Introduction

Neural electrodes with good electrical conductivity and optical transparency from visible to NIR could potentially allow for simultaneous 2-photon imaging and electrophysiology of brain tissues\(^1\).\(^2\). Additionally, ultra-miniaturization of the microelectrode arrays is needed to achieve higher spatial resolution of the neural recordings which requires simple fabrication techniques. Finding correlation of imaging data and electrical recordings can provide additional insights towards understanding of neural circuits. Here we present a design and fabrication of an ITO based transparent, flexible electrode array for simultaneous neurophysiological recording and 2-photon imaging.

Methods

The array consists of ITO metal electrodes patterned on parylene-C substrate and encapsulated with another layer of parylene. The design of the array is shown in Figure 2a. The array has 2 sets of 17 electrodes, thus providing a total of 34 recording sites. Each electrode is 12 µm x 12 µm in size. The ITO electrodes are connected using ITO traces of 6 µm width. These traces run in parallel up to 3.5mm and then fanout to form contact pads which is used to connect to a custom PCB. As shown in assembled system in Figure 2, the electrode array is connected to the custom PCB using heat-seal connector through a hot bar bonding process. The GRIN lens is attached to the electrode array’s recording sites using an optical adhesive.

Results

The electrochemical impedance spectroscopy results for the electrodes are shown in Figure 4b\(^1\). The mean and standard deviation of impedance magnitudes at 1kHz for 10 different electrodes was calculated to summarize the impedance characterization. The electrode array showed an AC average magnitude impedance of approximately 325 kΩ with a standard deviation of \(~46\) kΩ. The impedance of the electrode-electrolyte interface is good for signal acquisition with reasonable signal-to-noise ratio (SNR)\(^6\). The optical characterization was performed using the setup shown in Figure 4a. In Figure 4d, with electrode placed between the objective lens and the calibration target, we observe a clear image of the grid pattern present on the calibration target confirming that the electrode array is transparent at the desired wavelength of 920 nm for 2-photon imaging when imaged through the electrode array.

Conclusion

In this work design, fabrication and characterization of an ITO based ultra-miniaturized transparent electrode for simultaneous 2-photon imaging and electrophysiological recording application was discussed. The impedance spectroscopy measurements and 2-photon imaging of fluorescent calibration target was used to show its capability to perform both these tasks.

References


Fig.1. Diagram of the electrode array design

Fig.2. Assembled system with array connected to a custom PCB using heat-seal connector, GRIN lens connected using optical adhesive

Fig.3. (a) Impedance measurement setup using Intan System (b) Magnitude of the AC impedance measured for 10 different channels using the setup.

Fig.4. (a) Setup for 2-p imaging through electrode array with 920nm IR laser (b) 2-p imaging showing transparent target grid through the array.