Komitet Mechaniki Polskiej Akademii Nauk

Politechnika Rzeszowska
im. Ignacego Łukasiewicza

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Prof. Barbara Kudrycka

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EKSPERYMENTALNA ANALIZA UWALNIANIA LEKÓW Z ELEKTROPRZĘDZONYCH NANOWŁÓKIEN

EXPERIMENTAL STUDY OF DRUG RELEASE SYSTEM BASED ON ELECTROSPUN NANOFIBERS

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Keywords: drug delivery, electrospinning, nanofibers

Nanofibers produced by electrospinning of biologically active substances became attractive material for encapsulating living cells, bacteria, and drugs for targeted therapy. Here, we aim to use nanofiber matrices as neurosurgery protective membranes and drug carriers. Proper administration of drugs requires precise control of the diffusion process during the time of release of days or even weeks. Construction of such system is a tedious experimental task. To avoid hundreds of tests it is aimed to build a numerical model including essential information about composition, process conditions, and fibers geometry necessary to construct suitable polymer matrices for dedicated drug delivery systems.

Dye release from a single nanofiber

Even though the release kinetics were studied experimentally for a number of substances, the physicochemical mechanisms of drug release have not been fully elucidated. Hence, we commence our study with a simple geometry of single nanofiber spanned in a cuvette filled with selected liquid (Fig. 1). Spatial and temporal variation of the fluorescent light intensity is measured using a CCD camera and spectrophotometer. It allows to evaluate variation of concentration profiles and access diffusion parameters for selected configurations and compositions of liquids/polymers.

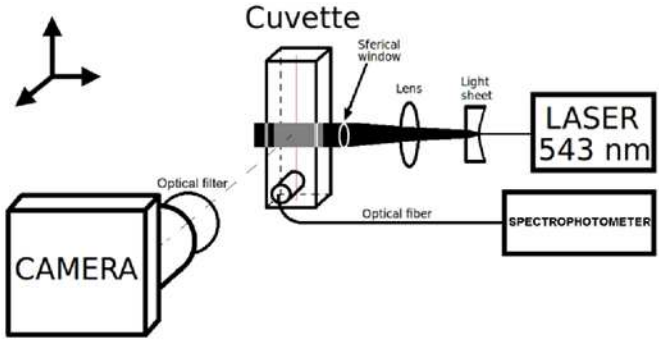

Figure. 1 Experimental setup. Laser with excitation wavelength $\lambda = 532$ nm, light–sheet optics, disposable cuvette with single fibre spanned along the central axis, CCD camera, optical filter 600 nm ± 15 nm and spectrophotometer.

Synthetic nanofibers of poly (ε-caprolactone) blended with rhodamine B were produced in the electrospinning process. For the single fiber experiments rotating disk was used as a collector. Two methods of loading nanofibers with dye were investigated: simple fiber with uniformly distributed dye and core-shell nanofiber with encapsulated dye.

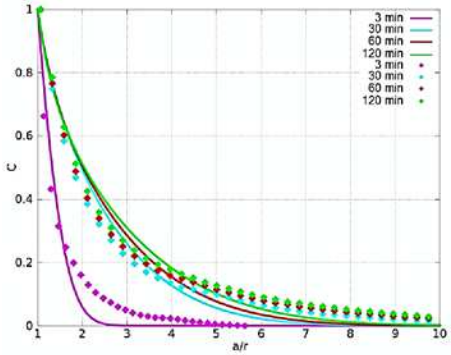

Figure 2. Dimensionless concentration – distance profile for uniform nanofiber. The measured concentration profiles (points) fitted by the analytical model (lines). Apparent diffusion coefficient is D = 1.3e-9 m2/s.

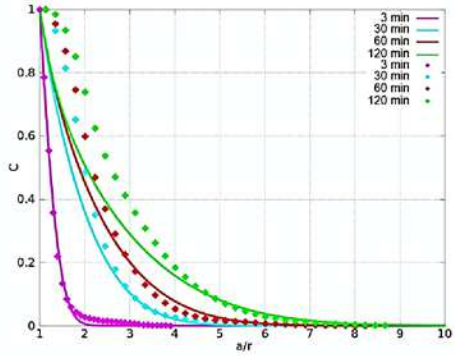

Figure 3. Dimensionless concentration – distance profiles for core-shell nanofiber. The measured data (points) and the fitted analytical model (lines). Apparent diffusion coefficient is D = 0.6e-11 m2/s.

Figure 2 presents concentration profiles of released dye (colored markers) obtained at several time steps for uniform nanofiber. They are compared with analytical solutions obtained for infinite cylinder with constant surface concentration. Evidently this simple model is far from physical reality. Beside molecular complications of the diffusion process it is necessary to include variation of internal and external diffusion in time and space.

Figure 3 demonstrates different behavior of the release characteristics obtained for the core-shell nanofiber. The sigmoid behavior of the concentration profiles at higher concentrations can be explained as the effect delayed diffusion through the shield of already washed out core. The apparent diffusion constant changes by two orders of magnitude giving perspectives for constructing delayed drug release system.

Dye release from a polymer matrix

Recently our electrospun nanofibreous mats appeared to be affordable to prevent excessive cicatrisation after neurosurgical procedures (patent pending, 2011). Additional functionality of these mats is tested for controlled administration of the drugs. This should help to avoid brain neurodegeneration frequently present after traumatic injury. Various factors have a significant effect on the release profile of a drug substance. Comparing with a single nanofiber the diffusion from mats strongly depends on their structure and porosity. This nonlinear behavior of the release process is additionally biased by environmental changes.

The construction of the targeted drug release mats is supported by single nanofiber studies. The data obtained for individual nanofibers are related with drug release measurements from nanofibreous mats. The intention of our present research is to find parameters which allow for optimization of drug release process, so that the administered dose allows for the maintenance of drug levels in the desired therapeutic window, while not causing any systematic damage.

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