TEMPERATURE DEPENDENCE OF CYCLIC BEHAVIOR OF POLY (LACTIC ACID)/HYDROXY-APATITE NANOCOMPOSITES

NECMI DUSUNCELI*

DEPARTMENT OF MECHANICAL ENGINEERING,
AKSARAY UNIVERSITY, 68100 AKSARAY, TURKEY
*E-MAIL: DUSUNCELIN@AKSARAY.EDU.TR

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Introduction

PLA is a biodegradable and biocompatible polymer widely used in biomedical applications for fracture fixation, interference screws, suture anchors and meniscus repair [1]. To enhance mechanical and physical properties of PLA (which has rather modest elastic moduli and strength and demonstrates brittleness at ambient temperature [2]), it is melt-blended with polymers with high tensile and impact strength [3], chemically modified with plasticizers, toughened with impact modifiers [4], and reinforced with microparticles and nanoparticles [5]. Although mechanical properties of PLA and composites with PLA matrices have been analyzed in a number of studies, a thorough examination of the influence of temperature and loading rate has not yet been performed [6]. This study focus on experimental investigation of the cyclic behavior of poly(lactic acid) (PLA)/hydroxyapatite (HA) composites under tension in the interval of temperatures from room temperature to 50ºC at cross-head speeds of 1 mm/min. Observations show that the presence of filler leads to a slight increase in elastic modulus and maximum stress at 1.5% strain level and induces slightly growth of recovery up to 1 MPa stress level. Given a filler content, maximum stress at 1 MPa decreases with temperature.

Materials and Methods

Poly(lactic acid) Polymer 4042D (density 1.24 g/cc) was purchased from Nature Works LLC (USA). Biphasic synthetic Hydroxyapatite (70% (HA)/Beta Tri Calcium Phosphate (30% (βTCP)) ceramics powder BioGraft (particle size 0.37 μm) was supplied by Ifgl Bio Ceramic Ltd (India). Ceramics powder was mixed with PLA in proportion corresponding to 5 wt%. Dumbbell specimens for tensile tests (ASTM standard D-638) were molded by using injection-molding machine Arburg 320C. To assess glass transition and melting temperatures, DSC (differential scanning calorimeter) measurements were performed by means of Mettler Toledo DSC 823E apparatus at heating rate 20 K/min under nitrogen flow. Glass transition and melting peaks of PLA and PLA/HA composite equal T_g = 63ºC, T_m = 155ºC, and T_g = 68ºC, T_m = 157ºC, respectively. Specific enthalpies of melting read 10.2 J/g and 19.1 J/g, which corresponds to degrees of crystallinity 11 and 21%. Mechanical tests were conducted by means of universal testing machine Instron-5568. The specimens are loaded with a constant strain rate up to 1.5% strain and unloaded with the same strain rate up to 1 MPa stress with cross-head speeds 1 mm/min at temperatures 23, 30, 35, 40, 45 and 50ºC.

Results and Discussion

Experimental stress-strain diagrams of PLA and PLA/HA composite are depicted in FIG. 1. The mechanical behavior of PLA/HA composites is brittle at room temperature and becomes ductile at elevated temperatures. Maximum stress at 1.5% of PLA/HA is slightly higher than that of PLA and decreases with temperature. Maximum stress at 1.5% decreases strongly with temperature. Unloading behavior of PLA/HA at high temperature level are nonlinear. Viscoelastic recovery after unloading decreases with an increase in temperature.

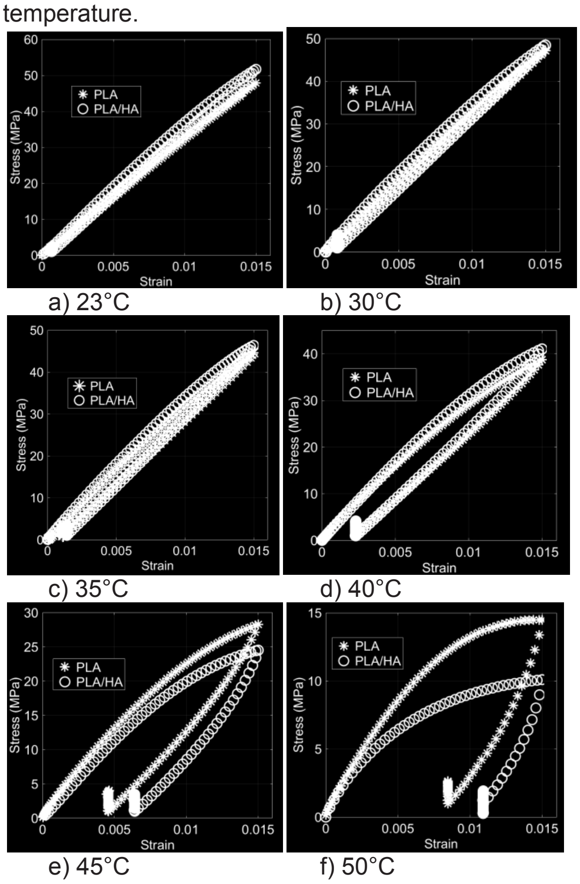

FIG. 1. Comparison of cyclic behavior of PLA and PLA/HA.

Calculated maximum stress and recovered strain of PLA and PLA/HA nanocomposite are given in TABLE 1.

TABLE 1. Maximum stress and recovered strain.

σ_{max} at 1.5%	Temp.°C	23	30	35	40	45	50
	PLA	47.9	47.1	44.6	41	28.4	14.4
	PLA/HA	51.7	48.4	46.4	38.7	24.5	10.1
%recovered strain at 1 MPa							
	PLA	1.43	1.41	1.38	1.27	1.04	0.65
	PLA/HA	1.43	1.41	1.39	1.27	0.86	0.4

Conclusions

A thorough investigation is performed of the effects of temperature on the cyclic behavior of PLA/HA composites under uniaxial tension. Reinforcement of PLA with HA induces a slight increase in elastic modulus and a decrease in maximum stress at 1.5% strain. Loading–unloading behaviors of PLA/HA are nonlinear and temperature dependent. Viscoelastic recovery after unloading decreases with increasing temperature.

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