SU-8 SPIKE ELECTRODES FOR NEURAL SIGNALS

J.F. Ribeiro[1], M.F. Silva[1], V.F. Cardoso[1], N.S. Dias[2,3], L.R. Jacinto[1,2], J.P. Carmo[1], G. Minas[1], and J.H. Correia[1]
[1]Dept. of Industrial Electronics, Campus Azurem, 4800-058 Guimaraes, PORTUGAL
[2]Life and Health Sciences Research Institute, School of Health Sciences, Campus de Gualtar, 4710-057 Braga, PORTUGAL
University of Minho
[3]DIGARC, 4750-810 Barcelos, Portugal
Polythecnic Institute of Cavado and Ave

ABSTRACT

Electrodes are widely used to record biological signals from living tissue, namely in neuroscience where researchers need to record brain signals *in vivo*. This paper presents a rapid low-cost prototyping technology for protocol-specific electrode designs. The suggested fabrication process combines SU-8 photoresist patterning in multiple layers with the deposition of intermediate conductive layers (in this case Au layer). The fabricated electrodes were specifically designed for an electrophysiological experiment that required simultaneous recording in the pre-frontal cortex (PFC) and stimulation in the hippocampus of the rat brain.

KEY WORDS: Neural electrodes, SU-8, implantable

INTRODUCTION

The high demand for electrodes specifically designed for each experimental protocol that requires recording and stimulation of neural tissue is driving new electrode technologies [1]. However, the development process of new electrode designs are often time consuming and expensive (e.g. electrode arrays), since it either requires the optimization of a great number of fabrication parameters to achieve structures with high-aspect-ratio (e.g. silicon etching processes) or the alternative fabrication processes are usually expensive (e.g. reactive ion etching) [2].

This work presents an alternative electrode technology for animal studies *in vivo*. The new invasive electrodes are intended to be a low-cost solution for electrophysiological studies and may be completely redesigned on an experiment-basis in a short-time. Thus, specific electrode designs are provided for each experimental protocol, depending on the brain regions to be recorded and/or stimulated. The new electrodes presented in Figure 1 are needle-shaped and design for recording the pre-frontal cortex (PFC) and stimulate the hippocampus in the rat brain. The SU-8 allows the fabrication of tough needles with high-aspect ratio and flexibility enough to penetrate the neural tissue smoothly and with low tissue damage [3]. In order to test an example of the SU-8 fabricated electrodes, *in vivo* recordings were performed in a male Wistar rat, as seen in Figure 2.

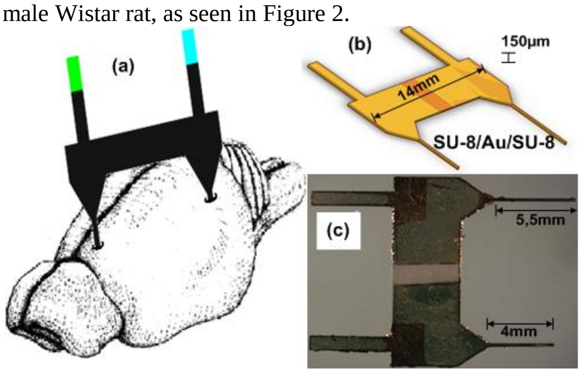

Figure 1: SU-8 electrode: a) illustration of insertion in the rat brain; b) schematic drawing; c) fabricated SU-8 electrode.

Figure 2: SU-8 electrode inserted in a male Wistar rat.

SU-8 Photoresist

The SU-8 100 from MicroChem Corporation is an epoxy based photoresist with a high functionality, high-optical transparency and high-sensitivity to ultra-violet (UV) radiation. Developed structures are highly resistant to solvents, acids and bases and have excellent thermal stability, making it well suited for permanent use applications. SU-8 can be patterned with aspect-ratios as high as 20, and with thicknesses between nanometers to 1 mm [4]. In comparison with other hard materials, the SU-8 photoresist presents the best compromise between mechanical characteristics and easiness of shape definition to be used as physical support for neural electrodes. There are a high number of candidate materials to be used as the conductive film of neural electrodes. Gold was the selected material to coat the SU-8 electrode due to its excellent surface inertness and because it provides no native oxide [5]. The gold was deposited by thermal evaporation in a few minutes to prevent the damage of SU-8 photoresist.

