Flexible Fibers for Optoelectronic Probing of Spinal Cord Circuits

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Introduction

In the past decades, significant progress has been made in the neural stimulation and recording technologies, yet not in the development of devices interfacing with spinal cord. This is in part due to the complex neurophysiology, and inhomogeneous and flexible structure of the spinal cord. Advances in optical neural interrogation tools have recently enabled cell-specific neural stimulation compatible with concomitant recording of neural activity. Thus it is highly advantageous to create flexible multifunctional neural probes that can conform to the spinal cord geometry and mechanical properties, while allowing for optical stimulation and neural recording.

Materials/Methods

Our polymer fiber probes exhibited low-loss light transmission which is about 1.9-3 dB/cm (polycarbonate (PC) core/ COC cladding/Silver Nanowires (AgNW) and Polydimethylsiloxane (PDMS) coating). The polymer fiber probe could also function while being bent to small radii of curvature (<1mm).

Integrated electrode composed of silver nanowires (AgNWs) exhibited tip impedance 100s kΩ.

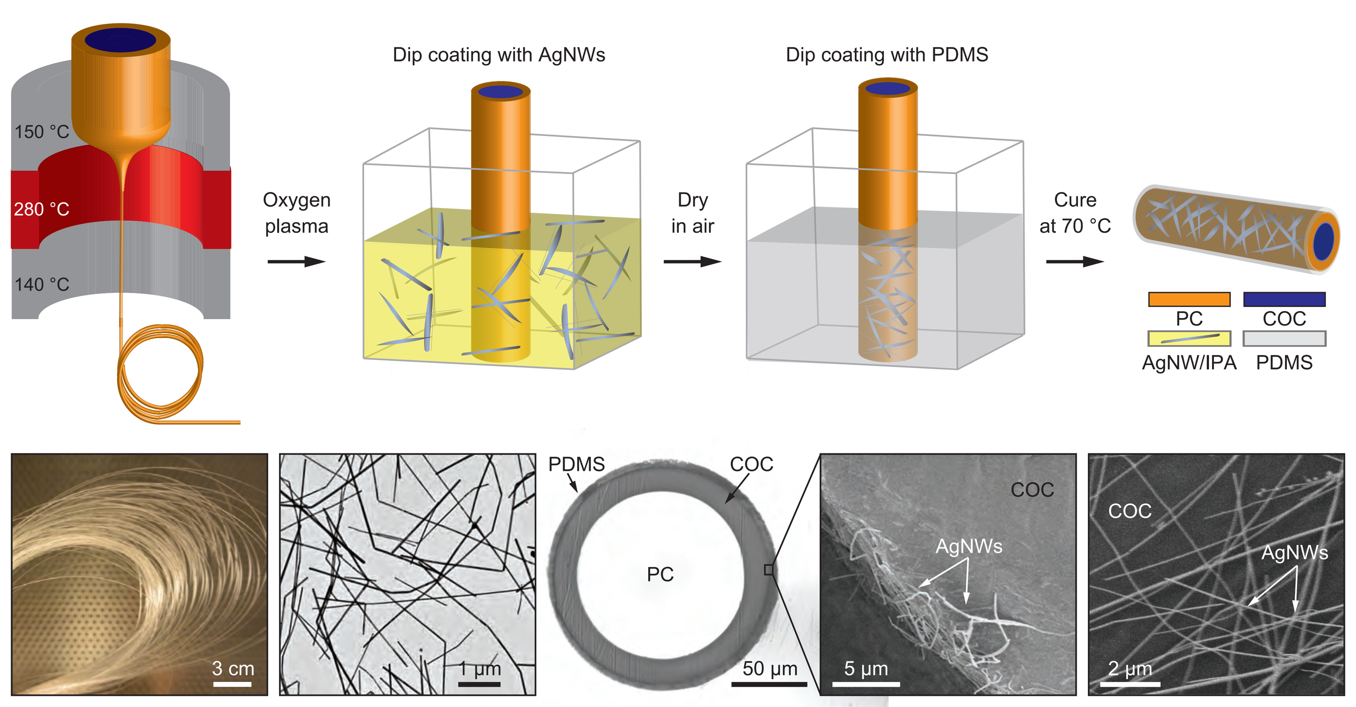
This device enabled us to perform simultaneous recording and optical stimulation in the spinal cord of transgenic mice expressing the light sensitive protein channelrhodopsin 2 (ChR2).

