A NEW NEURAL RECORDING ELECTRODE ARRAY WITH PARYLENE INSULATING LAYER

Changlin Pang[1], Jorge G.Cham[2], Zoran Nenadic[2], Yu-Chong Tai[1], Joel W. Burdick[2], and Richard A. Andersen[3]

[1]Caltech Micromachining Lab, California Institute of Technology
[2]Department of Mechanical Engineering, California Institute of Technology
[3]Division of Biology, California Institute of Technology

ABSTRACT

This work presents a new electrode array applied with parylene technology, used for recording of high-level cognitive neural signals. All dry etching processes were developed to fabricate the silicon probes using double-side-polished (DSP) wafers. Instead of inorganic materials (e.g. silicon dioxide, silicon nitride), the electrodes and conduction traces are insulated by parylene, which is a polymer material with high electrical resistivity, mechanical flexibility, biocompatibility and easy deposition process. As a result, the probes exhibit better electrical and mechanical properties.

Keywords: Neural probe, parylene, neural prosthesis

1. INTRODUCTION

A neural prosthesis is a direct brain interface that enables a primate, via use of surgically implanted electrode arrays and associated computer algorithms, to control external electromechanical devices by pure thought only (Figure 1) [1]. The new electrode array, described in this paper, is designed and used at the front end of this neural prosthesis to record high-level cognitive signals. Silicon has well-recognized advantages in probe fabrication. Two main fabrication methods are developed to make silicon probes. One is based on boron diffusion and wet etching technologies [2], the other depends on dry etching and silicon-on-insulator (SOI) technologies [3]. Each of these has its own unique set of advantages and limitations. Most of these probes use silicon dioxide or silicon nitride as insulating materials. In experimental conditions, these materials are subject to large stress, which can lead to failure. In addition, silicon dioxide is known to hydrate over time, which limits the probes' ability for long time chronic neural recording. With the properties of high electrical resistivity, mechanical flexibility, biocompatibility and easy deposition process, parylene is a good substitute. Parylene C was used as insulating layer on neural probes by Xu [4], but each probe contained only a single recording site, and a special process was required to open the probe tip. Our work first demonstrates the use of standard lithography processes to fabricate multi-site neural probes with parylene insulating layer.

2. DESIGN AND FABRICATION

The geometry design of the probes is shown in Figure 2. Four shafts (in 400μm spacing) with four Pt electrode sites each (10μm × 10μm in 100μm spacing) are in front a thicker plate, resulting in a 16-site 2D electrode array. The shaft thickness is 50μm and the shaft width is 75μm at the base and 45μm at the outmost section. The probe fabrication process flow is shown in figure 3, which is based on dry etching technology. First, XeF_2 etching is

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performed on the silicon surface. The first insulating parylene layer is then deposited and the conduction trace lines (Cr/Au) are patterned by lift-off process. The second protection parylene layer is coated and patterned. Ti/Pt is then patterned as electrode sites. The probe shape is defined by front side DRIE etching, and then back side DIRE etching is performed to define the probe thickness.

3. RESULTS

Fabrication results are shown in Figure 4. The probes were tested mechanically and electrically on rat brain cortex. Following a craniectomy over the barrel cortex, the probes were easily inserted into brain tissue without buckle or cracking. Electrode impedance is around 1.5MΩ at 1kHz. Neural signals were properly recorded. Figure 6 shows the sample filtered neural data recorded from one channel of the neural probe in rat cortex and the sample action potential waveforms.

4. DISCUSSIONS

The silicon surface etched by XeF_2 has high roughness (Figure 5(a)). This roughness helps the parylene grab hold of the silicon surface mechanically, greatly enhancing adhesion. Instead of SOI wafers, double-side-polished (DSP) wafers were used, which are less expensive. Problems encountered include how to protect the probes during back DRIE etching and how to control the probes thickness without an oxide insulator layer. Experimental results show that the probes can be well protected by baked photoresist during back DRIE etching, as shown in Figure 5(b). In addition, by depositing protection photoresist on the backside of the finished probes to stop DRIE etching die by die, the probes thickness can be well controlled within 5μm on the whole wafer.

