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Fabrication of highly conductive hydrogel-patterned nanofiber for bioelectronics device applications

Dong Nyoung Heo, Junghoon Kim, Lijie Grace Zhang*
Department of Mechanical and Aerospace Engineering, The George Washington University, DC 20052, USA

School of Engineering & Applied Science
THE GEORGE WASHINGTON UNIVERSITY

Background & Objective

Polyimide(PI) based electrodes have been widely used as flexible biosensor and implantable device application, which can be micromachined in various designs suitable for implantation and have been shown to be biocompatible and stable over months of in-vivo implantation. However, the long-term efficacy of the polyimide based cuff electrodes tend to decrease due to nerve damage by mechanical mismatch, low oxygen permeability, and insufficient blood flow inside cuff electrode.

Previously, we resolve these problems with a newly developed PI nanofiber-based flexible electrode for stable neural signal recording, which can be fabricated via electrospinning and silver nanoparticles (AgNPs) inkjet printing. However, the toxicity of AgNPs has been shown in many publications.

Therefore, we developed the new conductive printing materials instead of AgNPs, which can be patterned on the surface of nanofiber sheet.

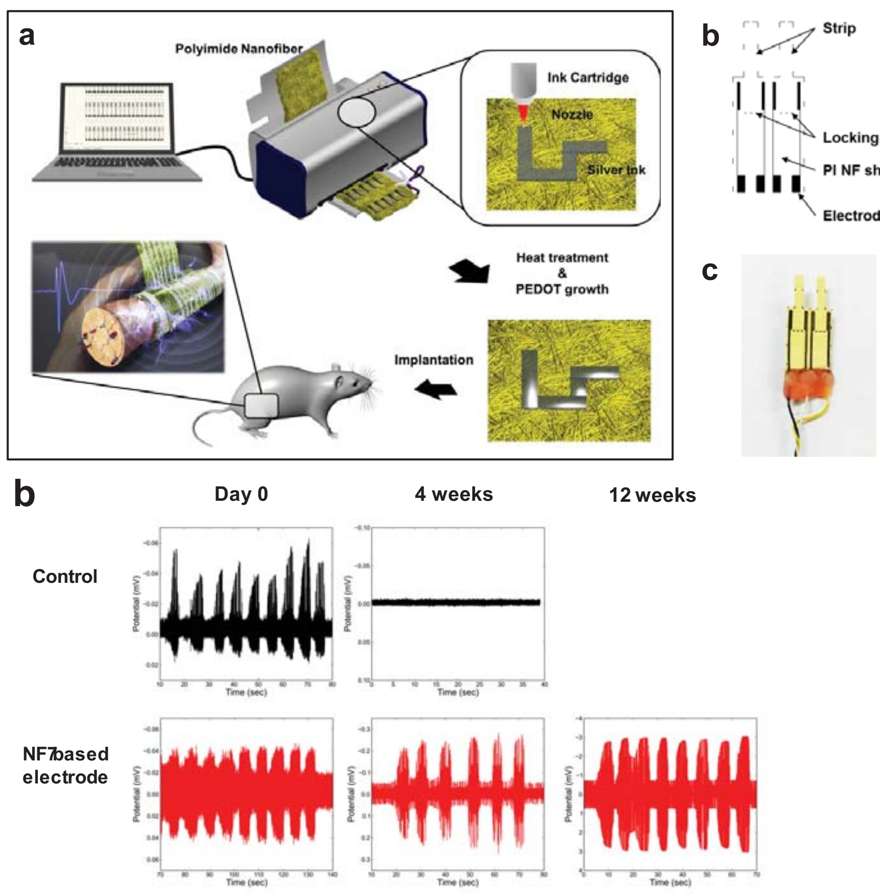

Fig. 1. NF-based nerve electrode with patterned conductive layer. (a) Schematic illustration of fabrication process using inkjet printing system. (b) Concept of pre-production design and (c) photographic image of the fabricated NF-based neural electrode. (d) Representative neural signal recording obtained from sciatic nerve tissue for 12 weeks using the control, NF-based electrode,