Thermal drawing process:

- Processing multipule materials simultaneously
- Creating arbitrarily long device with single process
- Draw down ratio up to 200 times in one step
- Constraint: the glass transition and melting temperatures of all the materials need to be similar

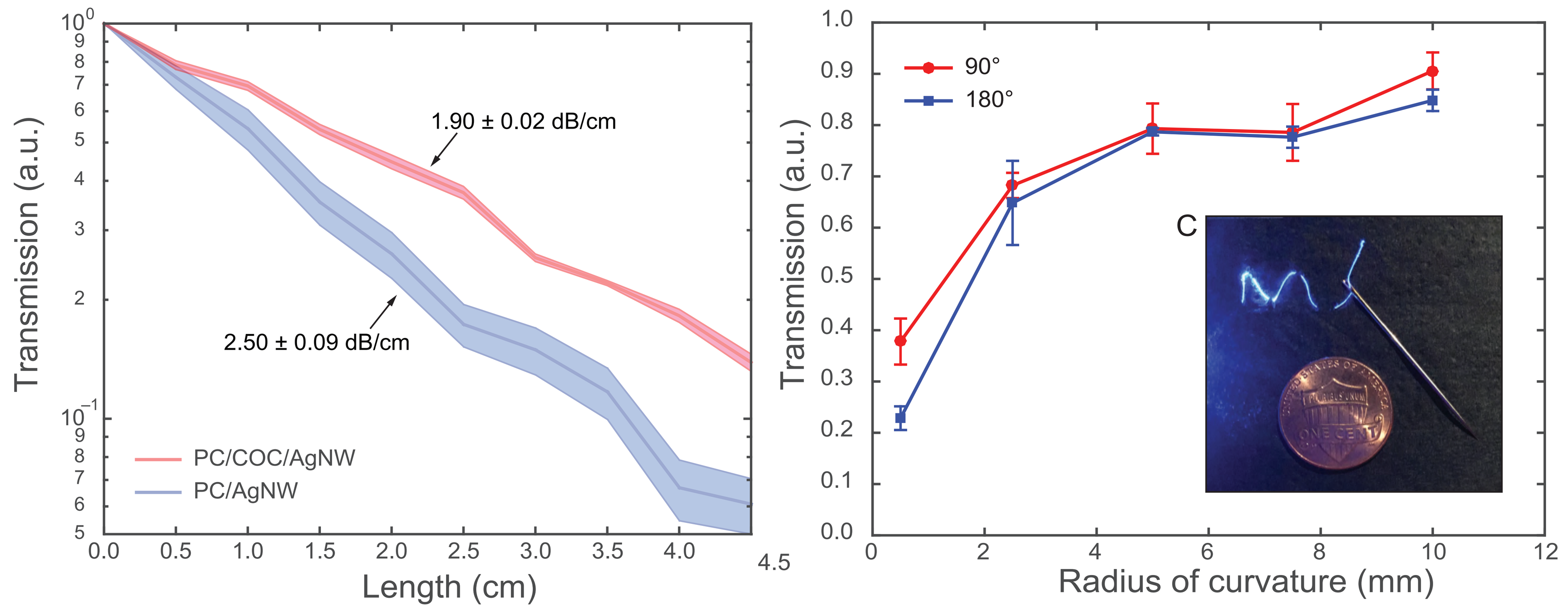
Silver nanowires (AgNW) coating:

