Glucose diffusivity of electrospun polycaprolactone scaffolds for tissue engineering bioreactor

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Glucose diffusivity of electrospun polycaprolactone scaffolds for tissue engineering bioreactor

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Introduction and Aim

Electrospinning is an efficient way to produce scaffolds for tissue engineering purposes. Optimization of cell seeding of polymer scaffolds is also essential in vitro cultivation of functional tissue constructs. In order to quantify the relationship between glucose diffusivities with/ without seeded cells across self-made and commercial electrospun scaffolds, a number of key parameters in electrospinning process, such as the flow rate and experimental duration are attempted for producing various electrospun fibres in which glucose diffusivity were then measured.

Materials and Methods

1) *Materials*:

- Polycaprolactone (PCL) pellets (Mw=80,000),
- Dichloromethane solution (DCM) and N,N-dimethylformamide (DMF) as solvent
- D-glucose-anhydrous as solute
- Cell culture medium (CCM)
- Purchased PCL scaffold as reference

2) *Fabrication for PCL scaffolds:*
The electrospinning was processed by an electrospinning setup. Firstly, PCL (12 wt.%) was dissolved in the DCM and DMF (3:1 v/v) solvent. The solution is well mixed at 600 rpm for 2h at room temperature (25±1°C). The PCL solution was placed in one or two 3mL plastic syringes. The voltage of 15 kV, a feed flow rate of 1 or 2 mL/h and a distance of 12 cm between needle tip and collector were maintained. The nanofibers were collected on a flat plate with aluminium foil. The experiment was carried out at room temperature and at 45% of humidity. The duration of experiment is 1.5hrs (one syringe) or 45mins (two syringes).

3)*Glucose diffusion experiment*:
A diffusion cell [1] was built to determine the glucose diffusivities in CCM. The scaffold is fixed in between. Samples are taken from both donor and receptor phase every hour until equilibrium is achieved. The glucose concentration is measured by YSI glucose analyser.

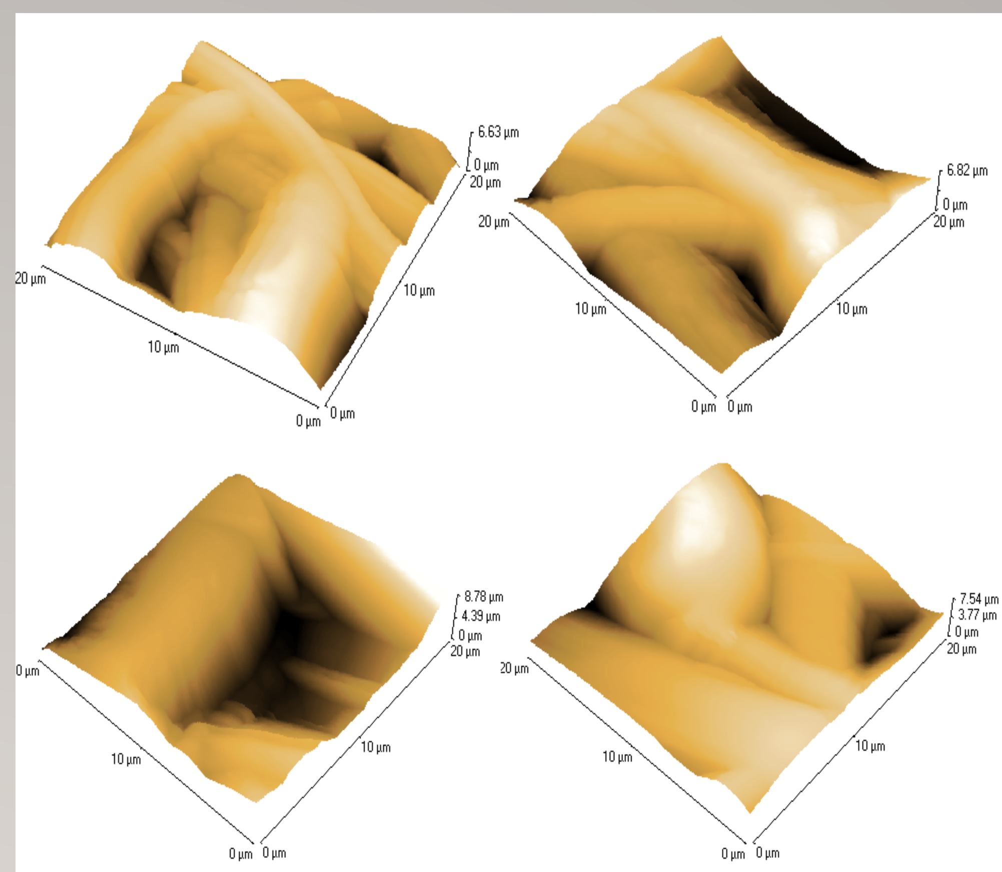

Figure 2
3D AFM images of
(a) 2 ml/h, 90 min with 1 syringe
(b) 1 ml/h, 45 min with 2 syringes

