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SpineRepair RTD 2013

FNSNF

Nanowire based Soft Electrodes

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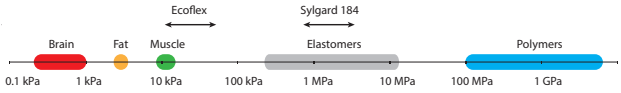
Motivation: chronic implants & novel applications

Goal Soft & stretchable micro-electrode arrays for chronic implantation and novel applications

Why
1. Stiff materials are limited for chronic use due to a mechanical mismatch to tissue (Fig. 1 & 2)
2. Stretchable electronics can enable diverse conformal devices for novel applications

Solution Soft conductive composite materials based on elastomers with incorporated nanomaterials with an elastic modulus closer to tissue (Fig. 3-11).

Fig. 1: Elastic moduli of different materials and tissues:



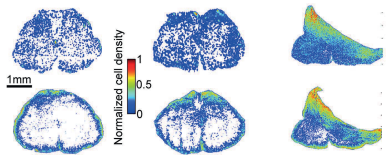


Fig. 2: Neuroinflammatory response to subdural spine implants in rats comparing sham surgery (left), soft implant (middle) and stiff implant (right) six weeks after implantation (top: microglia, bottom: astrocyte). From [1].

Materials & Methods

1 Micro-patterned stretchable conductor based on AgNW-PDMS

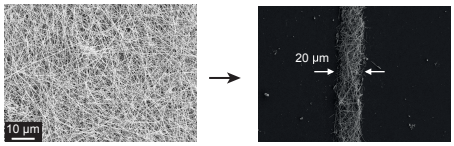


Fig. 3: Novel composite materials based on silver nanowire (AgNW) networks embedded in PDMS are promising for use as highly stretchable conductors [2] and can be micro-patterned using photolithography [3].

2 Pt-PDMS for interfacing tissue for recording & stimulation

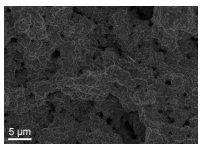


Fig. 4: Rough platinum-elastomer composite combines the electrochemical properties of platinum with the mechanical compliance of the elastomer making it a promising electrode material for chronic recording & stimulation [1].

Results A: AgNW-PDMS

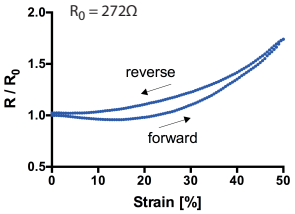


Fig. 5: Resistance change of a 1 cm long and 100 µm wide AgNW-PDMS track during a 50% strain cycle [3].

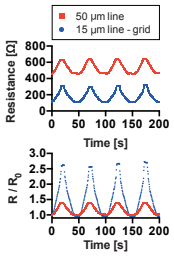
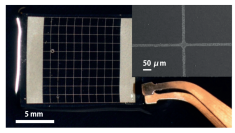


Fig. 6: Resistance change of AgNW-PDMS tracks and grids under 20% strain cycles [3].



Patterned AgNW-PDMS with 15 µm grid tracks.

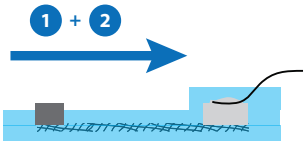


Fig. 7: Schematic side view of an electrode array (blue: PDMS, dark grey: Pt-PDMS, gray network: AgNW).

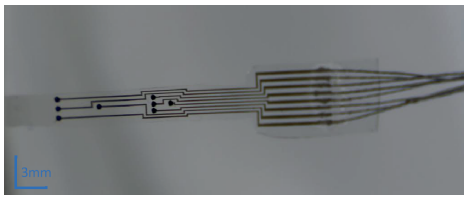


Fig. 8: A prototype of a soft & stretchable micro-electrode array which combines high stretchability & conductivity of AgNW tracks with Pt-PDMS electrodes providing good electrochemical properties for recording & stimulation of muscle & nervous tissue.

Results B: electrode array characterization

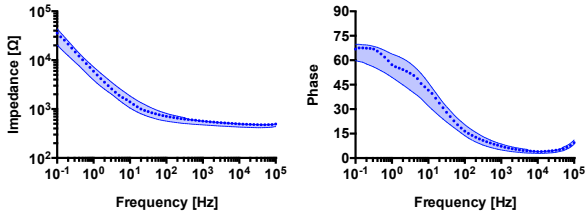


Fig. 9: Impedance and phase of a complete micro-electrode array measured in PBS (n = 7, electrode area of 0.4 mm²) with median and lower/upper border values.

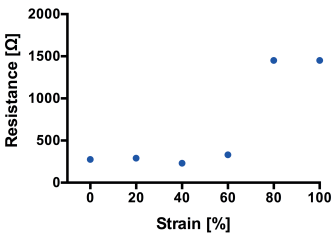


Fig. 10: Resistance change of a complete micro-electrode array under strain demonstrating a maintained electrode performance even during high deformation.

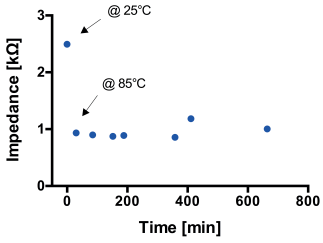


Fig. 11: Impedance at 1kHz over time between two electrodes of the complete array. The array was fully immersed in PBS heated to 85°C for accelerated life-time testing.

Acknowledgments

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[1] Minev, I. R. et al. Electronic dura mater for long-term multimodal neural interfaces. Science 347, 159-163 (2015).
[2] Xu, F. & Zhu, Y. Highly conductive and stretchable silver nanowire conductors. Adv. Mater. 24, 5117–22 (2012).
[3] Martinez, V., Stauffer, F. et al. Stretchable silver nanowire–elastomer composite microelectrodes with tailored electrical properties. ACS Appl. Mater. Inter. 7.24, 13467-75 (2015).

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