FABRICATION PROCESS

The structure is composed by three layers and was fabricated combining photolithography techniques for the SU-8 structural layers and a thermal evaporation technique for the deposition of the gold electrode layer. The steps of the fabrication process are summarized in Figure 3. After a proper cleaning of the glass substrate, a thin layer of Omnicoat (a1) is deposited by spin-coating to allow an easy stirring of the structure from the glass substrate at the final stage of the process (c4). After that, a 200 µm film of SU -8 100 is spin coated (a2), soft-baked and exposed to UV radiation with the desire mask (a3). Finally, a development process is necessary and a SU-8 developer is usually used in order to obtain the final structure. However, the need to deposit a gold film and another layer of SU-8 means that this step can only be performed at the end of the photolithography process of the second SU-8 layer. At this point, a thin gold layer (b) is deposited on top of the first SU-8 layer through a thermal evaporation technique. Three successive depositions are performed in order to prevent heating the SU-8 layer and subsequent deterioration of its properties and the structural pattern held in (a3). In addition, a mask is used to protect specific areas and separate the two needles of the structure that acquire distinct signals from different brain regions. Then, a new layer of SU-8 is deposited in step (c1) and processed in the same way as the first SU-8 layer. However, in this case, the mask is designed to protect specific parts of the underneath gold layer, which will act as electrode contacts to measure and acquire the brain signals. In step (c3), all the non-exposed SU 8 is developed, the gold deposited over the first non-exposed SU-8 layer is removed and the electrode contacts are exposed. Thus, the final structure is obtained (c4).

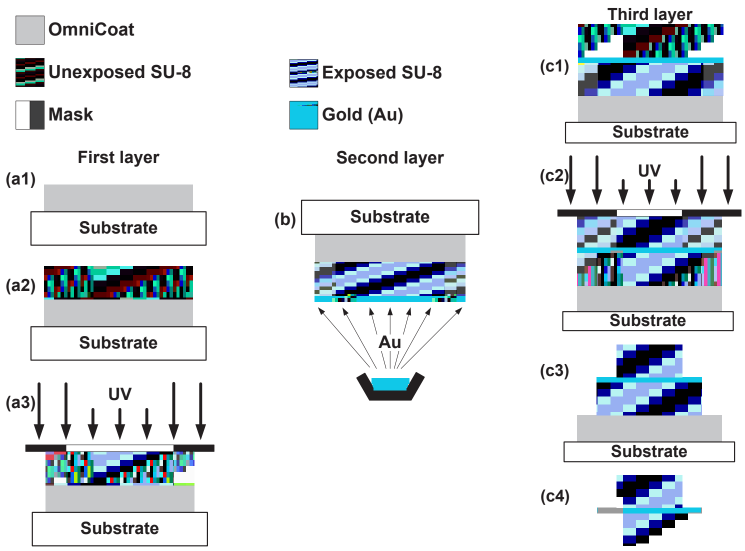

Figure 3: Fabrication steps of SU-8 electrodes: a) steps for first layer; b) step for second layer; c) steps for third layer.

CONCLUSIONS

The fabrication of a protocol-specific electrode design based on SU-8 photoresist was presented. This methodology is suitable for rapid prototyping of needle-shaped structures for acquisition and stimulation of brain tissue. The SU-8 photoresist seems to be appropriate to achieve electrodes with simultaneous high degree of flexibility and high-aspect-ratio structures for invasive brain recordings. The SU-8 is also though and our lithographic process allows the patterning of "exotic" shapes. Once the fabrication process of a specific electrode design is well established, its adaptation to other protocols (shapes and design) is a fast and low-cost procedure.

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