STEVENS INSTITUTE OF TECHNOLOGY 1870

Ph.D. DISSERTATION DEFENSE

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Degree: Doctor of Philosophy

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Title: Design, Fabrication, and Characterization of Melt Electrowriting Enabled 3D Structured Materials

Chairperson: Prof. Robert Chang, Department of Mechanical Engineering

Committee Members: Prof. Chang-Hwan Choi, Department of Mechanical Engineering
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ABSTRACT

A melt electrospinning writing (MEW) system that additively processes molten polymers has emerged as a reliable method to fabricate high-fidelity 3D structured materials, specifically fibrous tissue scaffolds for the investigation of biological performance outcomes as a function of microscale structural features. This dissertation aims to address two research challenges that represent bottlenecks to broadening the applications for MEW as a reliable additive manufacturing process.

Firstly, MEW leverages customized toolpath designs to fabricate various scaffold architectures. To achieve this, two toolpath design models are proposed for the design of customizable planar and tubular scaffolds. These two models enable the heterogeneous scaffold design by prescribing analytical model parameters. The heterogeneous planar scaffolds can possess at most three different morphologies, which can be analyzed by a matrix analysis model. Furthermore, the tubular scaffolds can possess multi-sided pores (pore side number $\geqslant$ 4) with heterogeneous distribution of various pore morphologies along the axial direction. These fabricated spatially heterogeneous scaffolds with well-defined, non-uniform pore attributes can serve as biomimetic, multiplexed platforms for biological investigations.

Secondly, deterioration in the MEW printing accuracy is observed to coincide with the occurrence of fiber deviation phenomena during the scaffold fabrication process. Herein, an efficient universal index (I_p), along with an evaluation protocol, is advanced to evaluate the printing accuracy of MEW. Specifically, the key scaffold design parameters (fiber diameter, inter-fiber distance, and layer number) are observed to affect the value of I_p significantly. Furthermore, the printing sequence can affect the printing accuracy when fabricating scaffolds with different inter-fiber distances along different printing directions. This dependency is most apparent when qualifying loosely structured scaffolds marked by inter-layer gaps. Lastly, residual charge densities entrapped in the scaffolds are measured, thereby furnishing mechanistic insights into the effects of charge on printing accuracy.