Research Plan

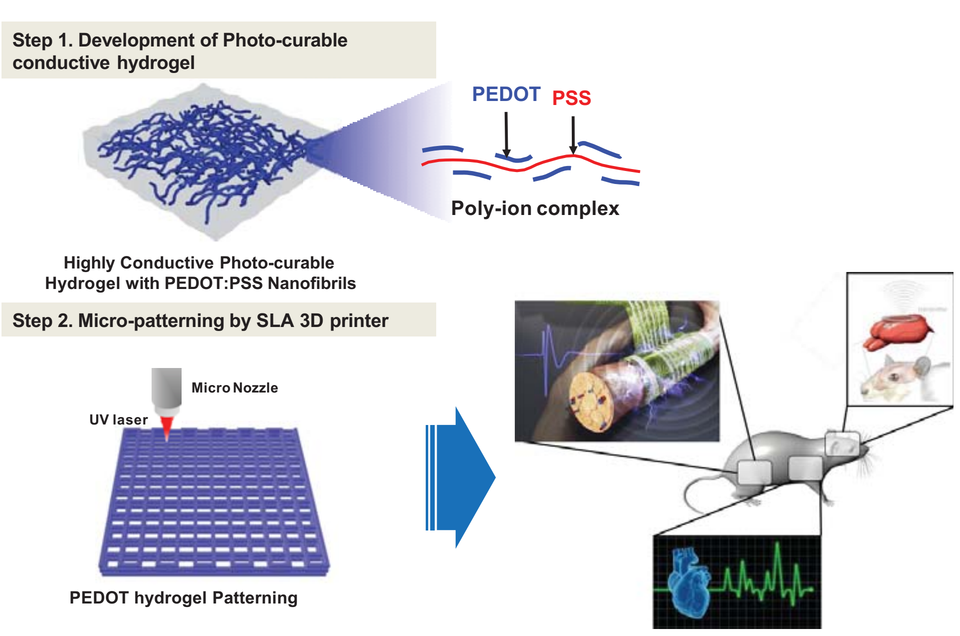

Figure 2. Photo-curable conductive hydrogel patterning on the nanofibrous membrane by stereolithography (SLA) 3D printing system

Characterization

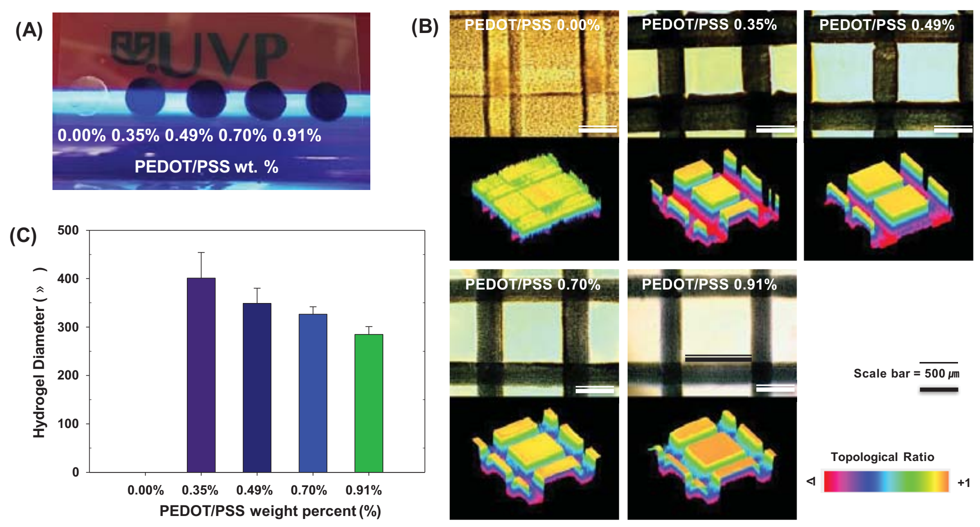

Figure 3. Fabrication of photo-curable conductive hydrogels. (A) Optical images of conductive hydrogels with various concentration of PEDOT/PSS 3D printing ink. (B) Optical and 3D surface plotting images, and (C) diameter of Photo-patterned PEDOT/PSS hydrogels

