Nanowire-Based Electrode for Neural Recordings in the Brain

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Research on implantable neural interfaces may empower new unprecedented possibilities for both basic research and clinical therapy. Nowadays neural interfaces suffer from a number of shortcomings related to *e.g.* instability with respect to recorded neurons and tissue reactions [1]. Nanostructured electrodes are considered as a promising alternative to conventional neuronal interfaces [2] since they may provide a number of important advantages: a better spatial resolution, a shorter cell-to-electrode distance, improved electrical properties, better biocompatibility, less tissue damage and new functionalities.

Here we report the design, fabrication and functional testing of GaP nanowire-based electrode with a controllable nanomorphology. The sensing part of the electrode was made of a metal film (15 nm thick Ti and 75 nm thick Au film) deposited on top of an array of vertical freestanding GaP nanowires covered with HfO_2, Figure 1. The nanowire arrays were epitaxially grown on (111)B GaP surface of 300 µm thick GaP substrates. Gold catalytic particles for the nanowire growth were defined with electron beam lithography. In this way a high degree of control over the nanowire array geometry (nanowire position, length, and diameter) was achieved [3]. GaP nanowires used in this work had ~70 nm diameter with only little tapering and were approximately 5 µm long. The nanowires were used as a backbone for metal nanostructured electrode. The GaP substrate was trimmed by grinding, which allowed the electrode implantation in to the brain. The functional testing of the electrode was done in saline solution and in the rat primary somatosensory cortex by recording spontaneous neuronal activity and recording electrically evoked intracortical potentials, Figure 2. We found that the nanowire-based sensing part withstands multiple brain implantations. These results demonstrate that the recordings are done with the nanowire sensing part and prove the feasibility of using nanowire based electrodes *in vivo*. In the future, this type of electrode can be used as a model system for analysis of nanostructured neuronal interfaces *in vivo*. This study should also be useful in further studies of complex nanoassemblies *in vivo*.

[1] J. Schouenborg, Progress in Brain Research, **194** (2011), pp. 61-70.
[2] N. A. Kotov *et al.*, Adv. Mater., **21** (2009), pp. 3970-4004.
[3] D. B. Suyatin, W. Hällström, L. Samuelson, L. Montelius, C. N. Prinz, and M. Kanje, J. Vac. Sci. Technol. B, **27** (2009), pp. 3092-3094.

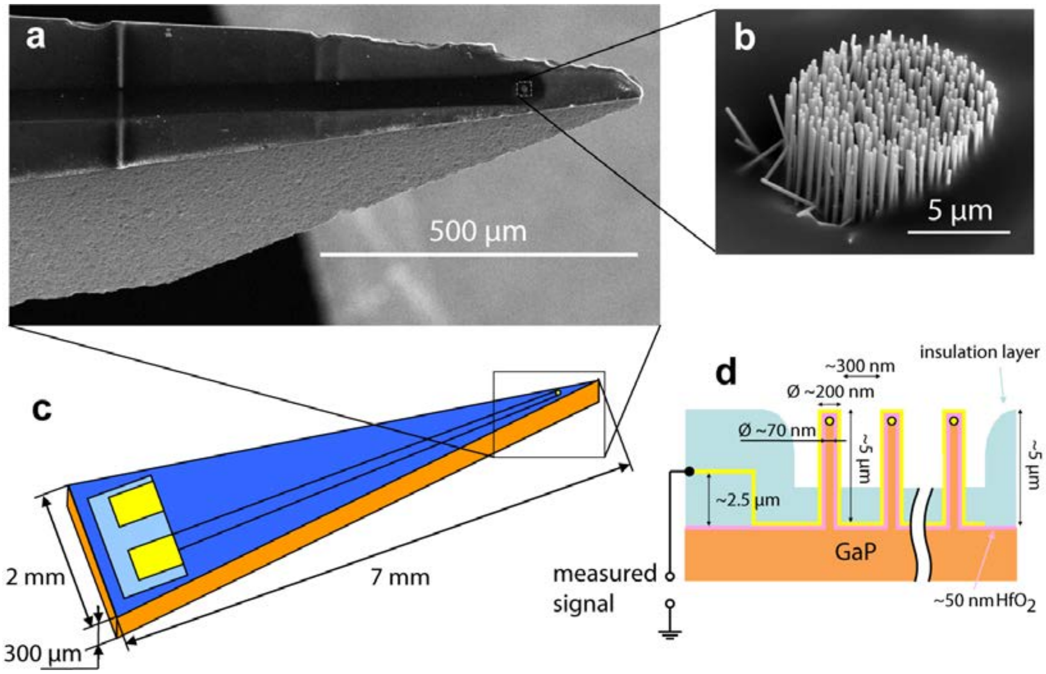

Figure 1: Nanowire-based electrode for in vivo neuronal signal recordings:
(a) SEM image of the nanowire-based electrode tip. (b) SEM image of the nanowire-based sensing region made with an array of freestanding epitaxial GaP nanowires covered with HfO_2 and metal film (15 nm Ti and 75 nm Au).
(c) Layout for the nanowire-based electrode. (d) Schematic for the nanowire geometry and the electrode layered structure.

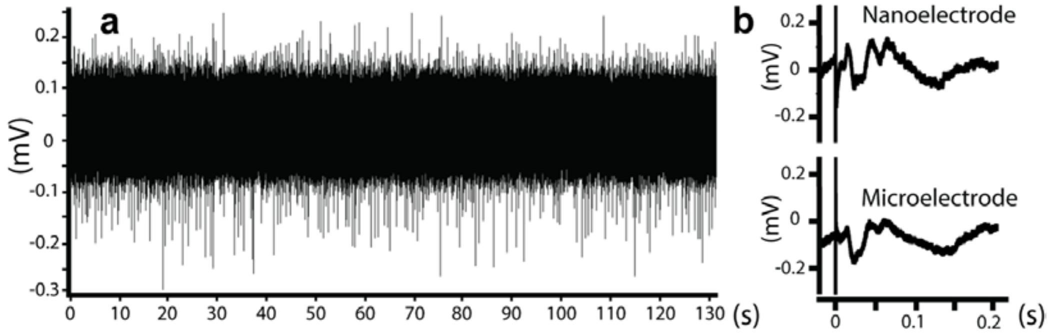

Figure 2: Acute in vivo recordings with a nanowire-based electrode in the rat primary somatosensory cortex: (a) Spontaneous neuron activity recorded at a cortical depth of approximately 1 mm. (b) Electrically evoked intracortical field potentials simultaneously recorded with a nanowire-based electrode and a microwire electrode (33 µm diameter tungsten wire with formvar insulation) glued together and implanted 400 µm below the cortex surface.