

Fabrication of Microneedles

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Abstract—This research paper was performed to study and utilizes two kinds of materials which match with two different fabrications in order to design an ideal shape of microneedles. The technology employs the polymer microneedles and the silicon microneedles with the height of 236 μm and 350 μm respectively. Moreover, the transdermal drug delivery investigation will be conducted by using the fabricated samples to estimate the feasibility of the microneedles.

Polymer microneedles were formed by molding the V-grooves structure on silicon wafer. The SU-8 negative photoresist was introduced for the subject structural material of the microneedles. Silicon microneedles were formed by KOH etching solution, solely depending on controlling etching time and the principle of Fast-etching planes.

Keywords—Microneedles, V-groove, SU-8, Photolithography, Fast-etching planes

I. INTRODUCTION

Micro-Electro-Mechanical System, MEMS, is a diverse technology, and its foundation and application includes the light, mechanism, electricity, materials and physics and so on. However, the application of the polymer material has become more and more popular under the development of the MEMS technology.

Recently, because of the great progress of the science and technology, people not only concern how to remedy the diseases, but reduce the pain of a course of treatment. Microneedles have become a new type of the bio-medicine injector, it can throw the cuticle and not excite the nerve, and the patient will feel nothing. Moreover, it can be made by different kind of materials, like as SU-8, PMMA, PDMS, COC, silicon etc.

L. J. Guerin [1] is the first people to build the microchannel with the SU-8 by surface micromachining and setup several thermal sensors in it; it starts the application of the SU-8. In 1999, Liwei Lin [2] utilizes the bulk and surface micromachining on silicon wafer with the height 1, 3, 6 mm, respectively; it includes the microchannels and enhances the strength of the holder to make the structure of microneedles stronger. In 2003, Kabseog Kim et al. [3] use the SU-8 negative photoresist and multiple backside exposure to create the height 200~400 μm microneedles on the glass and sputter a layer of the metal. In the same year, Han J. G. E. Gardeniers et al. [4] present to employ the DRIE and KOH anisotropic wet-etching to fabricate the microneedles. In 2004, Kuo et al. [5] utilize the SU-8 negative photoresist and PDMS make the microneedles array and the SU-8 is the main structure for the PDMS shaping. Besides, Seung-Joon Paik et al. [6] adopt the

silicon wafer to make the microneedles as the cantilever beam and combine the PDMS in the same year. This structure includes the microchannels and microneedles and it utilize the tube to deliver the drug. In 2005, Nicolle Wilke et al. [7] calculate the etching rate on the different direction of the silicon wafer and put it under the accurate position, collocates the KOH anisotropic wet-etching to fabricate the microneedles array with octahedral structure. In MEMS 2006, J. M. Lippmann et al. presented the new process via polymer investment modeling to build the microneedle array with 160 μm width and 280 μm length.

II. DESIGN THEOREM

The structure of the human skin includes viable epidermis (100~300 μm), dermis and hypodermis. Therefore, the main design of the microneedles is to destroy the viable epidermis and the length should be longer than 300 μm . Moreover, we also think over three basic factors to fill the bill, the staff (region 1), styles (region 2) and body structure (region 3) shown in figure 1.

Region 1 is design for the people to hold, region 2 is the key point that if the shape can pass through the skin and deliver the drug, at present the shapes are always monocline, trihedral, cone or cantilever beam, and region 3 can be devise as the hollow or substance structure, the hollow structure includes the microchannels and the drug can be delivered continuously. The substance structure, in the main, is to break the viable epidermis, and then the drug will permeate into the skin.

This research utilizes two kinds of materials to fabricate the ideal shape of microneedles, polymer microneedles and silicon microneedles.

2.1 Polymer Microneedles

First, this study utilizes the SU-8 2050 as the material of the microneedles. SU-8 is a high contrast, epoxy based photoresist designed for micromachining and other microelectronic applications. The UV-light absorptivity of SU-8 is lower than others and therefore can get the high-aspect ratio structures.

Because we adopt the turning model technique to fabricate the microneedles, we should consider the situation about the V-groove on the silicon wafer.