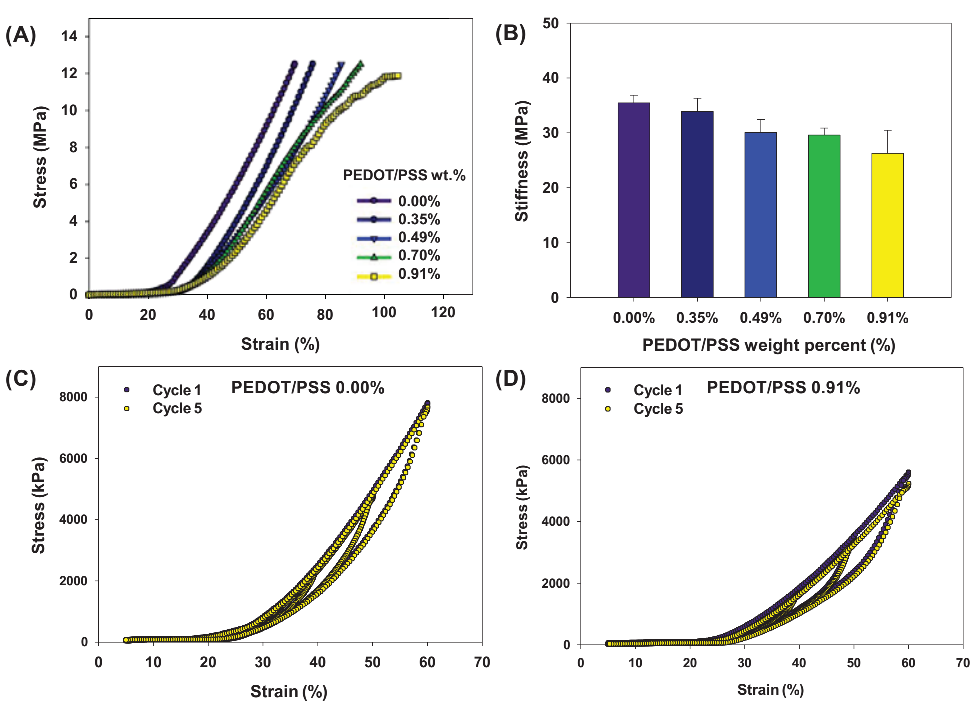

Figure 4. Mechanical Properties of Photo-curable PEDOT/PSS hydrogels. (A) Compressive stress-strain curves of conductive hydrogels with various concentration of PEDOT/PSS, and (B) their stiffness. Recovery of hydrogels (C) without and (D) with PEDOT/PSS, after five cycle of loading and unloading up to 50 % strain.

