Refined model of electret state instability in biodegradable PLA films

Yurij A. Gorokhovatskiy[1], Elena A. Karulina[1], Daria A. Ignatyeva[2]
[1]*The Department of General and Experimental Physics, Herzen State Pedagogical University of Russia, St. Petersburg, Russia*
[2]*Higher School of International Educational Programs, Peter the Great St.Petersburg Polytechnic University, St. Petersburg, Russia*
Anne_Rut@mail.ru

AIMS OF THE INVESTIGATION

- Elaboration of the electret state stability mechanism in polylactide (PLA) films by confirming the model of charge-dipole centers.
- Determination of the distribution type of these centers in PLA films with different thicknesses.

METHODS

- Thermally stimulated relaxation of the surface potential (TSRSP)
- Fourier-transform infrared spectroscopy (FTIR).
- Attenuated total reflectance (ATR).

SAMPLES

- The initial polylactide (PLA) polymeric films.
- The composites based on PLA with various fillers ($BaTiO_3$, SiO_2, etc.).
- Two types of sample thicknesses: thin films (about 40 μm) and thick films (more than 180 μm).

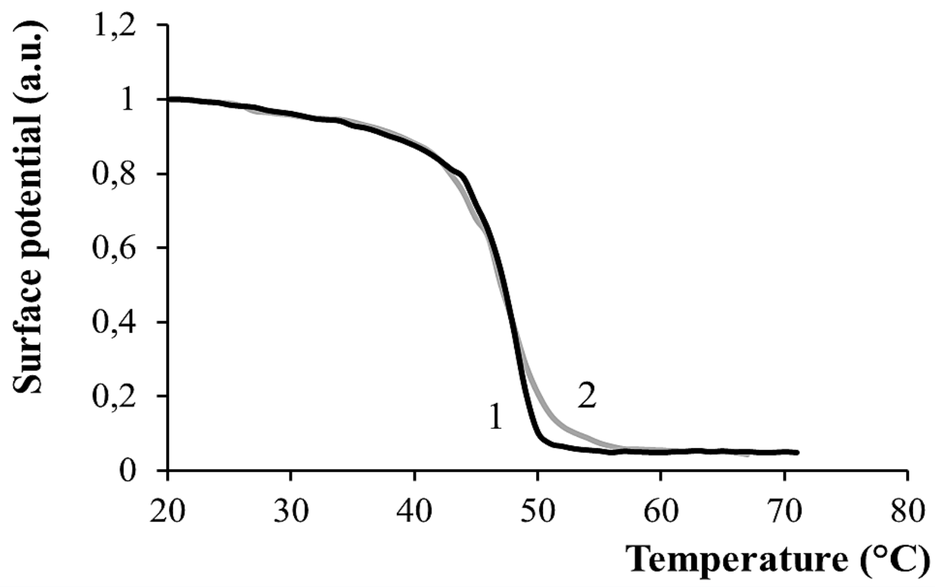

Fig. 1. TSRSP curves of initial PLA at the same heating rate, electreted in the field of negative (curve 1) and positive (curve 2) corona discharge

- The TSRSP curves practically do not differ from each other for electreted in opposite signs of corona discharge PLA films. In that case charge relaxation process proceeds via bulk conductivity [1, 2].
- The introduction of hydrophilic fillers into the polymer matrix of PLA leads to lower the bulk conductivity and to increase the electret state stability [1, 2].