According to the Miller index, the silicon wafer has several different types, {100}, {111}, and {110} and so on. We adopt the {100} silicon wafer and use the different concentration KOH for anisotropic wet-etching to make the V-groove. Because the angle between the (100) and (111) is 54.7°,

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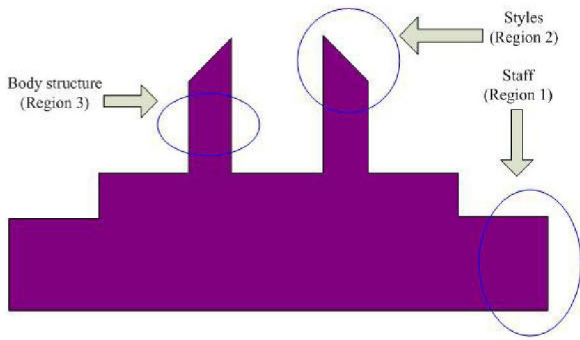


Figure 1. The design of microneedles.

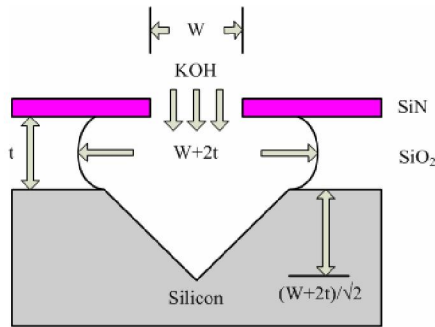


Figure 2. The dimension diagram of V-groove.

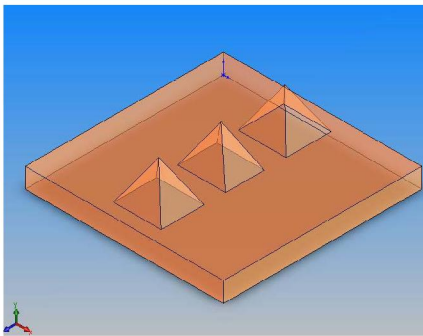


Figure 3. The design of polymer microneedles array.

and the etching rate is $R(100) > R(110) > R(111)$ (R : Rate), we can reserve the two adjoin (111) simply. The dimensions of the V-groove can be design by Eq. (1), w is the width of expose square, t is the thickness of the oxide and considers the undercut we can obtain the depth, x , as shown in figure 2.

$$\frac{x}{(w + 2t)/2} = \tan 54.7^\circ \quad (1)$$

The final design of polymer microneedles as shown in figure 3, the V-groove is $320 \mu\text{m}$ square, the depth is $227 \mu\text{m}$ and the staff is 0.5 cm square.

2.2 Silicon Microneedles

Except the polymer microneedles, we also utilize the silicon as the materials. This kind of microneedles is use silicon as the major material, and {100} silicon wafer is good for wet-etching, we also choose the KOH as the etching solution with protection layer of nitride and oxide.

Rely on the silicon has different etching rate on diverse crystal orientation and the corner compensation, we can get four

Table 1. The crystal orientation with different etching solution

Crystal Orientation	Etching Solution
(110)	KOH, 40°C
(212)	30 wt% KOH+25 wt% propanol 80% Hydrazine+20% H ₂ O KOH+IPA
(130)	KOH, 80°C
(331)	EDP, EDPB 30 wt% KOH+25 wt% propanol
(411)	KOH(15-50 wt% KOH, 60-100°C)

(111) planes with 54.7° between the etched facet and the horizontal surface, as shown in figure 4. In the wet-etching period, the concentration of KOH is 30wt% and the temperature is 80°C . figure 5 shows the design of silicon microneedles.

The corner compensation is to avoid producing the non-(111) planes, Fast-etching planes, by the lateral etching in chief. In this research, we use KOH as the etching solution, the solution concentration is 30 wt% and the working temperature is 80°C . With different etching solution, we can get the different Fast-etching planes, shows in Table 1.

III. THE PROCESS OF FABRICATION

3.1 Polymer Microneedles

At first, we will build the V-groove with the depth of $320 \mu\text{m}$ on silicon wafer, and then we'll coat the SU-8 on the silicon wafer with the depth of $450 \mu\text{m}$ and use the scraper to put the SU-8 uniformly. Silicon wafer covered the SU-8 will be set in the oven to break away the bubbles and smooth the surface by heating and vacuum. Finally, we'll use the SU-8 developer to form the microneedles.

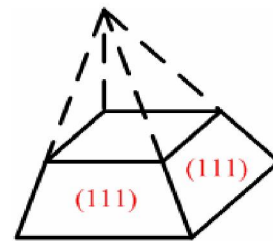


Figure 4. Schematic illustration of KOH etching on silicon wafer.

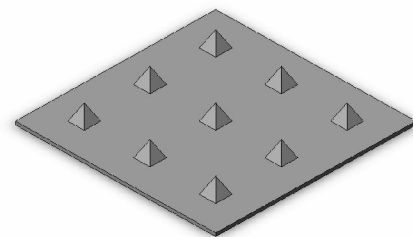


Figure 5. The design of silicon microneedles array.

