and γ-relaxations of unplasticized CA are still a contentious topic in the scientific community [7]. The cooperative motion of side groups with the main chain or the movements of individual monomeric units might be the cause of the β-relaxation observed in unplasticized cellulose acetate. Einfeldt *et al*. reviewed differing views on the γ -relaxation of cellulose-based materials [8]. According to the initial explanation of γ-relaxation [9], the methyl side group of the glucopyranose unit was the sole one that could spin freely. A plausible explanation that was put forth by others [10] suggested that both methyl and hydroxyl side groups could freely rotate. [11] Local motions of the cellulose chain under a thermodynamic point of view were comparable with β-relaxation motions. [12] McBrierty *et al*. and others supported γ - relaxation with bounded water. [13] The last summarized interpretation of γ - relaxation was based on an energetic point of view, according to which a single glucopyranose unit switched from boat to chair conformation.

This paper's results of an investigation of the thermal properties of CA according to the molecular weight. The thermal behavior is investigated using thermal gravimetric analysis (TGA) and the morphological characteristic is analyzed using scanning electron microscopy (SEM).

METHODOLOGY

Materials

Cellulose acetate (CA) powder, with Mw 30,000 and 50,000, was purchased from Sigma Aldrich. The materials were used without further purification.

Sample Preparation

A thermogravimetric analyser (DTA/TG Exsstar SII 7300, Hitachi medical system, Tokyo, Japan) was used to analysed the mass-loss property of the materials. CA with Mw 30,000 and 50,000 was heated between 25 and 600 ◦C with a heating rate of 10 ◦C/minute under nitrogen atmosphere. The morphology of CA was analysed using a scanning electron microscopy with a magnification of 2,500x.

RESULTS AND DISCUSSION

Surface morphology analysis

The surface morphology of CA is represented in Figure 1. It shows that CA with Mw 30,000 had a rough and compact morphology, and CA with Mw 50,000 had a small particle on the surface. On the surface of the CA, a specific quantity of pores was discovered, however, their sizes varied.

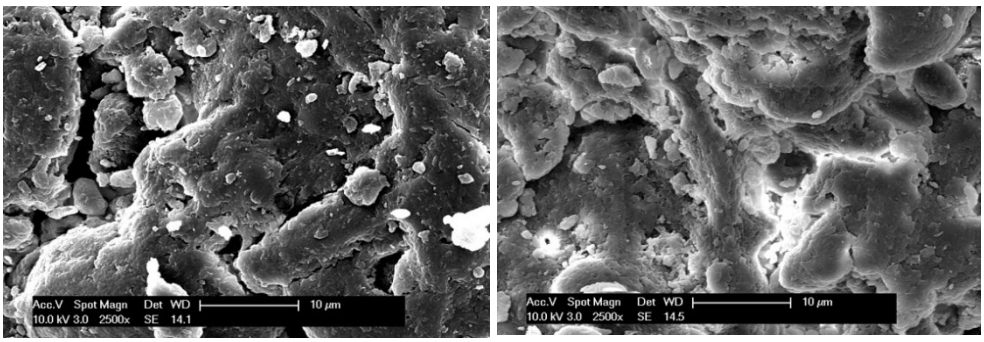

Figure 1. SEM image of cellulose acetate with Mw 30,000 (left) and 50,000 (right) with magnification of 2500x

Thermal gravimetric analysiS

The TGA traces for CA (Mw 30,000 and 50,000) are displayed in Figure 2 and 3 respectively. It features three different areas. The sample is first dehydrated from room temperature to 100 ºC, which was thought to be a notable characteristic. The breakdown of CA to the monomer of Dglucopyranose, which is seen to be between 270 ºC and 400 ºC, is the second step area in the TGA trace. At lower temperatures, however, between 210 ºC and 400 ºC, CA broke down. The degree of crystallinity can be used to explain why the beginning thermal degradation temperature for CA decreases following the Mw. Due to the complete breakdown, the last step area was seen to begin at around 400 ºC for both CA. About 10% more carbon is produced by CA (Mw 50,000) than by CA (Mw 50,000).