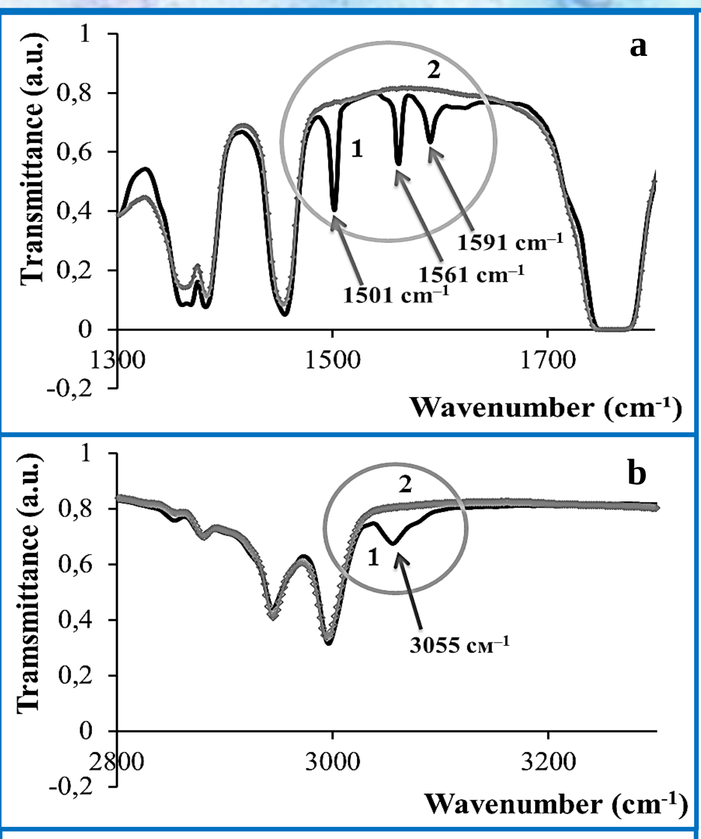

Fig. 2. The IR transmission spectra of the initial PLA (curve 1) and the PLA composite with the hydrophilic filler barium titanate ($BaTiO_3$) (curve 2) in the wavenumber range:
a) from 1300 cm $^{-1}$ to 1800 cm $^{-1}$;
b) from 2800 cm $^{-1}$ to 3300 cm $^{-1}$

- In the presented sections of the IR spectrum (fig. 2 a, b), characteristic bands of the initial PLA (sample thickness: 40 μm) are visible as well as additional bands 1501 cm^{-1}, 1561 cm^{-1}, 1591 cm^{-1}, 3055 cm^{-1}, which determine the presence of charge-dipole centers in the PLA structure [3].
- Charge-dipole centers can capture free charge carriers, which affects the conductivity of polymer films [1, 3].
- The input of the hydrophilic $BaTiO_3$ in the PLA structure leads to disappearance of these bands [1, 2]. The concentration of charge-dipole centers decreases, because molecules of water, hydrogen and oxygen are captured by particles of a filler in the near-surface regions of the polymer. This process in turn entails an increase the stability of the electret state.

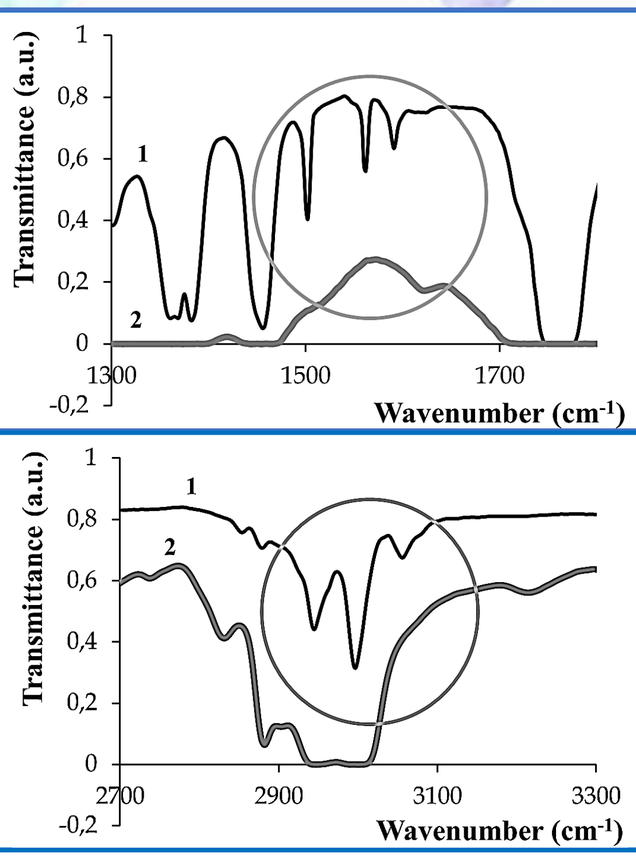

Fig. 3. IR transmission spectra of films of the original PLA with a thickness of 40 μm (curve 1) and 226 μm (curve 2) in the range of wavenumbers:
a) from 1300 cm $^{-1}$ to 1800 cm $^{-1}$;
b) from 2700 cm $^{-1}$ to 3300 cm $^{-1}$