Table 1 Characteristics of electrospun scaffolds and glucose diffusivities in both water and CCM

Sample no.	Flow rate (ml/h)	Duration (mins)	Number of syringes	Average Fiber-fiber space (µm)	Average fiber diameter (µm)	Effective diffusivities in CCM $\times 10^{11} m^2/s$	Effective diffusivities in water $\times 10^{11} m^2/s$
1	1	90	1	1.380±0.75	0.782±0.41	2.830±0.12	6.31±0.31
2	2	90	1	3.800±1.69	2.100±0.76	3.750±0.29	8.27±0.23
3	1	45	2	1.880±0.77	0.905±0.64	3.220±0.11	7.38±0.27
Commercial scaffold				20-30			17.8±5.0

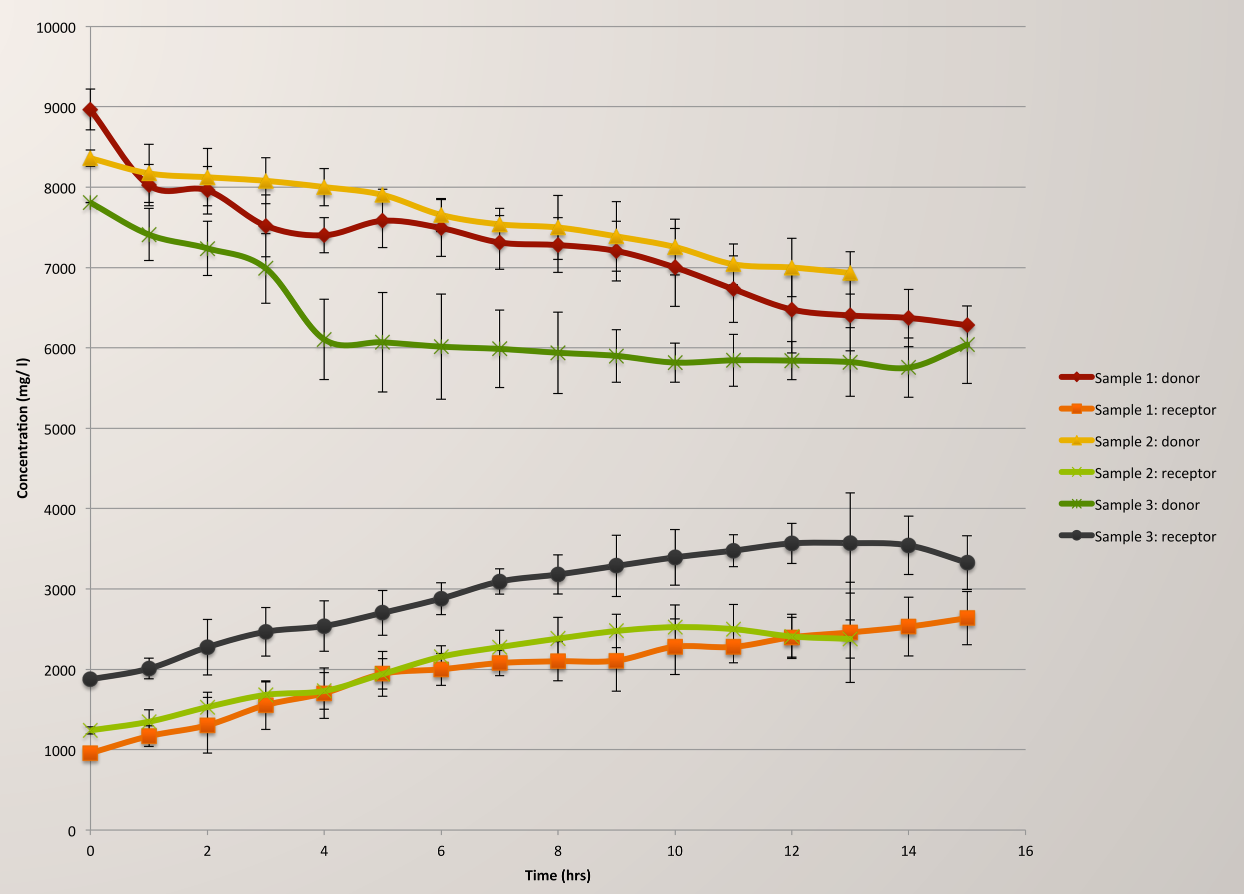

Figure 3 Glucose concentration change vs time across electrospun scaffolds in CCM (repeated 3 times each samples)

Results

Data revealed an increase in both fiber-fiber space and fiber diameter at a larger flow rate due to the insufficient solvent evaporation and gravitational force. The fiber-fiber distance and fiber diameter are also slightly increased with the usage of two syringes. The diffusivities in CCM through these 3 scaffolds are shown in table 1, which increases with increasing fiber-fiber space, indicating less resistance of glucose molecules diffusing through the pores. Data also showed a significant reduction of glucose diffusion coefficient through materials saturated with CCM at a given temperature.

