Polymer-Based *In Vivo* Transducers with Conductive Polymer Mixture Polydimethylsiloxane Composite Electrodes

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Abstract

There is an emerging demand for flexible, tissue-conformable microelectrode implants that can follow the curvature and topography of the brain. This includes the optimization of electrode geometries and their electrical properties for the recording of individual spikes at cellular resolution. Currently, the integration of electrical components into flexible electronics and the generation of durable conductors is still challenging. Here we present a second generation of flexible, PDMS-based MEAs designed for recording within the media-longitudinal fissure in the prefrontal cortex (PFC) of rodents.

1 Methods

1.1 Design

The electrode-, track- and connection pad-patterns were sketched out with standard layout software (Expert, Silvaco), transferred into high-aspect ratio negative photoresist and molded into PDMS by soft lithography. The fabrication steps have been explained before [1]. Here, a polymer MEA (*polyMEA*) composed of 18 electrodes with diameters ranging from 50 µm to 130 µm in 10 µm increments was designed for recording from different brain layers (Fig. 1).

Fig. 1. Overall layout and connecting scheme for the presented *in vivo* *polyMEA*. A) CAD design and resulting *polyMEA*; pad width: 414 µm. B-D) *polyMEA* squeeze-clamped between an Omnetics strip connector (A79006-001) 0.757 mm pitch, double-row pin connector (front, back and side). E) Cross section views of the *polyMEA* electrodes (left), pads (middle) and buried tracks (right). Scale bars: 1 mm (B-D), 100 µm (E).

1.2 Material Selection

PDMS (Sylgard 184, Dow Corning) was selected as the insulator substrate due to its flexibility and closer Young’s modulus to that of brain tissue. It is supplied as a two-component system being composed of a base and a curing agent (10:1 ratio (v/v)). As conductive material we chose a mixture of PEDOT:PSS (P Jet 700, Heareus) with additives (2.5% DMSO, 2.5% sorbitol) and carbon and graphite in PDMS to form a conductive composite. These were mixed until the DC resistance dropped below 10 kΩ per 1 cm distance.

1.3 Fabrication

After filling the cavities of the PDMS scaffold with the conductive material and curing it, the probe backside was insulated with a thin layer of PDMS. The probe was then folded along the shaft edge and a transparency temporarily slid between them to push its pads against the pins of an Omnetics nano-connector. The impedance characteristics of the electrodes were evaluated before and after connecting to the connector. For ensuring that the materials were biocompatible, we cultured neurons on *in vitro* probes made from the same materials and compared them with neurons on commercial MEAs (Multi Channel Systems) as controls.

2 Results

Biocompatibility was confirmed *in vitro* with cortical neurons on flexible MEAs (Fig. 2). Over a recording period of 40 days, the signal-to-noise ratio was about five, indicating that the probes and materials are sufficiently stable to be used in long-term recordings (Fig. 3).
MEA technology: New materials and designs

Fig. 2. Absence of cytotoxicity as validated in vitro for a cortical network (40 DIV) (electrode pitch: 400 µm).

Fig. 3. High signal-to-noise ratio in exemplary in vitro recordings (40 DIV). A) Short-term recording window with individual spikes, B) Long-term recording window. The low frequency noise was removed by a Bessel 2nd order, high-pass filtered (cut-off at 50 Hz).

Fig. 4. polyMEA impedance characteristics before and after connecting the probe to the Omnetics connector.

3 Conclusion
We developed a flexible MEA with 18 electrodes suitable for being implanted into the brain. We successfully evaluated the connection between the individual probe pads and their corresponding connector pins. The impedance of most recording sites in this in vivo polyMEA is below 1 MΩ at 1 kHz. This probe will be considered for chronic recordings.

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References