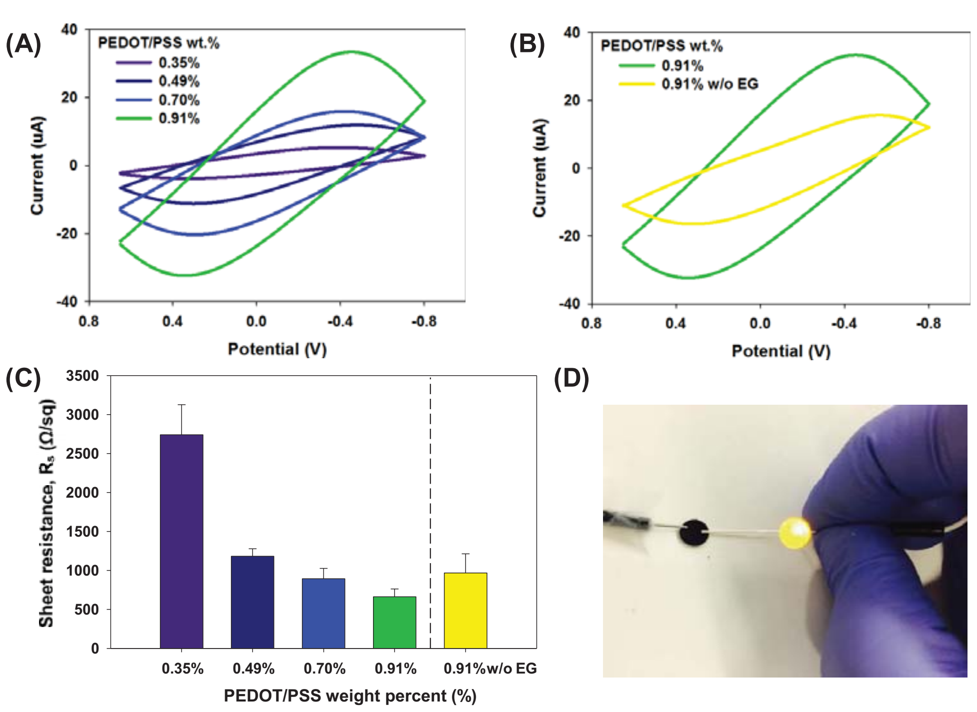

Figure 5. Electrochemical Properties. (A, B) Cyclic voltammograms with scan range from -0.8 to 0.65 V at a scan rate of 100 mV/s. (C) Sheet resistance measured by a four-point probe ohmmeter. (D) LED lamp connected with dried PEDOT/PSS hydrogel.

Cell characterization

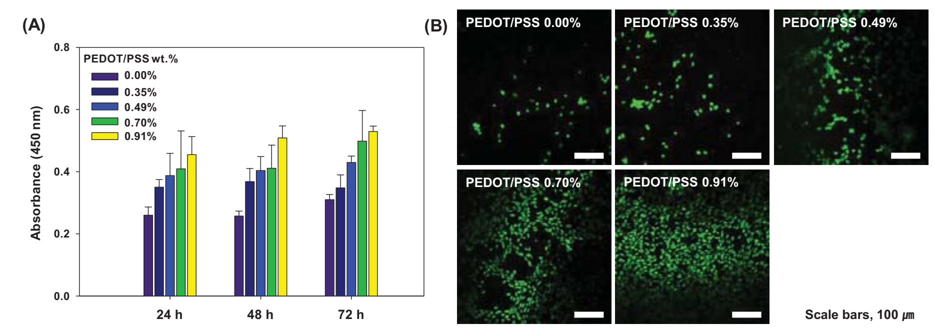

Figure 6. Proliferation and viability of dorsal rood ganglion (DRG) cells culture on the PEDOT/PSS hydrogel surface, investigated by (A) CCK and (B) live/dead assay