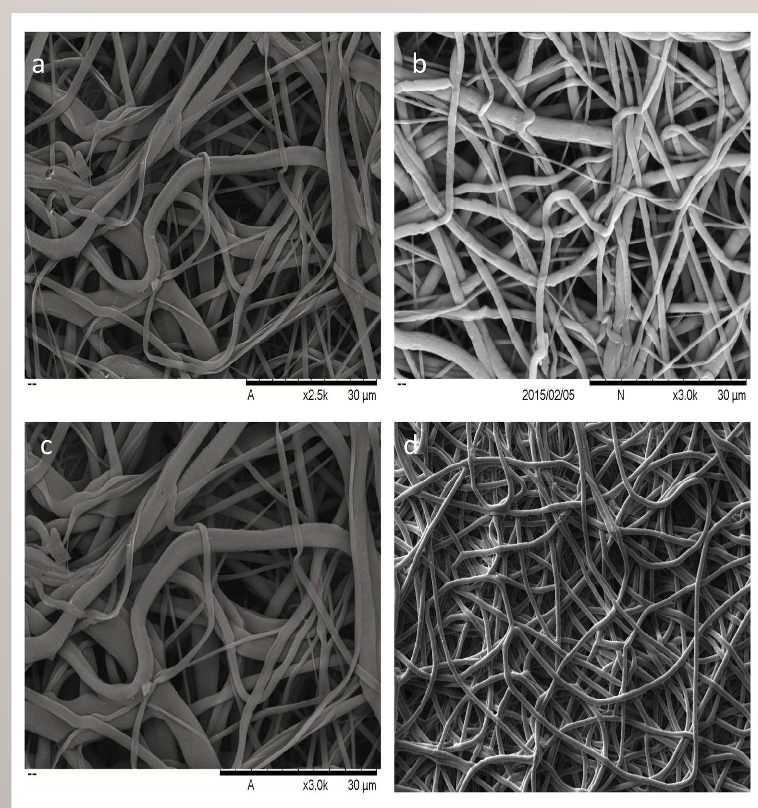

Figure 1
Images from SEM
(a) 1ml/h, 90mins with 1 syringe
(b) 2ml/h, 90 mins with 1 syringe
(c) 1ml/h, 45mins with 2 syringes
(d) Commercial scaffold

Conclusions

- The Fiber-fiber space and fiber diameter of all electrospun scaffolds are determined. Both of them are increased with higher PCL solution flow rate.
- The fiber-fiber distance and fiber diameter are also slightly increased if the flow rate is increased by the usage of two syringes for injecting the polymer solution instead of a single cylinder.
- In experimental work, diffusion coefficients of glucose through electrospun scaffolds in both water and CCM are obtained. As the pore size increases, the diffusivity increases. Results of same scaffolds in water and CCM are compared, the diffusion coefficients in CCM is smaller than those of in water.

Reference:
[1]H. Suhaimi, S. Wang, T. Thornton, D.B. Das, On glucose diffusivity of tissue engineering membranes and scaffolds, Chem. Eng. Sci. 126 (2015) 244–256.

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