In Vivo Optical Control of Spinal Cord and Muscle Function with Polymer Fiber Probes

Chi Lu1,2, Ulrich P. Frohiep2, Ryan A. Koppes2, Andres Canales1,2, Vittorio Caggiano3, Jennifer Selvidge1, Emilio Bizi3, Polina Anikeeva1,2

1 Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, MA
2 Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, MA
3 McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA

Introduction
Restoration of sensory and motor functions in paralyzed patients requires tools with simultaneous stimulating and recording functions. However, the flexible and fibrous geometry of spinal cord and the repeated deformation during normal motions really create technical barriers to have such tools. To address the technical challenges, we develop highly flexible fiber probes consisting entirely of polymers for combined optical stimulation and recording of neural activity. Combining with optogenetics, we apply the fiber probes in the spinal cords of the transgenic mice expressing the light sensitive ion channel, channelrhodopsin 2 (ChR2), and observe the neural activity and limb movements evoked by the optical stimulation.

Methods
Thermal Drawing Process:• processing multitudes materials simultaneously (Fig. Upper Left and Table)
• creating arbitrarily long device with single process
• Gdraw down ratio up to 100x (from cm to µm, Fig. Mid. and Bottom Left )
Material Characteristics:• transparent at λ = 473 nm (excitation peak of ChR2, Fig. a)
• >10x less stiff than silica fiber (Fig. b)
• functional at various bending angles and radii of curvature (Fig. c)

Conclusions
• We successfully applied a fiber drawing process to a materials set consisting exclusively of polymers for simultaneous optical stimulation and electrical neural recording in the spinal cord in vivo.

• Our fiber probes exhibit low optical losses and maintain their functionality at deformation angles up to 270°, radii of curvature as small as 500 µm, and following repeated loading.