- High conductivity -> High signal-to-noise ratio
- Cost efficient (thickness of coating ~ 1 μm)

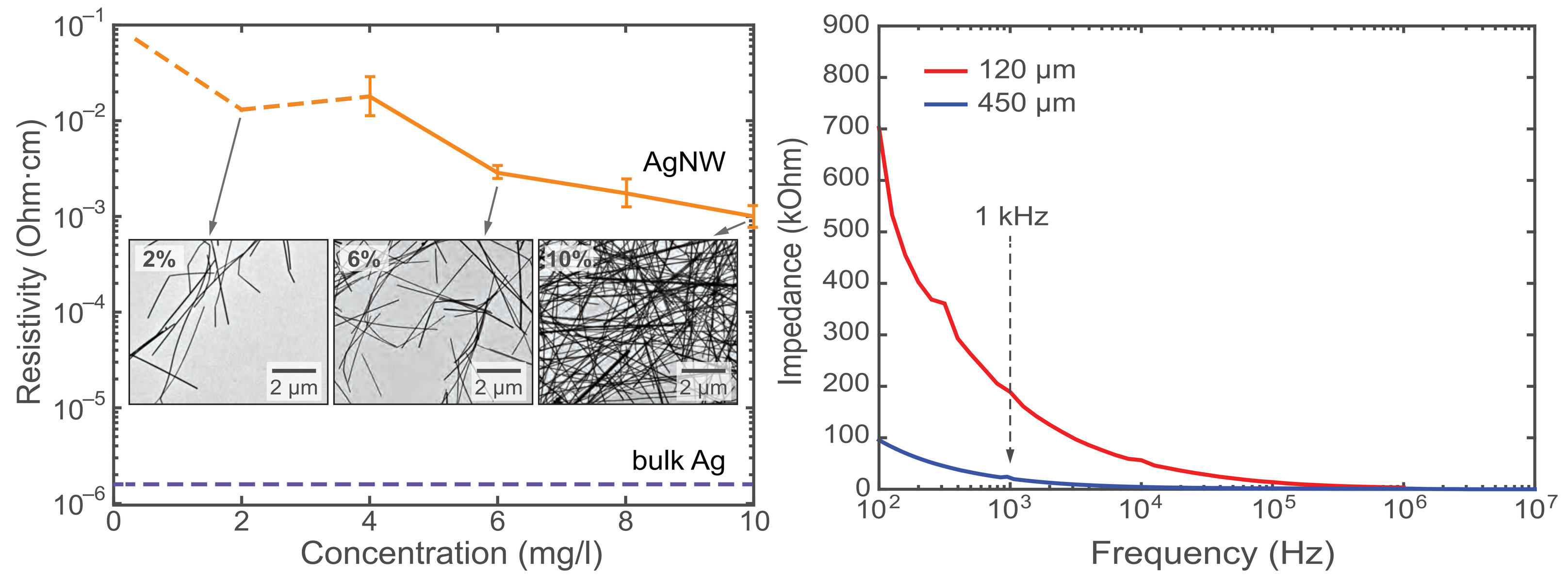


Optical and electrical charactreizations

- dB loss ~ 1.9 dB/cm
