Solvent-cast 3D Printing with Different Molecular Weight Polymers

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Introduction

• Solvent cast 3D printing (SCP) is a novel printing technique that uses "inks" containing a polymer dissolved in a volatile solvent
• Printing with different molecular weight (MW) polymers enables us to modify mechanical properties without changing polymer type or scaffold architecture
• This project centers on characterizing how printing polymer molecular weight affects the mechanical properties of SCP scaffolds

Methods

• Ink Formulation: 370 mg/mL poly(caprolactone) (PCL) total dissolved in hexafluoroisopropanol (HFIP) at three ratios of 80 kDa:25 kDa by weight: 100:0, 90:10, and 80:20
• Printing: Inks 3D-printed with a customized Nordson EV printer with 32-gauge needle (inner diameter = 100 µm) at 70 psi or 56 psi depending on ink viscosity and line speeds of 0.4 mm/s for the first layer and 0.2 mm/s for subsequent layers
• Rheology: Inks were tested at room temperature at shear rates of 5 s⁻¹ and 9 s⁻¹ using a TA Instruments Discovery Hybrid Rheometer-2 with a modified parallel plate
• Fiber Diameter: Scaffolds were sputter-coated with iridium and imaged using a Hitachi 3500 scanning electron microscope (SEM). Fiber diameter were measured using the open-source program ImageJ.
• Tensile Testing: Arrays with 25 filaments (length = 60 mm) were printed and mounted on paper guides before testing on a Zwick/Roell Tensile Tester with a crosshead speed of 25 mm/min and 100 N load cell.

Rheological Characterization of Ink Viscosity

Figure 1: Viscosity (Pa s) of inks containing different ratios of 80 and 25 kDa PCL at shear rates of (A) 9 s⁻¹ and (B) 5 s⁻¹ (N=1-3)

• Ink viscosity was matched to a predetermined set of print pressure and print speed to ensure consistent scaffold morphology across groups
• Shear rates 5 s⁻¹ and 9 s⁻¹ correspond to print pressures 56 psi and 70 psi, respectively
• The viscosity of the 90:10 and 80:20 inks at 5 s⁻¹ showed a lower viscosity and were therefore printed at a lower pressure based on prior work
• Viscosity of inks with 70:30 and 60:40 ratios were too low for printing and were not included in subsequent experiments

Scaffold Architecture and Filament Diameter

Figure 2: SEM images of (A) 100:0, (B) 90:10, and (C) 80:20 scaffolds. (D) Filament diameters measured for 100:0, 90:10, and 80:20 scaffolds (N=2-4).
• Overall scaffold architecture similar between groups with small differences likely due to deformation during SEM sample preparation
• Filament morphology was similar across the different scaffold groups
• The filament diameter increased as the viscosity of the inks decreased

Filament Stiffness

Figure 3: Macroscopic image of filament arrays in a paper guide for tensile testing.
• Increasing 25 kDa PCL content in the ink decreased filament stiffness
• Data shows that blending higher and lower MW species affects mechanical properties
• 80 kDa and 25 kDa PCL blends can be successfully printed using SCP
• Ink viscosity was used to identify optimal print parameters
• Filament morphology and diameter did not significantly change across different ink formulations
• Increasing amount of lower MW PCL reduced filament stiffness overall

Figure 4: Filament stiffness values (MPa) for 100:0, 90:10, and 80:20 ratios (N=2-3)

• 80 kDa and 25 kDa PCL blends can be successfully printed using SCP
• Ink viscosity was used to identify optimal print parameters
• Filament morphology and diameter did not significantly change across different ink formulations
• Increasing amount of lower MW PCL reduced filament stiffness overall

Conclusions and Future Work

• Increase sample size for all experiments
• Perform microindentation of bulk scaffolds
• Blend with other MWs to expand range of mechanical properties


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