Chronic 2-photon calcium imaging through transparent PEDOT:PSS microelectrode arrays in awake mice

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Abstract: We developed conformal, transparent PEDOT:PSS microelectrode devices suitable for chronic implantation for simultaneous calcium imaging and electrophysiological recordings in awake rodents.

1. Introduction

The ability to acquire neural activity from the surface of the brain can improve the accuracy of next generation brain-machine interfaces. Adapting the use of conformally thin parylene C in conjunction with conductive polymer PEDOT:PSS coating on the electrode sites, we were able to improve the electrochemical properties of our devices that allowed us to record over several months in mice with chronically implanted devices. In agreement with Schander et al. (2016), we demonstrated minimal tissue response to PEDOT arrays implanted for 10 weeks in rodents through immunohistochemical staining of neurons, astrocytes, and microglial cells[1,2]. Here we extend this work to show simultaneous 2-photon optical imaging and electrophysiological recordings of cortical neuronal activity in awake mice with chronic PEDOT:PSS microelectrode array implants.

2. Methods

We fabricated thin-film PEDOT devices using a scalable, monolithic fabrication approach as previously described [2] (Fig 1A). The microelectrode array was then bonded to a custom PCB with the dimensions of 13.6 mm x 9.4 mm and an FFC connector (Fig. 1B). Electrochemical characterization and recordings were conducted using Intan RHD 2000. We implanted arrays in Emx1-Cre/Ai32 mice expressing Channelrhodopsin-2 in excitatory neurons [3,4]. Expression of the calcium indicator jRGECO1a was induced via transduction with pAAV.Syn.NES-jRGECO1a.WPRE.SV40 [5]. We designed a headpost which allowed permanent fixation of the interface board inside a protective casing.

3. Results

Electrode impedances fluctuated from the initial >1 MΩ to <100 kΩ on subsequent days after implantation (Fig. 1C). Upon optogenetic stimulation, we observed an electrophysiological response (Fig. 1D and E) as well as calcium response. The average amplitude of electrophysiological response to the stimulation yielded over 1500 μV across channels, while cells observed around 40-60% change in fluorescence intensity depending on the activity of the individual cell.

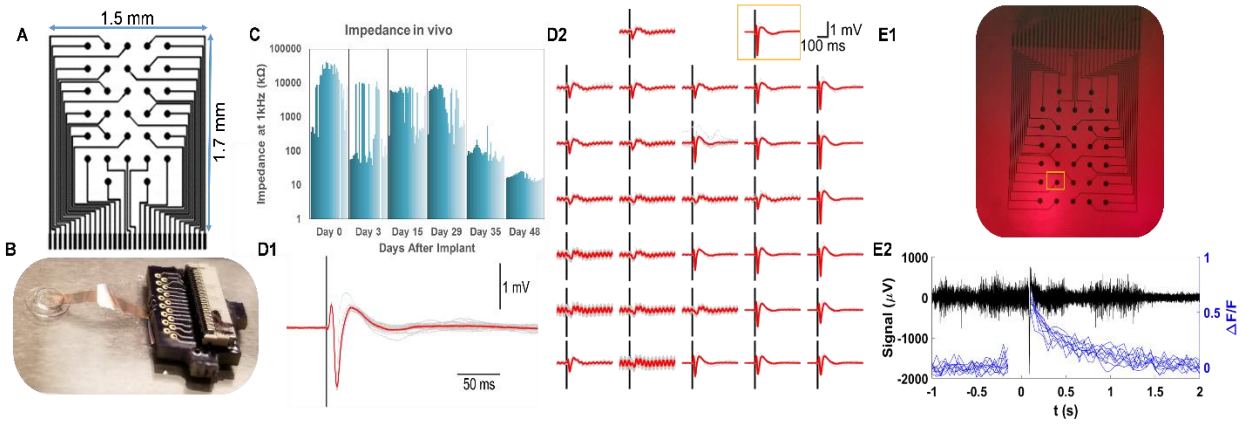

Fig 1. Chronic multimodal data acquisition with a 32-channel optically transparent PEDOT:PSS microelectrode array. **(A)** Device geometry. **(B)** Array bonded to custom-made PCB (right) and glass window for implantation (left). **(C)** *In-vivo* impedance measurements after implantation show a trend towards decreasing values over time. **(D1)** Trial average of electrical response to optogenetic stimulation from one electrode. **(D2)** Trial average of electrical response to optogenetic stimulation across electrode array (yellow box highlights). **(E1)** jRGECO1a fluorescence from one AAV injection site beneath the array; the yellow rectangle highlights the electrode shown in G. (**E2**) Example trace of simultaneous optical and electrophysiological with optogenetic stimulation at time 0s.

4. Conclusions

Here we show the first instance of chronic simultaneous neurorecordings using PEDOT:PSS microelectrode devices, 2-photon calcium imaging, and optogenetic stimulation in awake mice.

References

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