- High transmission under small bending radii of curvature

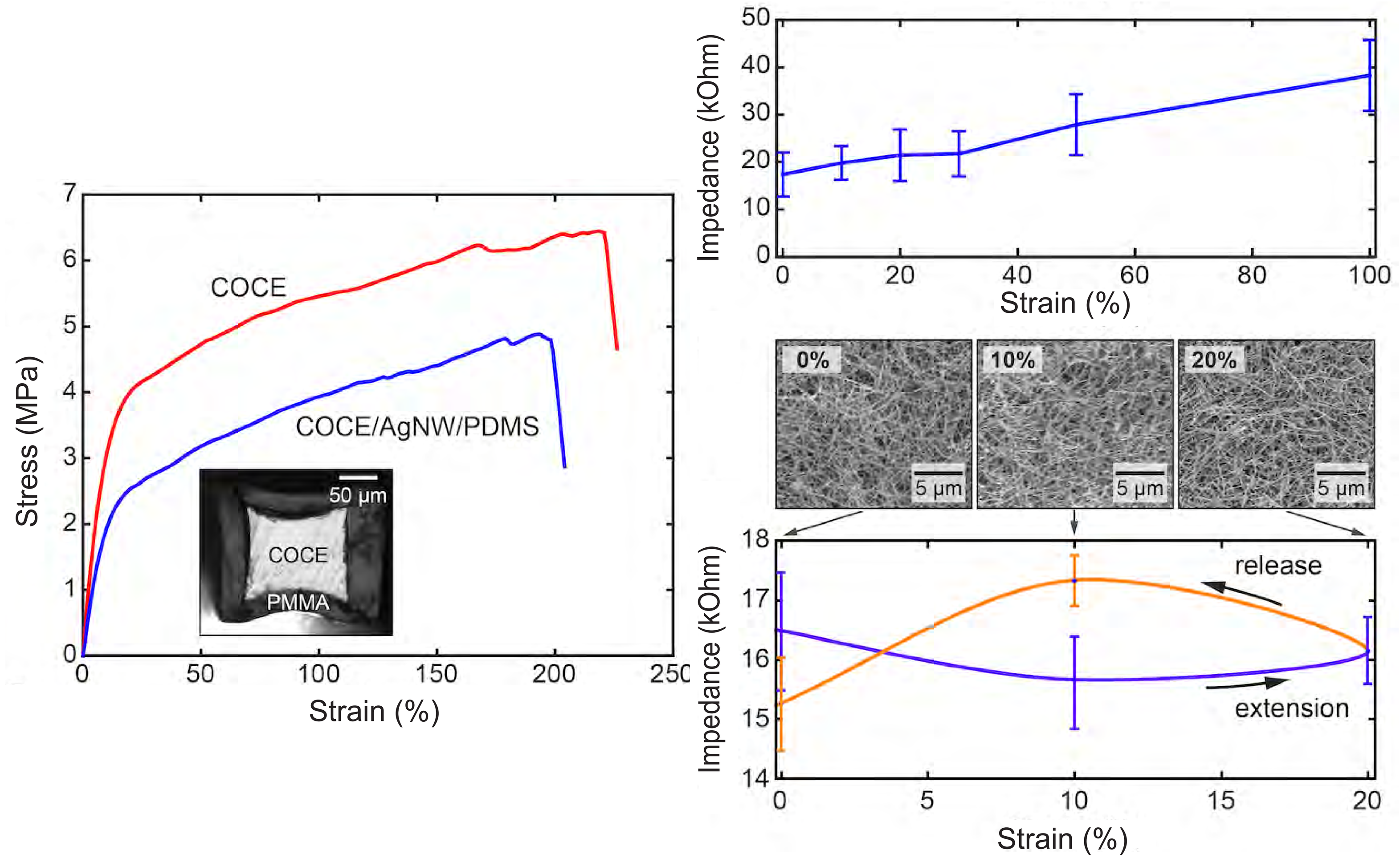


- Conductivity increases with concentration of AgNW solution
- Impedance ~100s of kOhm at 1k Hz