5. CONCLUSIONS

All dry processes were developed to fabricate the new multi-site neural probes with parylene insulating layer. With the advantages of parylene material, the probes perform with good mechanical and electrical properties. Neural signals were properly recorded from rat cortex.

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Changlin Pang, MC 136-93, Caltech Micromachining Lab, Pasadena CA 91125, USA, phone: 1-626-395-2254, fax: 1-626-584-9104, email: changlin@caltech.edu.

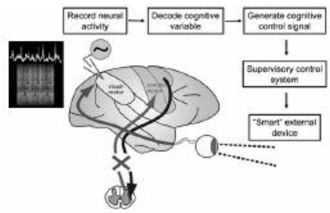

Figure 1. Schematic of the pathway of information flow for the cognitive-based neural prosthetic paradigm.

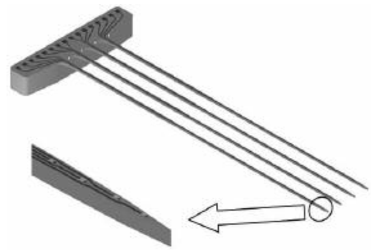

Figure 2. Geometry design of the probes.

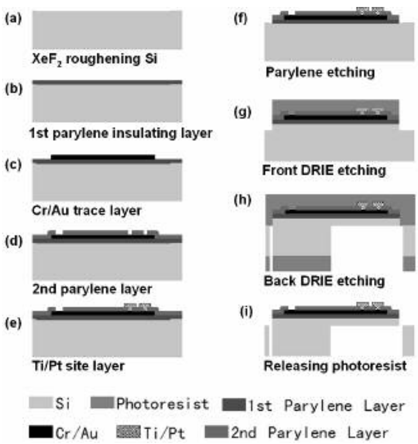

Figure 3. Fabrication process flow.

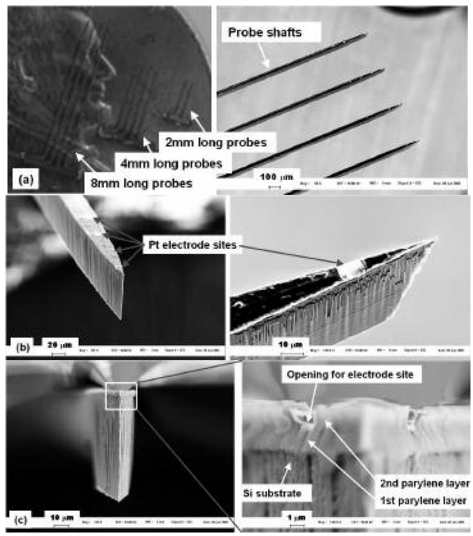

Figure 4. The optical and SEM pictures of the fabricated probes. (a) Pictures of the whole probes and shafts; (b) SEM pictures of the probe tip with multiple electrode sites; (c) SEM pictures of front side view of the probe tip, showing the interface between parylene layer and Si substrate and the interface between two parylene layers.

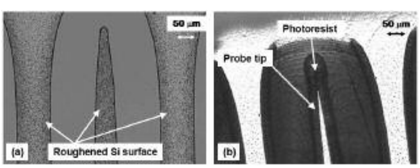

Figure 5. Fabrication process pictures. (a) Roughened Si surface; (b) Photoresist protection for probe tips during back DRIE etching.

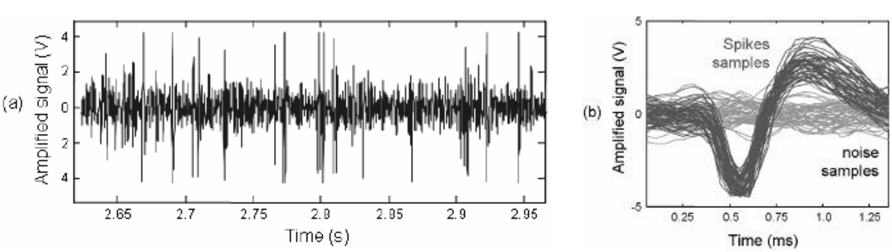

Figure 6. (a) Sample filtered neural data recorded from one channel of the neural probe in rat cortex; (b) Sample action potential waveforms.