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A novel assembly method for 3-dimensional microelectrode array with micro-drive

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ABSTRACT

This paper reports a novel assembly method for 3-dimensional (3D) microelectrode array with the aid of anisotropic conductive film (ACF). For this purpose, a unique silicon probe with trenches encircled bonding pads was fabricated to realize the ACF-bonding with flexible cable. This design is meaningful because it can realize planar bonding for subsequently convenient 3D stacking and the time-consuming plating is not needed to form bumping on pads. The reliability of the ACF-bonding is demonstrated by measuring the electrochemical impedance spectra (EIS) of the bonded probes with different structural and dimensional bonding pads. The bonded probes are further assembled into 3D arrays and integrated with micro-drive for chronic neural recordings. The excellent recording performance indicates that the ACF-bonded probes are reliable and suitable for chronic neural recordings.

1. Introduction

Simultaneous recording of neural activities in different brain areas are increasingly drawing the attention of the neuroscientist [1–3], which create new technique in the structural design of implantable microelectrode as well. One of the main purposes of neuroscientist is to record as many neurons as possible from different brain regions, searching for behavior-related neural activities. Up to now, plenty of different electrode designs have been developed such as micro-wire bundles [4], carbon fiber arrays [5,6], polymer probes [7,8] and silicon-based microelectrode arrays (MEAs) [9–11]. Among these designs, the silicon-based Michigan microelectrode arrays (Mi-MEAs) are the most promising one due to its high-density recording sites with a strongly increased spatial resolution in a minimized dimension. By using the high-speed electron beam lithography (EBL), the fabricated Mi-MEAs can reach up to 200 recording sites per shank [12]. However, as the electrode size drops to micro scale (higher spatial resolution), the impedance of electrode increases and the quality of signal recordings decreases (lower sensitivity). Thus, signal detection will be hindered by glial scar formation around the implants when the Mi-MEAs are chronically used [13]. It will be advantageous that if the implanted Mi-MEAs can be precisely moved postoperatively to break away from the scar. Fortunately, this function can be realized by using the screw-driven micro-drives.

Custom designed and manufactured micro-drive arrays provide two distinct advantages: (1) individual control over the depth of each electrode for accurate positioning in targeted brain volume and (2) flexible and modular arrangement of the electrode arrays to hit distributed brain regions [14]. Nowadays, the most commonly used micro-drive arrays are made of micro-wire electrodes. However, the total recording channels are seriously limited by the device weight that mice are capable of carrying on their heads [15]. Another problem of the micro-wire electrode arrays is that they can hardly be aligned accurately because of the manual assembly process which makes the preparation and implantation of the micro-wire arrays in mice brain quite difficult. Fortunately, these problems can be solved with the advent of the micro-machined Mi-MEAs. Indeed, standard MEMS fabrication processes enable the Mi-MEAs with 2D and 3D designs [16,17]. The 2D Mi-MEAs can be comprised of multiple shanks with longitudinally distributed recording sites and their assembly into 3D arrays will provide

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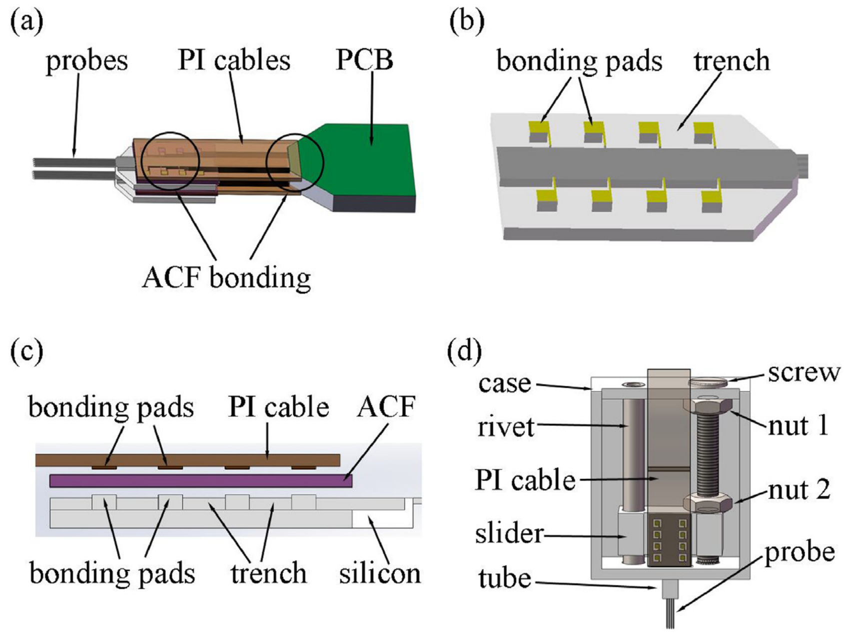

Fig. 1. (a) The schematic diagram of the assembled 3D Mi-MEAs, (b) the enlarged views of the bonding pads on silicon probe, (c) the sectional view of the aligned bonding pads and the applied ACF, (d) the schematic diagram of the 3D printed micro-drive integrated with the Mi-MEAs.

