Microneedle Array Integrated on a Flexible Substrate to Fabricate Dry Electrode

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Abstract. Low and stable contact impedance between the electrode-skin interface is crucial for the acquisition of high quality biopotential signals. A layer of gel or glue containing ions is often introduced between the skin and the commerical Ag/AgCl electrode. However, a dry electrode, often made from rigid material, seldom has a gel-like cushion when attached to the skin. This kind of hard contact makes subjects feel uncomfortable due to the higher stress imposed on the electrode to get good contact necessary for low impedance and high quality biopotential signals. A flexible dry electrode can adapt to the surface of the skin by bending more than by pressing. In this study, we developed a flexible dry electrode structure based on a silicon needle array on a PDMS substrate. By coating a layer of conductor on it, a flexible dry electrode was fabricated. The flexible substrate can keep contact with the skin in a natural way. Low impedance can be obtained with low pressure.

Keywords: Flexible dry electrode, biopotential, needle array, PDMS

1. Introduction

Commercial wet electrodes have two shortcomings. First, their preparation time is long. The skin should be cleaned or degreased by soft abrasion to reduce the thickness of the stratum corneum (SC). Electrolytic gel must be applied between the electrode and skin [Matteucci et al., 2007; Yu et al., 2009]. Second, wet electrodes must be operated by professionals and the procedures are complex, so it can hardly be used for home care [Griss et al., 2001]. Dry electrode technology can overcome these disadvantages. There are many types of dry electrodes. One type has a surface composed of microneedle arrays. With this microstructure, the height controlled needles can penetrate the SC barrier of the skin to decrease the interface impedance between electrode and skin [Griss et al., 2001; Griss et al., 2002; Yu et al., 2011]. However, this kind of dry electrode, as shown in Fig. 1A, is fabricated with silicon, metal, or other rigid materials. Although most of these dry electrodes with lower impedance were reported, these dry electrodes are far from an application in the potential market. One reason is the uncomfortable experience [Baek et al., 2008] when one uses the dry electrode. Higher stress must be imposed on the electrode to keep a good contact between the electrode and skin. In this process, the skin, as well as the tissue under the skin, must endure the whole deformation. It will cause discomfort including pain and redness. To overcome these shortcomings, we developed a dry electrode with a micro-needle array on a flexible PDMS substrate. Thus, the electrode can adapt to the curved skin surface and decrease the deformation degree of the skin.

2. Material and Methods

Four-inch double-sided polished n-type silicon wafer with <100> crystallographic orientation, 200 µm thickness and 0.001 cm resistance was used in this study. A layer of PDMS membrane with a thickness of 2 mm was used as flexible substrate.

The production process of the flexible dry electrode comprises three steps. The first step is to bond the silicon wafer to the PDMS membrane. The second step is to produce micro-needle arrays by lithography patterns and deep dry etching processes. The third step is to dice the wafers and sputter the conductor metal layer on both sides of the structure. The metal of the structure side wall establishes front-to-back electrical contact. The fabrication process is shown in Fig. 1B.

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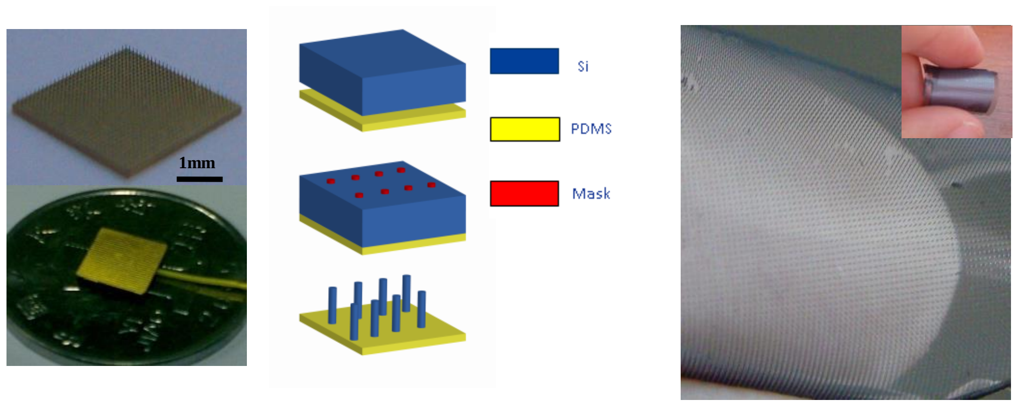
3. Results

The completed flexible dry electrode made with a micro-needle array is shown in Fig. 1C. Due to the very strong bond force between the silicon and PDMS substrate (the bond is mainly composed of Si-O), the micro-needle can be fastened on the substrate firmly. The diameter of the micro-needles is 50 µm, the height of the micro-needle is 150 µm, and the space between the needles is 200 µm. The rigid needles combined with flexible substrate can satisfy impedance demands as well as comfort demands for a dry electrode, especially in a long-term wearing situation. Thanks to the substrate made from PDMS membrane, the electrode is flexible and can bend easily around the finger.



A **B** C

Figure 1. *Rigid dry electrode and improved flexible structure. (A)Rigid dry elctrode made from silicon. (B) Fabrication process. (C) A completed silicon needle array bonding on a PDMS substrate stretching naturally on a finger (inset shows another piece of silicon needle on PDMS structure).*

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