Isopotential mapping of electron beam-induced dielectric charging of PHB nonwoven fabric structures using Sobel-Feldman gradient operator

Gradov O.V., Gradova M.A., *Olkhov A.A., Iordanskii A.L., Kholuiskaya S.N.*

N.N. Semenov Federal Research Center for Chemical Physics RAS, Moscow, Russia

e-mail: o.v.gradov@gmail.com

Introduction

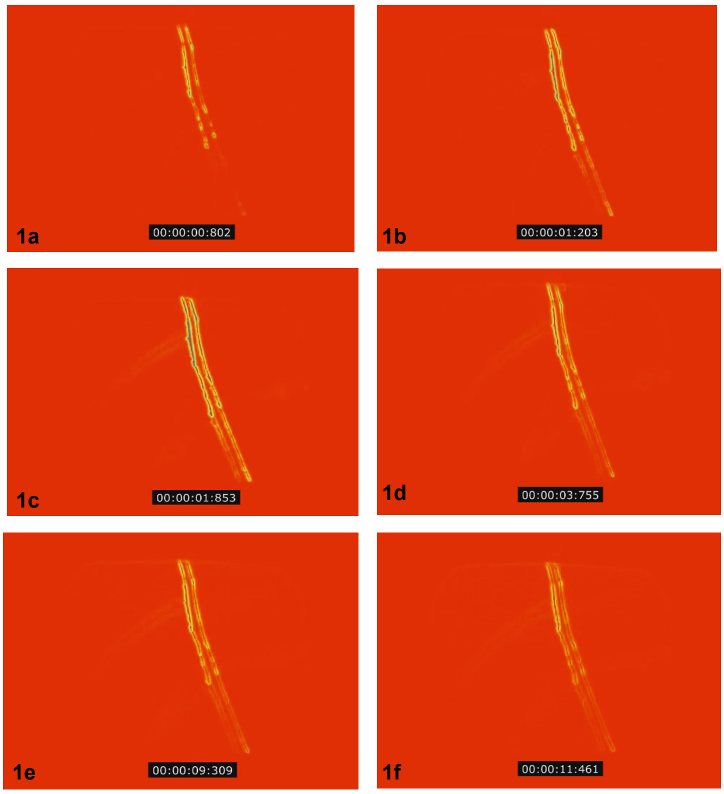
Dynamic imaging of the time-dependent charging phenomena under the electron beam and electric double layer mapping on the surface of polymer fibers are the most useful techniques for studying electrophysical properties of polymers. This work briefly describes a novel method for dynamic isopotential mapping of the electron beam-induced dielectric charging of nonwoven polymer fibers of polyxydroxybutyrate (PHB) using Sobel–Feldman gradient operator.

Experimental

Double layer charging was studied on dielectric polymer fibers of PHB (polyhydroxybutyrate) produced by electrospinning. The experiment was performed by a customized experimental setup based on the scanning electron microscope JEOL JSM T330A with coulisses for transmission electron detector and EDXS and a handmade system for rapid and time-lapse image registration. The double layer registration was performed with a millisecond temporal resolution (adequate for the layer discharging times as a capacitor). Fiber charging was induced by the electron beam bombardment at accelerating voltage of 5-10 kV without previous sputtering of the sample. Image flow was processed using software in a real time mode or in post processing mode. Particularly, image flow was analyzed by Sobel–Feldman operator (Sobel filter) based on convolving the image with a small, separable, integer-valued filter for “gradientmetric” edge detection as a discrete differentiation operator, computing an approximation of the gradient of the image intensity function.

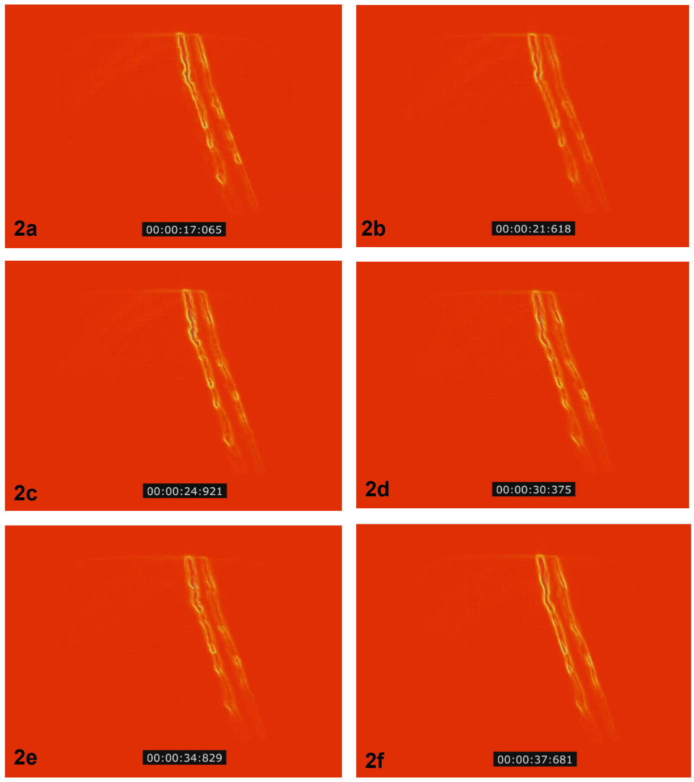
Results

Figure 1 shows dynamic images of the electric double layer charge propagation under electron beam at 500x magnification. It can be seen that the charge isoline positions change in time and the charge propagation occurs cyclically, but not periodically, and the charge often accumulates on the heterogeneities of the fiber structure which prevent its further propagation.



Results

Figure 2 shows the dynamic images of the double electric layer charge distribution and propagation under electron beam at 1000x magnification. Perturbation of the double layer charge often influences the local fiber micromorphology.



Discussion

The qualitative interpretation of the imaging data recorded was compared with the classical models for the effects of electrical surface inhomogeneities on potential distribution in ionic double layer known in literature. It has been proved that the path of charge distribution along the fiber can be approximated by any model for the soft matter dielectric structures, such as neurofibers and long (linear) supramolecular biopolymer strings (including several types of chiral strings), for example, DNA. Similar phenomena can be observed in biomembrane structures as the double layer interaction forces by the multiple ionizable groups. The quantitative interpretation of the data obtained is the object of our forthcoming papers.

Conclusions

A novel method for dynamic measurements of discharging of dielectric polymer materials under the electron beam has been developed and tested. Polyhydroxybutyrate (PHB) sample obtained by electrospinning has been studied as an example. It has been shown that its charging corresponds to the known models inherent in many biological and biomimetic systems.

Acknowledgments

This work was carried out within the framework of the Sate Assignment of the Ministry of Science and Higher Education of the Russian Federation (project 0082-2018-0006, registration code AAAA-A18-118020890097-1).