

Tuning Wettability of Electrospun Three-dimensional Scaffolds through Morphology Control

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ABSTRACT

Surface wettability plays an important role in determining implant's fate due to direct influence of protein/biomolecule adsorption that governs cell adhesion. The importance of the physical parameters, such as, overall porosity, pore directionality, difference between 2D and 3D scaffold structures are also highly critical. Also, the correct chemical structure of the scaffold material is crucial for the overall performance of an implant. Amongst various methods, fabrication of 3D scaffolds using electrospinning has generated great interest for the production nonwoven fibres of nano to micron range porosity. Fluoropolymers have been used in a wide variety of blood-contacting medical device applications due to thrombo-resistance, reduced inflammation, and increased re-endothelialisation. Therefore, in this work with a view to achieve low adhesion, low friction and good biocompatible vascular graft implant, a variety of surface morphologies have been produced by electrospinning Poly (vinylidene fluoride-co-hexafluoropropylene)-PVDF-HFP by tuning viscosity, surface tension and solution conductivity. The contact angle of spin coated PVDF-HFP surface was lower than that of three-spun surfaces. These electrospun surfaces have shown less number of cells due to their ultrahydrophobic behaviour.

Keywords: **wettability, scaffold, morphology, electrospinning, hydrophobicity**

1 INTRODUCTION

During the last decade electrospinning has emerged as a solution technique in the field of tissue engineering, which is an interdisciplinary/ multidisciplinary area to impersonate the native tissues in living for their treatment/rehabilitation and advancement of quality of life[1]. Use of living cells, biomolecules and synthetic materials are the core subjects of tissue engineering applications[2]. Several strategies/techniques adapted to generate 3D tissue engineering scaffolds[3-5] but most of the scaffolds produced by conventional methods are not capable to provide enough nutrients, oxygen and surface area for the growth of cells [6]. Therefore, electrospun scaffolds of polymer fibres at nano-

scale level may be one of the desirable structure used in tissue engineering because they can be easily manipulate for desired porosity and fibre diameter [7].

A fluoropolymer, Poly (vinylidenedifluoride) with its copolymer-co-hexafluoropropylene (PVDF-HFP) has been widely used [8, 9]. It is expected that PVDF-HFP based nanofibres may be able to effectively mimic the native tissue as scaffold for small diameter artificial vascular graft because PVDF-HFP is non-thrombogenic, elastic, biocompatible, resistant to infection, durable and resilient in comparison of other biomaterials, used as vascular scaffolds. It is concluded from the literature review[10] that ultrafine PVDF-HFP fibers can be produced by using electrospinning technology. However, the systematic investigation of the effect of intrinsic (viscosity, surface tension, conductivity) and extrinsic (distance, voltage, flow and concentration) processing parameters on morphology, protein and cell adhesion on PVDF-HFP ultrafine fibers was not reported.

In the present study we have correlated the effect of intrinsic and extrinsic parameters on morphology of solid and electrospun surfaces and their further effect on protein and cell adhesion.

2 MATERIALS AND METHODS

2.1 Polymer solution preparation

PVDF-HFP with an inherent viscosity of 2300-2700 Pa and ~400,000 molecular weight was purchased from Sigma Aldrich, Australia. 8, 10, 12, 14 and 16 wt% dissolved in 70/30 ratio of N,N-dimethylacetamide (DMAc) and acetone (from Sigma Aldrich, Australia) and left for overnight mixing with a magnetic stirrer at a temperature of 20 °C.

2.2 Preparations of electrospun fibrous mats

A voltage is applied to the solution at room temperature in capillary tube, charge repulsive forces oppose the surface tension and the fluid jet elongates out of the capillary wall and forms a conical shape, which is called Taylor cone. At a certain critical value the electric field overcome the surface tension of the solution and a charged jet of solution is ejected from the Taylor cone [11]. In this study a high voltage DC power supply was used to generate potential differences between 13 to 17 KV. One electrode of a high voltage was

applied to a vertically (18-gauge) blunt-end metal needle. The polymer solution was fed from a 20ml glass syringe to a needle via Teflon tubing and the flow rate was controlled by a precision pump to maintain a steady flow from capillary outlet. Fibres were obtained using an earthed collection system, which consisted of an aluminium foil collector on a copper plate measuring 10 X 10 cm.