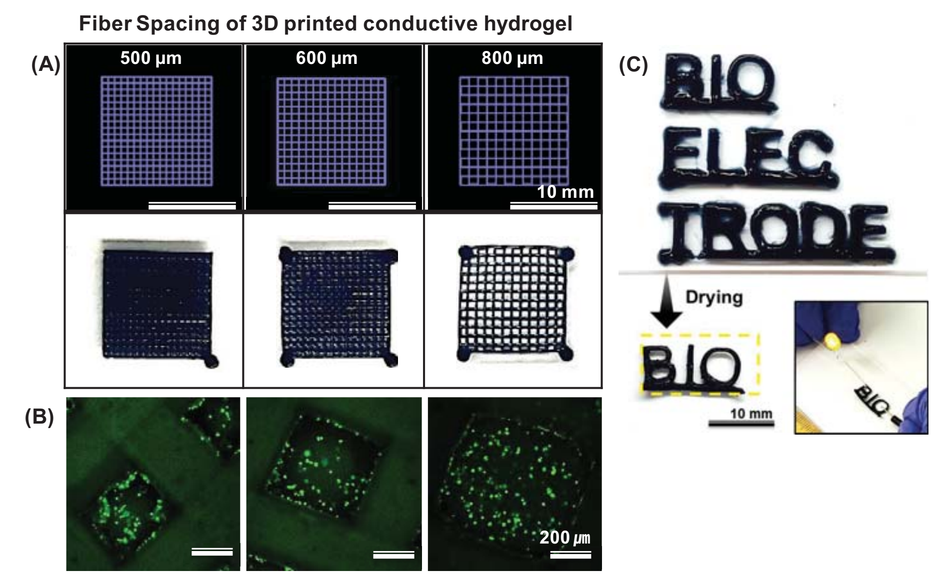

Figure 7. (A) Inputting AutoCAD patterns of parallel squares with the different width and the resulting patterns using photo-curable PEDOT/PSS hydrogels. (B) Encapsulated DRG cells in GelMA hydrogels with 3D printed PEDOT/PSS hydrogel on day 1 confirmed by live/dead assay. (c) Optical images of PEDOT/PSS hydrogel in the swollen and dried states. Dried hydrogel electrically connects to an LED lamp.

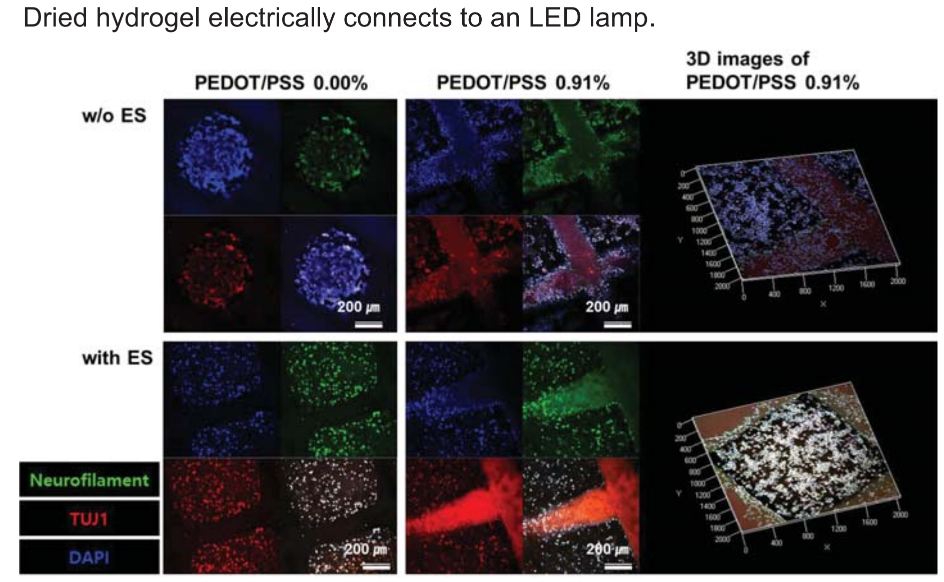

Figure 8. Immunofluorescence images of encapsulated DRG cells in GelMA hydrogels with 3D printed PEDOT/PSS hydrogels, which were treated without or with electrical stimulation for 2 days. Cells were stained with neurofilament (green), Tuj1 (red), and cell nuclei (blue).

Conclusion

In conclusion, we have successfully designed and developed a photo-patternable conductive hydrogel consisting of polyethylene glycol (PEG) hydrogel as the photo-curable polymer, and PEDOT/PSS as an advanced conductive polymer, which could be patterned by SLA 3D printing system. The electrochemical properties and cell proliferation rate of the conductive hydrogel were significantly increased with increased PEDOT/PSS concentration. Also, encapsulated DRGs in the conductive hydrogel showed an increased differentiation after treatment with electrical stimulation. Our findings suggest that 3D printable conductive hydrogels can be widely applicable to neural tissue engineering field. Also, we are going on to study the patterning on the electrospun nanofiber surface with developed conductive hydrogel for *in vivo* electrophysiological signal recording.