- The IR spectrum of the initial PLA films (sample thickness: 180 μm), absorption bands attributed to charge-dipole centers are either strongly weakened or not observed at all in comparison with thin PLA samples (fig. 3 a, b).
- The charge-dipole centers are characteristic only for near-surface areas. That's why they disappear in the thick PLA samples.

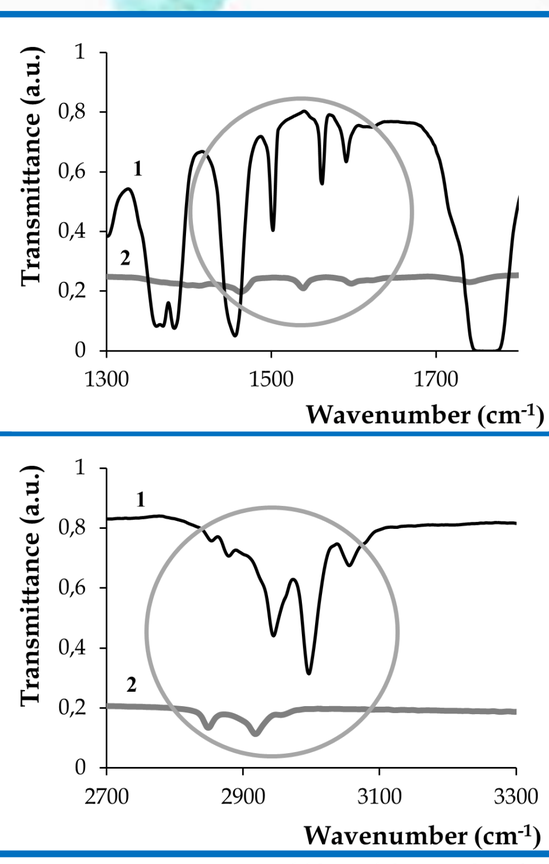

Fig. 4. IR transmittance spectra of films of the initial PLA 40 μm (curve 1) and the ATR spectra of the initial PLA 226 μm (curve 2) in the wavenumber range:
a) from 1300 cm $^{-1}$ to 1800 cm $^{-1}$;
b) from 2700 cm $^{-1}$ to 3300 cm $^{-1}$

- The ATR spectra of the initial PLA films (sample thickness: 180 μm), demonstrate absorption bands corresponding to charge-dipole centers (fig. 4 a, b).
- The ATR spectra exhibit a shift of all absorption bands to longer wavelengths (about 100 cm $^{-1}$).
- Absorption bands associated with charge-dipole centers are present in all ATR spectra: both in the spectra of the initial PLA and in the spectra of composites based on it [4].

CONCLUSIONS

- The ATR made it possible to detect the presence of charge-dipole centers absorption bands in thick PLA films.
- The ATR allowed registering the concentration of these centers in the near-surface zone of the polymer matrix.
- The intensity of the absorption charge-dipole centers bands turns out to be weakened. Therefore, the bands are masked and are not observed in thick films.
- The distribution of these centers is nonuniform over the thickness of the polymer matrix.
- The distribution of these centers has a saddle-like shape. The highest concentration of centers is observed in the near-surface zones.
- The nonuniform distribution of charge-dipole centers over the thickness of the polymer matrix allows explaining all experimental facts of the electret state stability of the composite PLA films.

REFERENCES

[1] Yu. A. Gorokhovatskiy, D. A. Ignatyeva, et al, "Charge relaxation mechanisms in composite films based on polylactide," Humanities and science university journal, № 27, 2017, pp. 46–55.
[2] L. A. Gribov V. I. Baranov, "Theory and methods of calculation of molecular processes," Spectra, chemical transformations and molecular logic, 2006, 480 p.