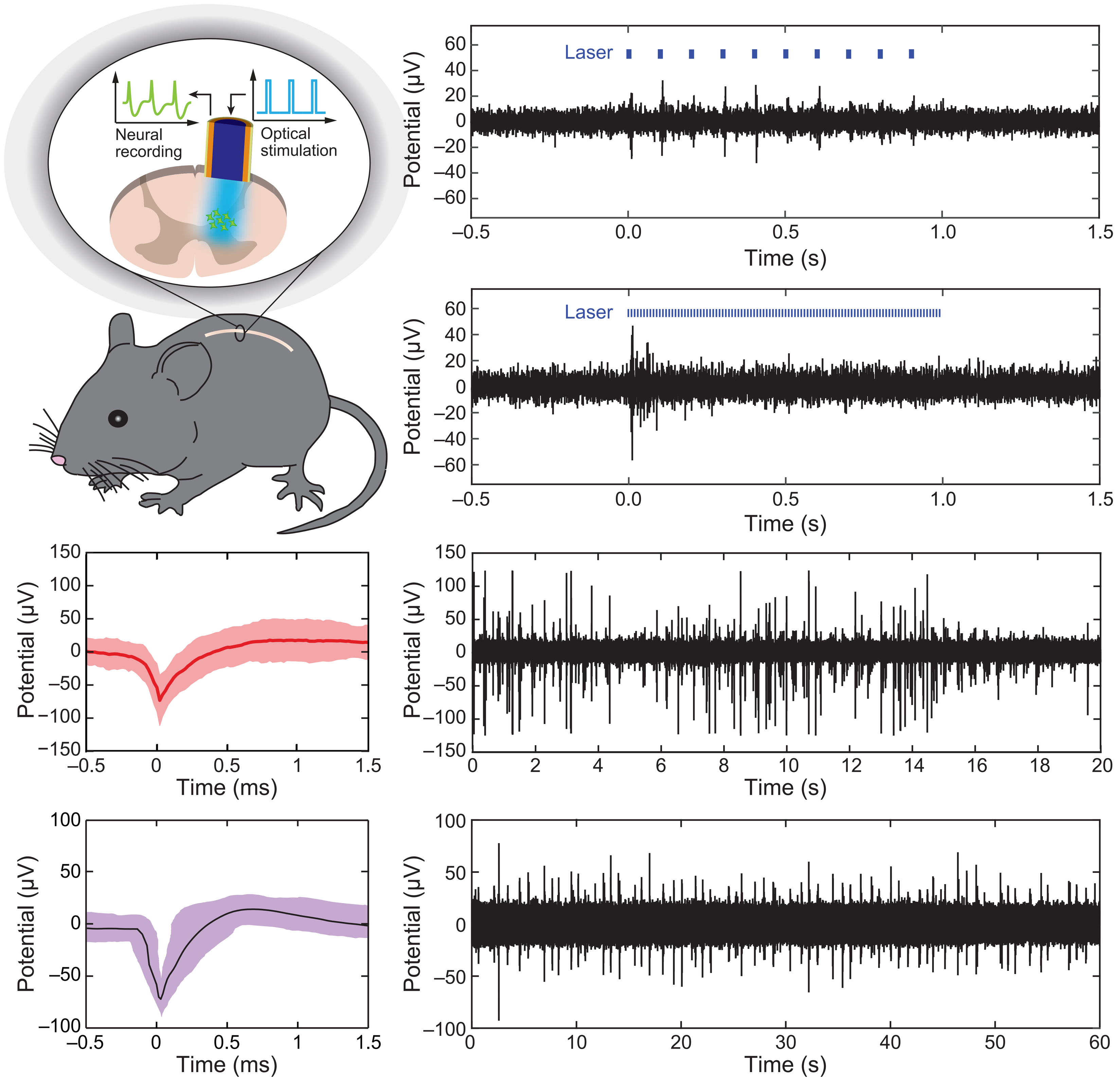
Stretchable electrode

- Electrode made with elastomer
- Conductivity is reversible under strain test



Simultaneous stimulation and recording

The fiber probes were applied in the lumbar spinal cord of transgenic Thy1-ChR2-YFPmice expressing ChR2 across the nervous system. Neural activity was robustly evoked by laser pulses and recorded by the same device. (473 nm, 5 ms pulse width, 10 Hz, 1 sec epochs, 5 sec interval, noise leve ±10 μV)



References

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