Printing of Biocompatible Polymers and their Composites for Biomedical Engineering.

Manoochehr Rasekh[1], Zeeshan Ahmad[1], Richard Day[2], Mohan Edirisinghe[1]

[1]Department of Mechanical Engineering, University College London, Torrington Place, London WC1E 7JE
[2] Centre for Gastroenterology & Nutrition, Windeyer Institute, University College London, 46 Cleveland Street, London W1T 4JF

Statement of Purpose: Electrically driven patterning of polymers is achievable and can be used to deposit fine (<5 μm) ordered structures, with control on porosity and bioactivity according to a predetermined architecture via computer control. These structures are assessed *in-vitro*; thus signifying future applications as topographical and tissue engineering devices. The natural rigidity of synthetic biodegradable polycaprolactone polymer (PCL) makes this material well suited for the fabrication of tissue engineering scaffolds and topographical structures. Topography is one of the most essential physical cues for cells which can control cell adhesion, proliferation and differentiation, in addition guide cell behaviour greatly. This study will focus on exploring the limits of spatial parametric variables in cellular interactions with biomaterials.

Methods: Two polycaprolactone (PCL) polymers; (density 1146 kgm^{-3} ;molecular weight: 14000 g/mol and density 1145 kgm^{-3} ;molecular weight: 80000 g/mol) and N, N-dimethyl formamide 99% (DMF) were used. Nano-hydroxyapatite (nHA) powder (<200 nm (BET), 97% synthetic) was used. Reagents required in the preparation of SBF solution were purchased were based on the studies carried out by Kokubo. The principle component of the processing (electrohydrodynamic needle) is made from stainless steel and has an inner and out diameter of 750 and 1140 μm respectively, which is coupled to a high power voltage supply, with a capability of supplying 30 kV. The polymeric solution was introduced into the processing needle using specially designed infuser pumps. The flow rate and applied voltage for the processing was determined and the method was optimized. Generated polymeric structures were collected on a microscopic glass slide and were analyzed using optical and electron microscopy.

Results: The electrohydrodynamic processing route is a robust method which is operational at ambient temperature. To demonstrate the interchangeable format between direct writing and random deposition, using Electrohydrodynamic processes, polymer PCL-80,000 (10 wt. %) was selected and prepared. Using a flow rate of 15μl/min (5.2-6.4 kV) electrospun fibres, albeit with beaded structures result demonstrating a transition between the spinning and the spraying processes. The topography changes from coiled patterns to wave-like patterning proceeding towards linear patterns. Once optimized straight line topographies can be generated (**Figure 1a**, width 5 μm) which is an order of two magnitudes smaller than the processing needle (inner diameter 750 μm). From a topographical perspective alteration to the line width is essential as this can be varied from cell to cell and can also be used to determine the bridging distances between cells as cell attachment is visible on PCL patterns (**Figure 1b**). Currently, interactions between parallel PCL prints are under investigation. PCL can also be used alongside nHA for preparing ordered scaffolds. Utilizing a nHA volume of 15 wt. % of polymer can result in bioactive morphologies, as highlighted by immersing them in simulated body fluid (SBF). Apatite formation is apparent as shown in **Figure 1c** (Low Mag.) and **1d** (High Mag.).

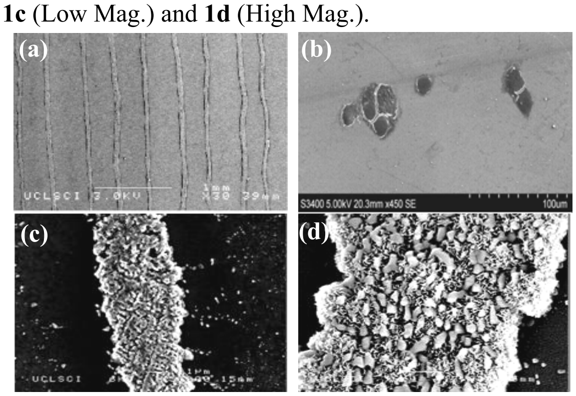

Figure 1.

Conclusions: We have successfully print-deposited polymer solutions into novel predesigned structures applicable for biomedical topographies and tissue engineering structures. Polymer solutions with different molecular weights can be readily print-patterned on substrates with alteration in parametric variables such as deposition (distance between needle exit and substrate), applied voltage, concentration of the polymer in solution and the selected polymer. Solvent evaporation based surface modification in conjunction with EH printing has also been shown, which further potentials the use of such structures in applications requiring porous structures. By incorporating bioactive elements into the processing solutions, bioactivity of the composite prints has been elucidated. Cell interactions with patterned topographies are currently being explored and the bridging distance is to be determined. This novel printing method with coarse processing needles and ambient temperature processing can deliver a plethora of structures required for advancing our understanding in cell topography interaction and novel tissue engineering methods.

References:

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