NEWS
Biodegradowalne wyroby włókniste" i dotyczy opracowania Politechnika Łódzka, Wydział Włókna i Metrologii Włókienn
BIOGRATEX

Numer projektu POIG.01.03.01-00-007/08

BIOGRATEX

18 KWIECIEŃ 2013

Biodegradowalne wyroby włókniste

Lodz University od Technology

DEPARTMENT OF MATERIAL AND COMMODITY SCIENCES AND TEXTILE METROLOGY

Electrical Properties of Polylactides

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1. INTRODUCTION

Polylactide (PLA) is linear aliphatic thermoplastic polyester made of renewable raw materials that is primary valued for its biodegradable properties. PLA is characterized by a high resistivity, a tendency toward electric polarization and static electricity. The natural electrical properties of PLA can be used to create materials with stable electrostatic charges such as the electrets used in biodegradable filtration materials. In this study, electret structures were formed in a PLA film via isothermal polarization above the glass transition temperature (Tg). The field effects obtained under various processing conditions (the field intensity, electret formation time and electrode materials used Au and Al) were investigated.

2. MATERIALS AND METHODS

The object of study was to produce a 30-µm-thick PLA film. The films were prepared via the melting method using an FW-190 laboratory system (FW-190, Zamak Mercator, Poland). Commercial PLA materials (PLA 4060D, Natureworks, USA) were utilized. The PLA properties: a density of 1.24 g/cm^3 with no preparation or softener, a glass transition temperature of 52–58°C, a melting point of 210°C, a crystalline-phase content of 9.7%, the relative permittivity of e = 2.35 under frequency 10^{-1} Hz.

Investigation of the volume conductivity of the PLA film

The PLA film samples (100 mm × 100 mm) were purified and tested using a sandwich system: Au-sample-Au. The conductivity of the films was tested at 25, 35, 40, 50, 60 and 70°C using a stabilized voltage device (Device 2130, RTF, Germany) and an electrometer (Keithley 610C, Keithley Instruments Inc., USA).The behavior of the PLA film in an electric field with an intensity of 3.341.7 MV/m was assessed to determine the current-voltage characteristics of the volume conductivity of the PLA film.

Formation of PLA film thermo-electrets

The PLA film was initially purified and placed in the electrode system: Au-sample-Au (Fig.1). The process conditions: Tp =70°C, field intensity Ep = (8.341.7) MV/m, time of electret formation $t_2 - t_1$ = 1 h and 3 h.

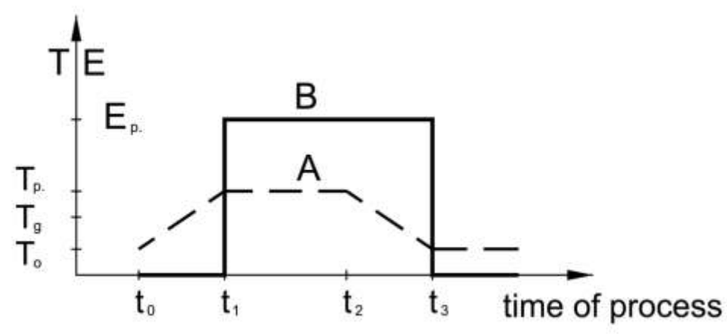

Fig. 1. Electret formation in an electric field: T0-ambient temperature, Tg-glass transition temperature, Tp-polarization temperature, E(t)-intensity of electric field, Ep-intensity of the electric field during polarization, A-characteristics of temperature changes, B-characteristics of DC field changes.

The charge on the PLA film's surface was determined in using a non-contact method by measuring surface potential of sample in relation to earth (Figure 2) in a compact, sensitive “field mill” instrument (JCI 140, John Chubb Instrumentation Ltd., UK).
The samples were stored under ambient conditions (t = 25°C, RH = 50%) in the “open circuit

