A Multi-Electrode Cuff For Neuronal Sensing In The Locust

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This paper describes the fabrication of an implantable multi-electrode cuff for sensing electrical impulses on a nerve cord of a locust. When coupled with a miniaturized telemetry backpack, the cuff will, for the first time, enable studies of neuronal signals in freely behaving insects. The larger objective is to gain insight into neural information processing underlying escape behaviors[1] in response to visual threats and collision avoidance in flying swarms.

The metal lines of conventional cuff electrodes are formed on a planar substrate and applied to a preformed cuff template. The smallest yet reported, 700 μm in diameter[2], is about 10 times larger than we need. These relatively stiff cuffs must be designed for a loose fit to avoid nerve damage, making it difficult to achieve signal isolation and to clearly differentiate between signals carried by neighboring axons in the nerve bundle.

Our cuff is formed [Fig.1] by the differential stress between a stiff SiO_2 backing film and a thin polyester substrate. Compressive stress in the sputtered oxide causes a loose curl which tightens to a 100 μm diameter as the polyester shrinks during subsequent heating to 225° C. Fig. 2 shows the snug fit of a cuff on a silver wire with the same diameter as a nerve cord. Even so, nerve damage has never been observed.

The metal lines must be deposited after the heat shrink step or they will crack. So the cuff is unrolled and loosely clamped to a substrate. Sputtered gold lines are formed by ion beam proximity (IBP) lithography and sputter etching using negative tone plasma polymerized methylethacrylate (PPMMA) resist.[3]. An insulating overcoat with a spiral of sub-5 μm vias on the interior cuff surface is formed by exposing a second coating of PPMMA. IBP with conformal resist is the key to patterning micron-scale features over the 2-3 mm topographic relief of the open cuff.

Figure 3 shows an example recording from the locust nerve cord obtained by a single electrode cuff. The largest spikes on the trace belong to an identified neuron, the Descending Contralateral Movement Detector (DCMD), which is thought to be involved in planning and execution of visually evoked escape behaviors.

The fabrication of multi-channel cuffs will be presented at the conference.

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[1] H. Fotowat and F. Gabbiani, J. Neurosci. (Cover article), 27(37):10047-10059 (2007)
[2] T. Stieglitz, M. Schuettler, and J. -U. Meyer, IEEE Proceedings of The First Joint BMES/EMBS Conference, (1999)
[3] D. Parikh, B. Craver, H. Nounu, F-O. Fong, and J. C. Wolfe, *Nanoscale pattern definition on non-planar surfaces using ion beam proximity lithography and conformal, plasma-deposited resist*, IEEE/ASME J. MEMS (submitted)

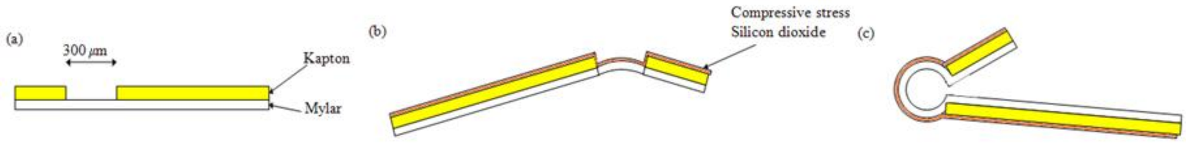

Figure 1: Micro-cuff fabrication- (a) Two handling tabs of 60 m thick Kapton adhesive tape are applied to a 2.5 m thick Mylar film leaving a open gap corresponding to the circumference of the final cuff; (b) a 400 nm thick backing film of compressive SiO_2 is sputtered onto the Mylar, causing a gentle curl; (c) finally, the structure is heated to 225° C where Mylar shrinks and the curl tightens to the final diameter.

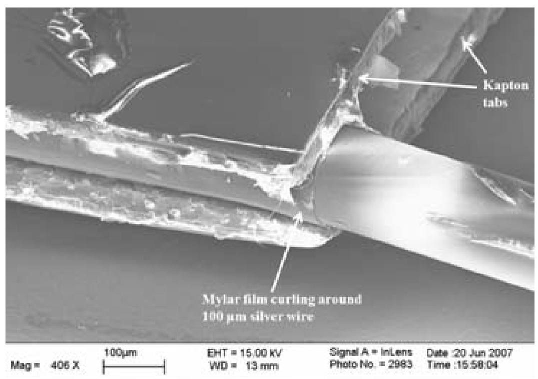

Figure 2: A cuff installed on a silver wire with approximately the same diameter (100 m) as a nerve cord.

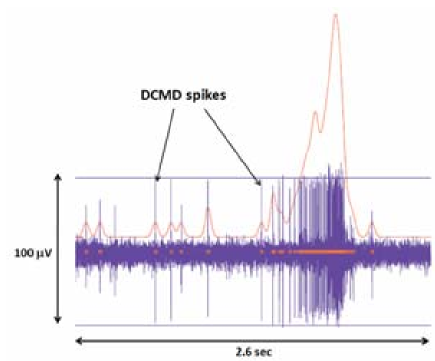

Figure 3: Example recording from the locust nerve cord obtained by a single electrode cuff. An identified neuron, the Descending Contralateral Motion Detector (DCMD) begins firing when a visual threat is presented to the locust. As the size of the stimulus increases, the frequency of the DCMD spikes increases, peaks, and decays. By measuring the timing of DCMD activity at various stages of the motor response, it is possible to determine its role in triggering escape behaviors.

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