The series of fabrication processes contain the several steps as below and shown in figure 6:

- (1) Wafer cleaning: Mixing H_2SO_4 with H_2O_2 as the Piranha to clean the silicon wafer and heat it up at $150\text{ }^\circ\text{C}$ to remove the mist.
- (2) Depositing the oxide and coating the photoresist: The depths of oxide and photoresist are $1\text{ }\mu\text{m}$ and $4\text{ }\mu\text{m}$ respectively.
- (3) Photolithographic: Utilizing the first mask to develop the V-groove.
- (4) Remove the oxide and photoresist: Using the BOE and Acetone to remove the oxide and photoresist separately.
- (5) KOH wet-etching: The KOH solution is $30\text{ wt}\%$ and the temperature is set at $60\text{ }^\circ\text{C}$.
- (6) Coating the negative photoresist, SU-8: The thickness of SU-8 is $450\text{ }\mu\text{m}$.
- (7) The 2nd photolithographic: This process develops the position of the bottom of microneedles.
- (8) Departing the SU-8 from the silicon wafer: Put the silicon wafer in the MF-319 and the microneedles will move off the silicon wafer.

3.2 Silicon Microneedles

The other kind of microneedles is using the silicon as the material. By employing the characteristic of anisotropic etching to fabricate the substance microneedles we needed. The process listed as below and shown in figure 7.

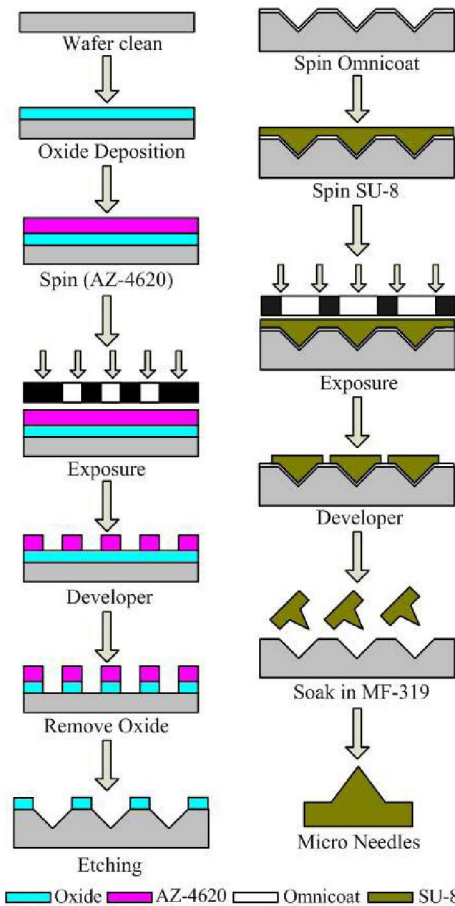


Figure 6. The fabrication process of the polymer microneedles.

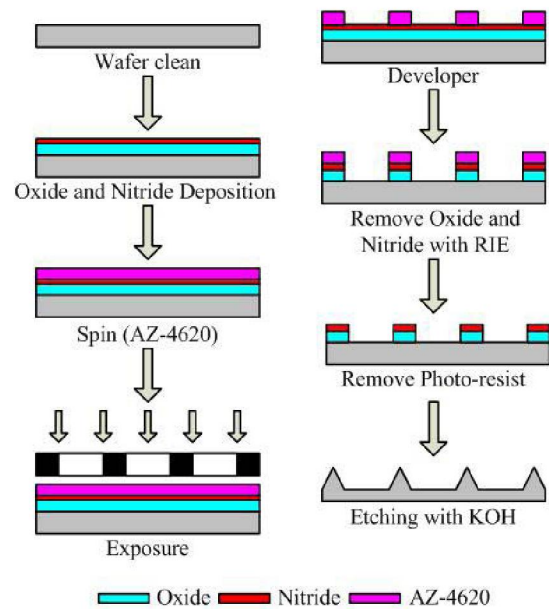


Figure 7. The fabrication process of the silicon microneedles.

- (1) Cleaning the wafer to remove the hydrocarbon and the mist.
- (2) Depositing the Oxide and Nitride with the depths are 1 and $0.2\text{ }\mu\text{m}$ respectively.
- (3) Coating the photoresist, AZ-4620.
- (4) Photolithographic and develop the microneedles.
- (5) Remove the unprotected Oxide and Nitride by Reactive Ion Etching, RIE.
- (6) KOH wet-etching: The KOH solution is also $30\text{ wt}\%$ at $80\text{ }^\circ\text{C}$.

