The Balance of Parameters Required for Melt Electrowriting High-Quality Scaffolds

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Introduction: Many different fluids have been used with nozzle-based 3D printing, including polyelectrolytes, colloidal inks, melt extrusion, hydrogel bioinks and polymer solutions [1]. A key printing aim of extrusion is to maintain fidelity once delivered from the nozzle, and methods such as coagulation baths or rapid solvent evaporation are often used to preserve structural fidelity of the 3D printed object. The melt processing of polymers are important for biomaterials research from several perspectives [2]. Firstly, this is how many existing, established, biomaterials are processed in the clinic. Obviating solvents helps processing within sealed or closed systems, helping at times to maintain sterility. For extrusion 3D printing, the rapid cooling of a melt onto a collector is an essential property. Rapid polymer cooling and solidification is an important factor in melt electrowriting (MEW), a technology used for scaffold fabrication [3].

Methods: Poly(ε-caprolactone) (PCL) was made under GMP conditions. A custom MEW printer (**Figure 1**) with syringe, 22G nozzle, collector distances 2 mm to 10 mm, applied voltage of 4-5kV, temperature between 85ºC and 90ºC, collector speeds 3 mm/sec – 6 mm/sec were typically used for printing. Stereomicroscopy and scanning electron microscopy (SEM) are used to demonstrate the scaffold morphology.

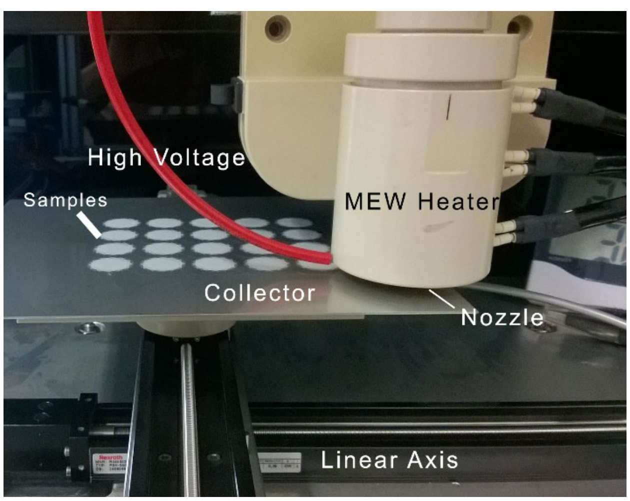

Figure 1: Photograph of a standard MEW printer, with one nozzle direct writing onto a metal collector.

Results & Discussion: An electrohydrodynamic effect with a molten polymer jet enables direct-writing capabilities of small diameter fibers into three-dimensional (3D) scaffolds. Fiber diameters depend on the conditions used and range from 45 µm down to 820±120 nm. This fiber resolution is therefore more than two magnitudes smaller than standard extrusion, since the molten filaments are electrostatically stretched rather than forced through an orifice. The diameter of the electrostatically drawn molten filament is also proportional to the flow rate and is therefore controllable with instrument parameters.

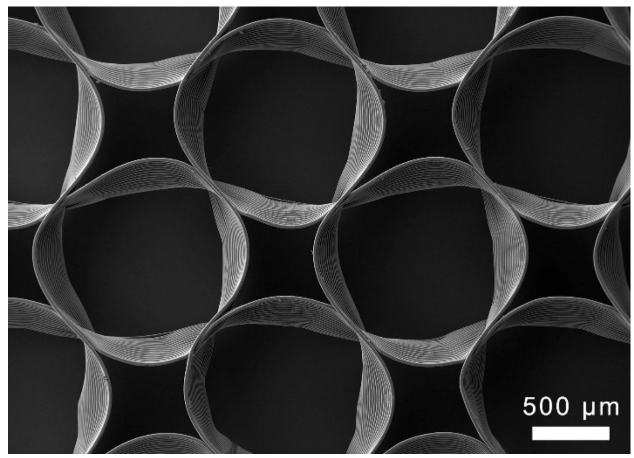

Figure 2: SEM image of MEW PCL scaffold

MEW scaffolds made from sinusoid paths (**Figure 2**) have a wall-tilting effect that makes them of interest for containing cell spheroids, microtissues and organoids. Instabilities within the MEW jet introduced artifacts within the fabricated scaffold such as fiber bridging and fiber pulsing.

In many ways, PCL is an ideal polymer to MEW-process. With a low melting point of 60ºC and slow degradation, PCL can remain being heated for long periods without measurable degradation.

Summary: MEW is a technique that has utility in the fabrication of scaffolds for tissue engineering and biomaterials. Many parameters balance to allow the generation of well-defined and repeatable scaffolds.

References

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3. Robinson, T.M., D.W. Hutmacher, and P.D. Dalton, Adv. Funct. Mater. 2019;29:1904664.