Investigation into the Influence of the Processing Environment on the Degree of Fibre Welding and Mesh Porosity

Jerome A. Henry[1,2], Abhay Pandit[1,2], Peter Neuenschwander[3]
[1]Department of Mechanical and Biomedical Engineering, [2]National Centre for Biomedical Engineering Science, National University of Ireland, Galway, Galway, Ireland, [3]Department of Materials, ETH Hönggerberg, Zürich, Switzerland

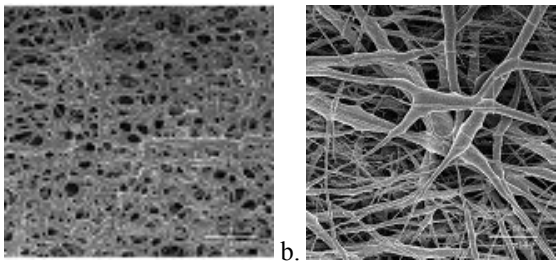
Introduction: Electrospinning is a process in which fibres are formed by passing a solution through a high electric charge. The significant parameters affecting the solution as it is passed through the electric field are solution viscosity, the electric potential, the distance between the needle and the target, the processing temperature and the type of solvent used. The number of fibres that are attached together can influence the mechanical properties and porosity of the electrospun mesh. The choice of solvent and the ambient temperature in which it is processed influences the porosity of the electrospun mesh. The greater the extent of fibre welding, the stronger the mesh will be, along with a subsequent decrease in the mesh elongation. The objective of this study was to investigate the effects of choice of solvent and processing environment on the degree of fibre welding and mesh porosity.

Methods: A biodegradable polyesterurethane was used for this study. Chloroform ($CHCl_3$), dichloropropane ($C_3H_6Cl_2$,) and trichloropropane ($C_3H_5Cl_3$) were the solvents used for electrospinning. A 27% (w/w) solution was made by dissolving the polymer in varying solvent compositions, as shown in the table below.

Solvent composition $CHCl_3$:$C_3H_6Cl_2$ (volume:volume)	Solvent composition $CHCl_3$:$C_3H_5Cl_3$ (volume:volume)	Target temperature (°C)
70:30	70:30	23°C
80:20	80:20	23°C
90:10	90:10	23°C
70:30	70:30	-70°C
80:20	80:20	-70°C
90:10	90:10	-70°C

Two separate processing temperatures were also investigated, -70°C and 23°C. Uniaxial tensile testing was performed on all samples at 37°C, n=3. Scanning electron microscopy (SEM) was used to assess the degree of fibre welding and surface morphologies. Differential scanning calorimetry (DSC) was used to investigate whether the processing environment or solvent influenced the thermal properties. Statistical variances between the mechanical test data were determined by one way analysis of variance (ANOVA). Tukey's honestly significant difference (HSD) test was used for post hoc evaluation of differences between groups. Groups were considered statistically significant for $p<0.05$.

Results and Discussion: *Electrospinning:* SEM examination revealed noticeable differences between the meshes processed at 23°C to those at -70°C. The meshes processed at -70°C were more porous and had a greater number of nano fibres compared to those processed at 23°C, as shown in Figure 1.



a. b.

Figure 1 – SEM image of mesh processed at (a) -70°C and (b) 23°C

Mechanical testing: There were statistical differences ($p<0.05$) between the meshes spun at 23°C and -70°C, and between the solvent compositions. The mechanical test data indicated that a decrease in the amount of chloroform in the solvent composition reduces the tensile strength and that the meshes prepared at 23°C were stiffer than those spun at -70°C, as shown the table below.

Volume ratios	**$CHCl_3$:$C_3H_6Cl_2$ 23°C**	**$CHCl_3$:$C_3H_6Cl_2$ -70°C**
70:30	0.20 ± 0.03^{a}	$0.02 \pm 0.01^{a,b,c,d}$
80:20	$0.10 \pm 0.02^{a,b}$	$0.03 \pm 0.01^{b,c,e}$
90:10	$0.16 \pm 0.03^{b,c}$	$0.15 \pm 0.03^{a,bd}$
	$CHCl_3$:$C_3H_5Cl_3$ 23°C	**$CHCl_3$:$C_3H_5Cl_3$ -70°C**
70:30	$0.17 \pm 0.02^{b,d}$	$0.03 \pm 0.01^{a,b,c}$
80:20	$0.12 \pm 0.02^{a,c,d}$	0.17 ± 0.01^{d}
90:10	$0.28 \pm 0.02^{a,c,d}$	$0.15 \pm 0.01^{a,d}$

Table – Tensile strength (MPa) data, mean ± SD, n=3. Identical letters indicate that the values are statistically different ($p<0.05$).

DSC: There was no variation between the different meshes with respect to the T_g and T_m values.

Conclusions: SEM revealed that fibres spun on a cold target produced a highly porous mesh whereas meshes processed on a warm target had lower porosity. Mechanical test data indicated that the solvent compositions with higher amounts of chloroform had superior mechanical properties. DSC results showed that the choice of solvent does not affect the thermal properties of the processed polymer. Hence it may be concluded that the choice of solvent and processing temperature has a significant influence on the mechanical properties and porosity of electrospun meshes.

Acknowledgements: Marc Simonet, Marco Camus, ETH Hönggerberg, Zürich, Switzerland.
Irish Research Council for Science, Engineering and Technology: funded by the National Development Plan.