2.3 Fibre Characterization

Philips XL30 FEGSEM with Oxford CT1500HF Cryo stage was used to characterize the morphology of the electrospun fibres after sputtering of platinum at an accelerating voltage of 10 kV. The diameter and porosity of the electrospun fibre mats were measured by Analysis 5 image software. Solution intrinsic parameters like viscosity, surface tension and solution conductivity was measured using standard protocol. The water contact angle was measured using goniometer.

2.4 Cell adhesion study

A comparative study of fibrinogen adhesion for 2 hours and bone marrow derived endothelial cell (BMEc) adhesion for 5 hours on solid and electrospun surfaces was carried out. Cell adhesion analysis was performed using SEM.

3 RESULTS AND DISCUSSION

An obvious effect of various solution concentrations on viscosity was observed because the intermolecular interactions between polymer chains get more dominant with increased concentration of PVDF-HFP. Due to this the viscosity gradually increased with increase in concentration. A marginal but gradual increase in surface tension, but a progressive decrease in solution conductivity was observed with increasing solution concentration.

3.1 Effect of electrospinning process on electrospun mat's properties and cell adhesion

We observed the influence of solution properties (viscosity, surface tension and conductivity) and electrospinning processing parameters including collection time on morphology and wettability of electrospun mats and their further effect on protein and cell adhesion process on solid and electrospun surfaces.

Being a hydrophobic polymer PVDF-HFP solvent cast surface has shown 95.8° contact angle, which is hydrophobic but when we used the electrospun technique for the production of fibrous surface of the same polymer, we found a significant difference in morphology of both surface preparation techniques as shown in Figure-1.

Similarly we performed contact angle analysis on all electrospun mats prepared from solutions of different polymer concentrations and different processing voltage, distance, flow rate and time. We observed that the electrospun mats

exhibit ultra to super-hydrophobic behaviour and their contact angle range we found from 147.5 to 160.5 degree as shown in Figure 2. This behaviour of electrospun mats is due to increased roughness of the surface that corresponds to Wenzel and Cassie-Baxter model [12].

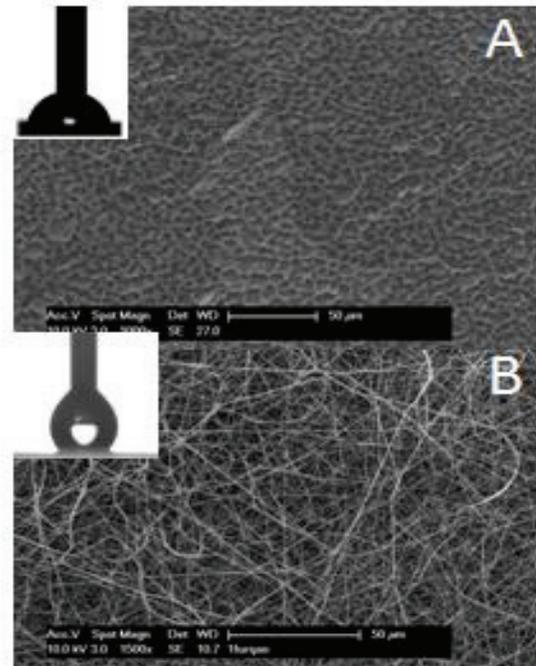


Fig-1 Showing wettability at (A) solvent cast and (B) electrospun surface

Besides the wettability difference of solvent cast and electrospun mats we did the analysis of wettability of different electrospun mats produced by different processing parameter and different concentration of solutions. Figure 2 shows the effect of solution concentration on quality of the electrospun surfaces and wettability of same polymer surfaces.

The morphology of electrospun mat has shown numerous pores which cause entrapment of air inside the surface whereas the solvent cast surface has shown very small crest and trough and there is lack of interporous connections as observed in electrospun mats. These pores generate a negative force of air against any kind of adhesion.

BMEc adhesion study on different substrates, demonstrates that the cell adhesion is less predominant on e-spin surfaces. Currently, more work is underway to understand that effect. However, the adsorption of fibrinogen is more on solvent cast surfaces which explain partly the cell-surface interaction behaviour. The low adhesion of BMEc also shows a correlation with high contact angle of electrospun surfaces and is well known that the high contact angle rough surfaces have cleansing effect and low adhesion property[13]. The low