IV. RESULT AND DISCUSSION

According to a series of design and fabrication process, we'll show the fabrication results as following.

4.1 Polymer Microneedles

At first, the V-groove was fabricated by KOH solution and the etching rate is $16\sim 20\text{ }\mu\text{m/h}$, figure 8 shows the α -step picture of the microneedles and the height is $235.8\text{ }\mu\text{m}$. Figure 9 is the finished V-groove after etching.

After etching, we'll cast the SU-8 photoresist on the silicon and develop the bottom of the microneedles shown in figure 10. The depth of SU-8 coating is $450\text{ }\mu\text{m}$ and we have to



Figure 8. The α -step picture of the microneedles.

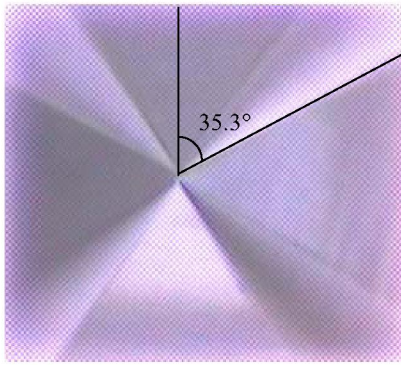


Figure 9. The finished V-groove after etching.

keep an eye on the soft-bake, exposure and the baking after exposure to ensure it dry. Finally, the microneedles will be put in the MF-319 for the stripping and figure 11 and 12 are the SEM-photograph of microneedles.

4.2 Silicon Microneedles

The silicon microneedles should consider the accurate etching time. Only the exact time will form the microneedles.

Figure 13 is the SEM-photograph of silicon microneedles and the etching rate is 60 $\mu\text{m/h}$.

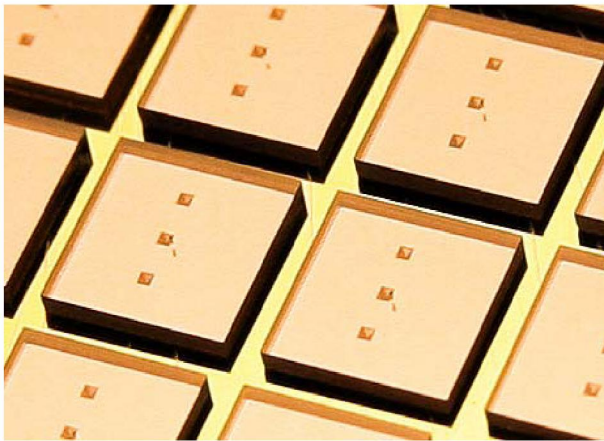


Figure 10. The backside picture of microneedles before the stripping.

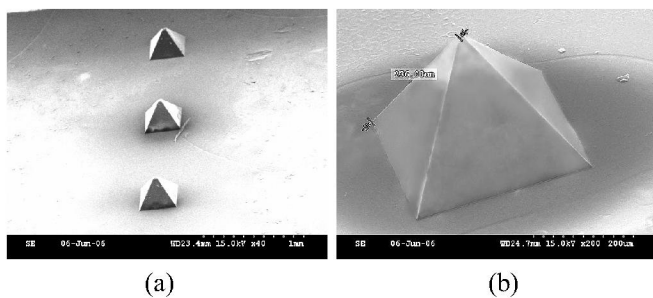


Figure 11. The SEM-photograph of polymer microneedles: (a) the microneedles array (b) the single microneedles.

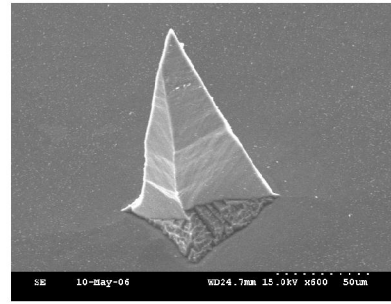


Figure 13. The SEM- photograph of silicon microneedles.

V. CONCLUSION

This study utilizes two different methods to fabricate the microneedles, polymer and silicon microneedles. The result of the purposed microneedles is to apply in the field of bio-medicine technology. We have accomplished a series of tests and improvements.

The future experiment is to use these two different kinds of microneedles to test the permeability of the medicine through the skins. By the destroying of the cuticle, the test reagent can permeate into the blood. Chemical enhancement and physical enhancement can both promote the medicine pass through the skin. The total experimental results will provide advantage for the bio-medicine technology in the future.

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