Effect of electrode design on the melt electrowriting of sinusoidal structures

Biranche Tandon[*1,2], Andreas B. Züge[1], Simon Luposchainsky[1,2], Paul D. Dalton*[*1,2]*

[1]Department of Functional Materials in Medicine and Dentistry and Bavarian Polymer Institute, University of Würzburg, Pleicherwall 2, 97070, Würzburg, Germany

[2]Knight Campus for Accelerating Scientific Impact University of Oregon, 1505 Franklin Blvd, Eugene, OR, USA

Statement of purpose: Melt electrowriting (MEW) is a 3D printing technology which allows for the precise placement and stacking of micron-scale polymeric fibers. The collection speed and applied electric field are two key parameters in MEW to maintain process stability and accuracy during printing [1]. It is important to balance these parameters as they directly relate to placed fiber diameter and thus mechanical properties of the constructs. This work investigates different electrode designs for MEW of poly(ε-caprolactone) (PCL) and the influence of the resulting altered electric field on the printing fidelity of non-linear sinusoidal constructs. A conventional flat electrode was compared to convex, concave, and offset electrode geometries.

Methods: Electrode designs as shown in Fig 1 were used in this study. A printhead temperature of 85°C, applied pressure of 0.2 MPa and applied voltage of 6.5 kV were used for all electrodes. A 25G nozzle was used for printing non-linear sinusoid constructs. The effect of different electrodes on mass flow rate of the polymer, jet speed, electric field distribution, fiber diameter and amplitude of the sinusoid prints were explored. The optimized experimental design was utilized to print sinusoid structures with various wavelength and amplitude combinations, and their mechanical properties were assessed.

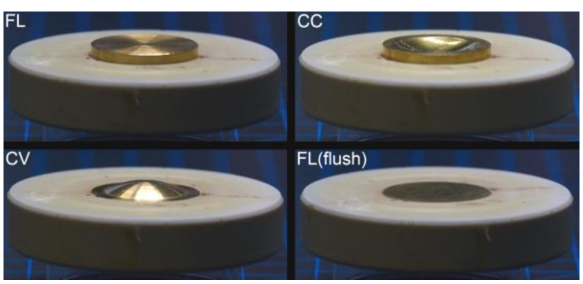

Figure 1 *Print head electrode designs tested in this study. Flat (FL), concave (CC), convex (CV) and flat flush (FL (flush)).*

Results and Discussion: The concave electrode design was expected to improve the lay-down accuracy of the designed patterns. The volume flow rate, however, reduced from ~2.57-2.6 µl/h for Fl/CV to ~2.45 µl/h for concave. This could be attributed to the nozzle temperature drop of 9°C leading to an increase in viscosity. Interestingly, the critical translational speed was counterintuitively found to decrease from ~650 mm/min to ~400 mm/min. It was found that the accuracy of the designed sinusoid prints was highly dependent on the difference of printing speed and the jet speed. The amplitude and wavelength of non-linear structures were found to impact the mechanics of the structural units which have the potential of being used as building blocks for scaffolds for muscle and tendon tissue engineering. As shown in Fig 2, the wavelength and amplitude impacted the load displacement curve in terms of the onset of the curve.

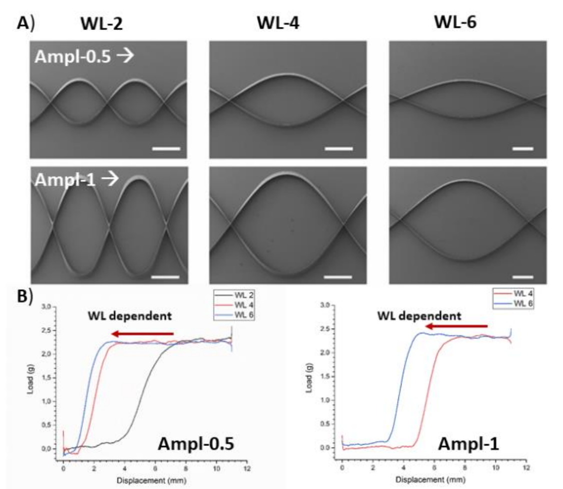

Figure 2 *A) Sinusoidal designs printed with different wavelength (WL) and Amplitude (Ampl) in mm. B) Load displacement graphs of tensile testing of the structures depicting alteration in mechanics depending on the WL/Ampl combination chosen. Scale bars are 500 µm.*

Conclusions: Different electrode designs were tested for their effect on designs printed using MEW. The concave electrode was found to influence flow rate and consequently the jet speed of the polymer which in turn was found crucial in maintaining print fidelity of sinusoidal structures.

References:

1. Robinson, Thomas et al. The Next Frontier in Melt Electrospinning: Taming the Jet. Advanced Functional Materials (2019, 1904664)