Fabrication of Hollow Silicon Microneedle Arrays for Transdermal Biological Fluid Extraction

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Advance in microfabrication technology enables the realization of microneedles, with the increasing interests in transdermal biological fluid extraction.[1-3] Such microneedles can only penetrate through the outer layer of skin without interfering with the nerve endings in the deeper layer, making minimal invasive and painless sampling fashion. This work presents an innovative double-side Deep Reactive Ion Etching (DRIE) approach for producing hollow silicon microneedle arrays.

The schematic processing is shown in Figure 1. A single layer of AZ 4620 photoresist with a thickness about 10 μm was spun onto one side (termed as 'backside') of a 4-inch wafer (double-side polished, Fig. 1a). Holes approximately 300 μm deep and 30 μm in diameter were etched into silicon by performing standard lithography (Fig. 1b) and DRIE (i.e., the Bosch process, Fig. 1c). Note that at this moment the other side of the wafer (termed as 'frontside') was still flat. In this way, the pillar pattern on the 'frontside' was defined by the same process (Fig. 1d), with the double-sided alignment to the holes on the 'backside'. This alignment also enables to accurately place the holes with offsets from the center of the needle, for addressing the tissue coring within the needle bore.[3] Pillars of approximately 300 μm in height and 200 μm in diameter were then etched by DRIE (Fig. 1e), making an overlap of 100 μm between the pillars and holes. Afterward the circular pillars were sharpened into needles and the through wafer holes were fully opened using a mixed solution of hydrofluoric acid and nitric acid (Fig. 1f and 1g), taking advantage of the lateral isotropic etching and the vertical anisotropic etching, i.e., the etching rate decreases from the needle tip to the base.[4]

In the experiments, solid microneedles with tip radii less than 5 μm were fabricated by performing DRIE and the subsequently wet etching on the frontside only (Fig. 2). Afterward the etching from both sides were integrated, resulting in the accomplishment of the hollow Si microneedles with two bore placements (Fig. 3). Figure 4 shows the hollow Si microneedle array with high uniformity. Ongoing work will focus on the skin penetration and the capillary filling of the holes.

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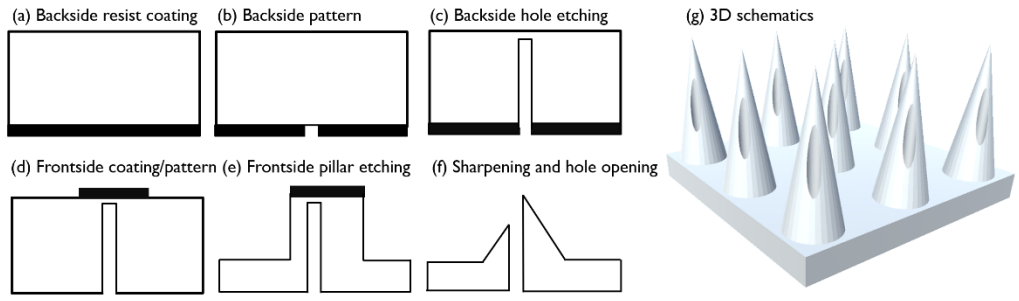

Figure 1: Schematic fabrication processing of hollow silicon microneedle arrays.

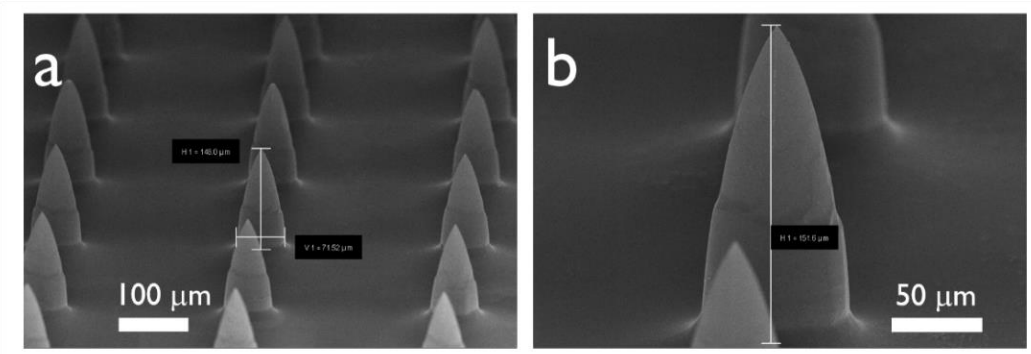

Figure 2: SEM showing (a) high uniformity of solid silicon microneedles array and (b) the zoon-in view of an individual almost-perfect sharp needle.

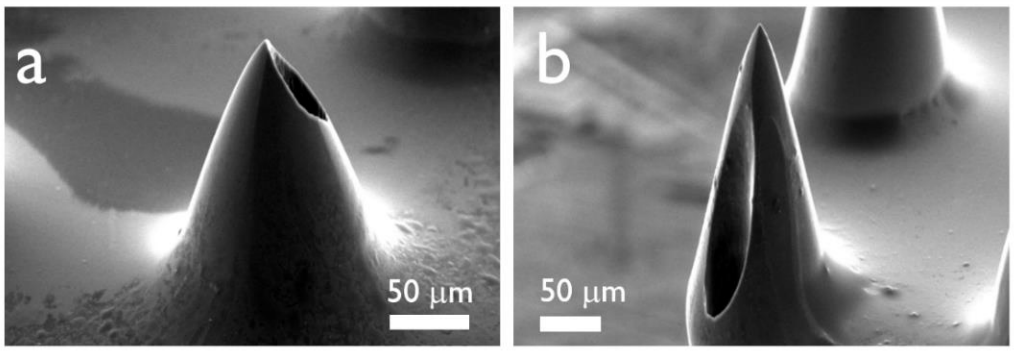

Figure 3: SEM showing the hollow Si microneedles with two different hole offsets for realizing (a) the "Micro-hypodermic" and (b) "Snake-fang" fashions.

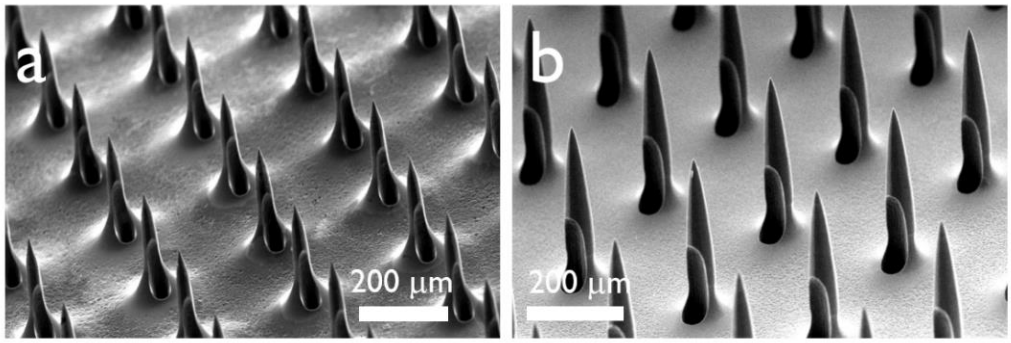

Figure 4: SEM showing the "snake-fang" hollow Si microneedle arrays with the needle base diameter of (a) 100 µm and (b) 60 µm.