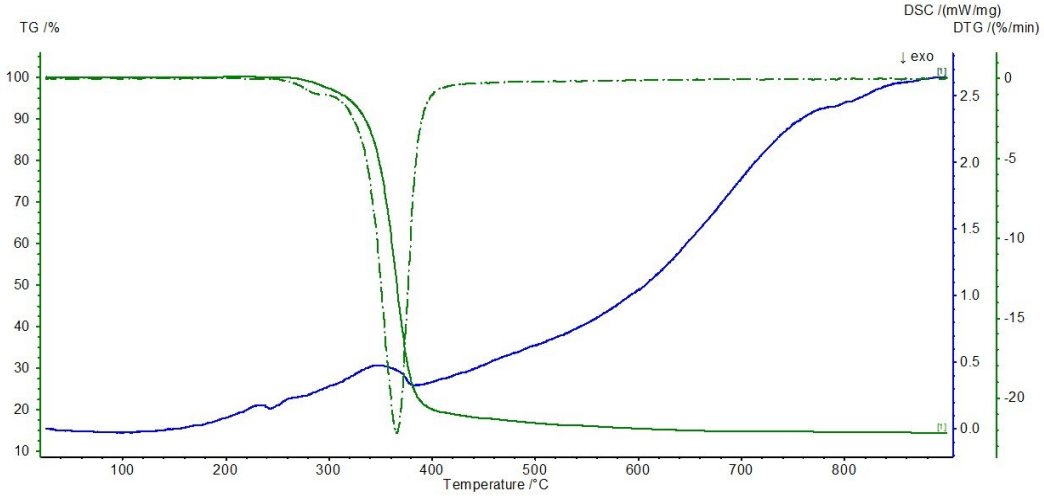

Figure 2. Thermal characteristic graph of cellulose acetate (Mw 30,000)

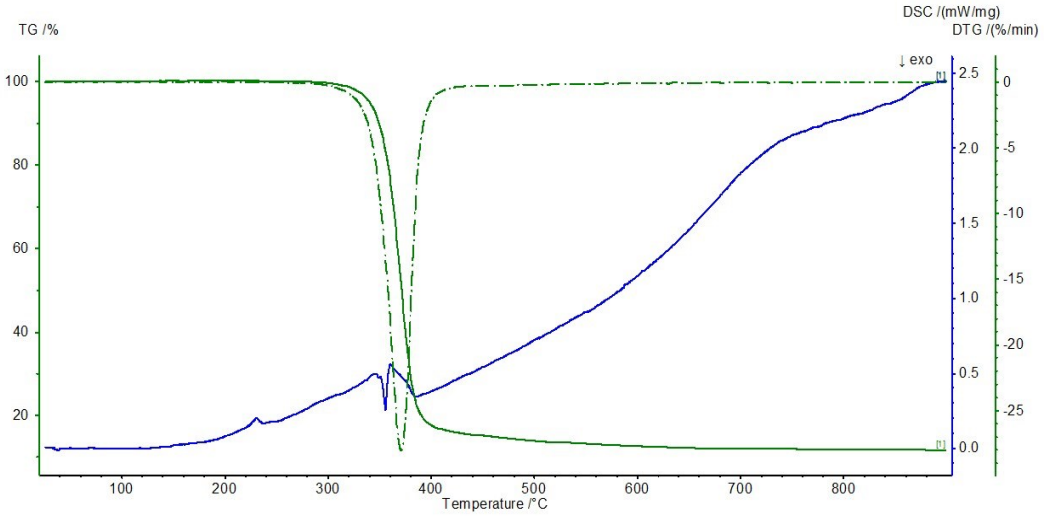

Figure 3. Thermal characteristic graph of cellulose acetate (Mw 50,000

CONCLUSION

The morphology of cellulose acetate according to the molecular weight is seen as similar looking to be rough and compact. The thermal properties of CA (Mw 50,000) are higher than CA (mw 30,000)

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REFERENCE

Guo, J.H. Effect of plasticizers on water permeation and mechanical properties of cellulose acetate: Antiplastization in slightly plasticized polymer film. *Drug Dev Ind Pharm*. 1993, 19, 1541-1555.

Fridman, O.A; Sorokina, A.V. Criteria of efficiency of cellulose acetate plasticization. *Polym Sci Ser.* B 2006, 48, 233-236.

Charvet, A; Vergelati, C; Long, D.R. Mechanical and ultimate properties of injection model cellulose acetate/plasticizer materials. *Carbohyhdr Polym*. 2019, 204, 182-189.

Lee, S.H; Shiraishi, N. Plasticization of cellulose diacetate by reaction with maleic anhydride, glycerol, and citrate esters during melt processing, *J, Appl Polym Sci*. 2001, 81, 243-250.

Kamide, K; Saito, M. Thermal analysis of cellulose acetate solids with total degrees of substitution of 0.49, 1.75, 2.46, and 2.92. *Polym J.* 1985. 17, 919-928.

Fox, T.G; Flory, P.J. Second-order transition temperatures and related properties of polystyrene. *J. Appl.Phys.* 1950, 21, 581-591.

Einfeldd, ,; Meiner, D.; Kwansniewski, A. Polymerdynamics of cellulose and other polysaccharides in solid state-secondary dielectric relaxation processes. *Porg Polym Sci*. 2021, 26, 1419-1472