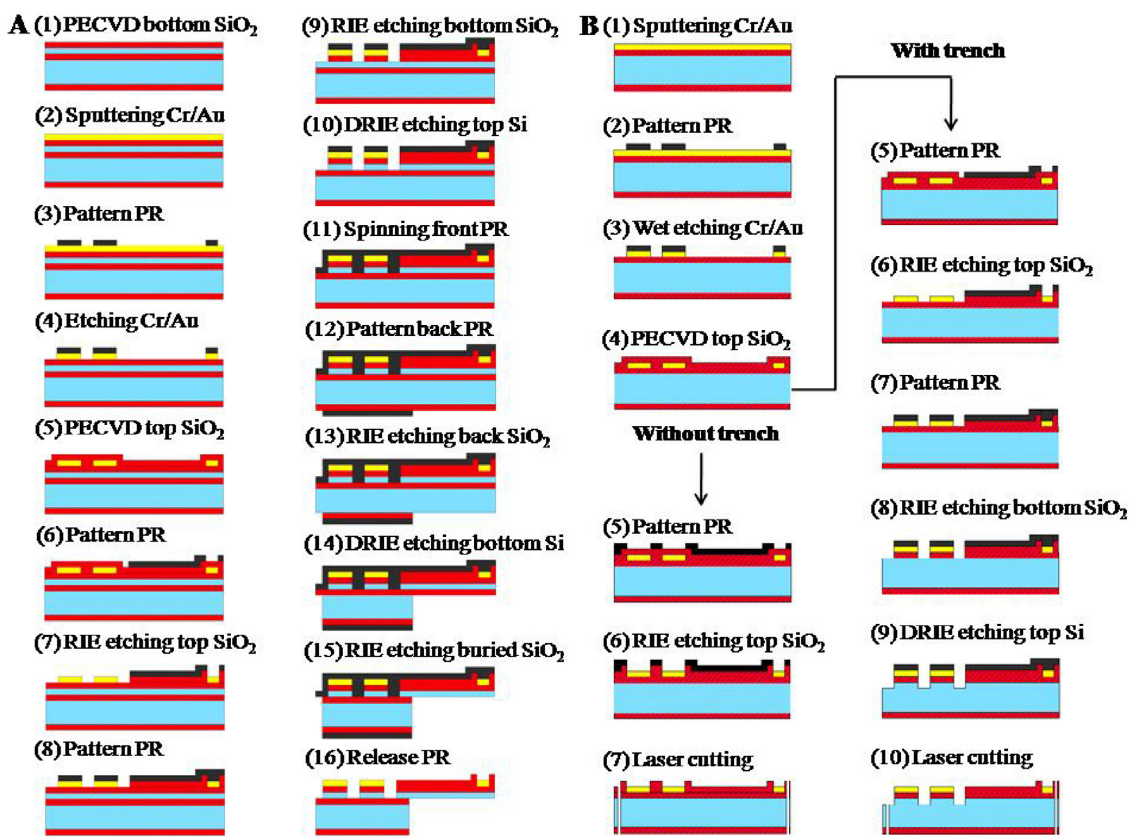

Fig. 2. A) The fabrication processes of the neural probe with trenches encircled bonding pads for *in-vivo* neural recording. B) The fabrication processes of the simplified neural probe with and without trenches encircled bonding pads for electrochemical characterization.

customized multi-region recordings. Thus, the assembly of 3D Mi-MEAs has been a research hotspot in MEMS.

In the past decades, a number of methods have been proposed for the assembly of 3D Mi-MEAs. For example, platform-based 3D microelectrode arrays generally comprise a silicon platform with slender slots from which probe combs insert into the targeted neural tissue [18,19]. However, transfer of the wiring from electrode arrays to platform presents complicated assembly steps such as mechanical interconnecting [18], electroplating [20] and soldering techniques [19]. Merriam et al. proposed a solution to this issue by using flexible conductive cables [21]. With this method, individual planar probes interfaced directly with highly flexible cables. Thus,