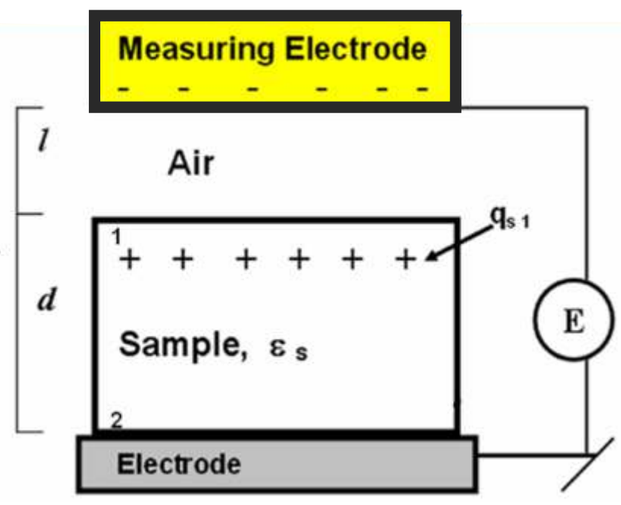

Fig.2. Experimental setup for measuring the surface charge density: 1-, 2- surfaces of sample, qs1 - the surface charge density on the surface -1 of the sample

3. RESULTS

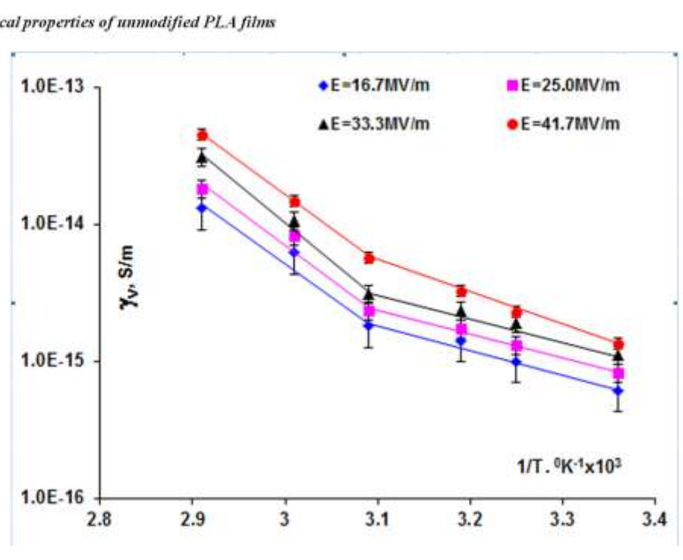

Fig.3. Temperature characteristics of the electric conductivity of a PLA film in contact with Au electrodes. The activation energy of the charge carrier conduction reaches (0.4÷0.7) eV at temperatures below the Tg and (0.9÷1.1) eV at temperatures above the Tg.

Electrical properties of the PLA film electret

Side of sample	Time after terminating charging	Surface charge densities, q_s, mC/m^2					
		E_p=8.3 MV/m	E_p=16.7 MV/m	E_p=25.0 MV/m	E_p=33.3 MV/m	E_p=41.7 MV/m	
						t_2-t_1=1h	t_2-t_1=3h
s_1	t=1h	+1.7	+4.3	+13.0	+24.0	+30.3	+40.0
	t=1day	-1,7	-1.7	+12.0	+17.3	+26.0	+30.0
	t=4 months	-2.2	-3.0	+ 4.3	+ 6.0	+18.2	+25.0
s_2	t=1h	-0.9	-8.6	-17.3	-26.0	-34.7	-45.0
	t=1day	-2.2	-6.6	-19.8	-17.3	-34.7	-44.0
	t=4 months	-4.3	-8.6	- 8.6	- 8.6	-22.5	-30.0

Table 1
Surface charge densities on both surfaces (s1 and s2) of the PLA thermoelectrets polarized in contact with the Au electrode (qs1, qs2 - charge densities surfaces of film in contact respectively with anode and cathode).

- The behavior of a PLA film with a low degree of crystallinity was investigated in a DC electric field within the temperature range of 25–70°C. The polymer exhibits low electrical conduction with increasing activation energy within the area of the glass transition temperature.
- Electrets were formed via isothermal polarization of the PLA film. The surface charge density on the PLA film thermo-electrets reached values ~10mC/m^2, within 4 months of terminating the process for PLA films polarized at field intensities of Ep 16,7 MV/m. The surface charge had a heterocharge character. The charge on the surface of polarized PLA film in contact with anode is positive, in contact with anode - negative.
- The values of the electret charge density could be increased with higher intensities of the polarization field. After 4 months the PLA film polarized at Ep > 16,7 MV/m was showed the applicable electret properties. PLA can be used as precursor of biodegradable thermo electrets.

This work was supported by Project 01.03.01-10-007/08-00, “Biodegradable fibrous articles-Biogradex.”