Ph.D. DISSERTATION DEFENSE

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Department/School:	Charles V. Schaefer, Jr. School of Engineering and Science / Biomedical Engineering
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Title:	Fabrication and Characterization of Conductive Scaffolds for Localized Electrical Stimulation to Enhance Neuronal Network Formation
Chairperson:	Prof. Hongjun Wang, Department of Biomedical Engineering, School of Engineering and Science
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ABSTRACT

Repair and manage peripheral nerve injuries particularly those large gap defects remain as significant clinical challenges, where conventional treatments often fail to achieve full functional recovery. Scaffold-guided regeneration of neural tissues paves a promising avenue to repair such nerve damage. In recognition of the unique physicochemical and hierarchical structure of native microenvironment that nerve cells reside, various nano/microfabrication technologies have been explored to recapitulate such complexities in the scaffold design. While recognizing the importance of structural and topological guidance in directional extension of axons and neurites of neuronal cells, the current progress still lacks the combination of topological guidance with localized stimulation for better regeneration. Thus, this dissertation research focuses on this gap by designing and fabricating electrically conductive fibrous scaffolds and multichannel nerve guidance conduits (NGCs) to enhance neural regeneration through structural guidance and electrical stimulation (ES). First, near-field electrostatic printing was employed to fabricate polycaprolactone (PCL) microfiber scaffolds functionalized with polypyrrole (PPy). Conductivity, mechanical properties, and coating parameters were systematically investigated. Biological evaluation using PC12 cells demonstrated enhanced neurite outgrowth on conductive scaffolds under ES, with direct current stimulation promoting greater neurite alignment than alternating current stimulation. Subsequently, biomimetic multichannel NGCs were developed using sacrificial templates to create longitudinally aligned, conductive microchannels. Finite element simulations evaluated the effects of channel geometry and conduit dimensions on mechanical performance and electric field distribution. Schwann cell studies further demonstrated improved cellular coverage on electrically stimulated conductive substrates, supporting their potential for promoting cellular organization. Overall, this research integrates advanced fabrication, computational modeling, and biological evaluation to establish a framework for developing next generation NGCs allowing for localized electrical stimulation. These findings provide valuable insights into scaffold architecture and localized electrical stimulation for future peripheral nerve regeneration strategies.