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Program Title(English) :Design and Fabrication of Photomask for Microneedle Pad Production
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1. 概要（Summary）

This project aims to fabricate silicon photomask for microneedle pad production via photocrosslink reaction. The fabrication process was designed to utilise both wet and deep RIE etching to create arrays of through-holes which will be further used as a light guiding to produce the microneedle pad.

Pattern feature providing high yield of microneedle production was investigated by varying hole diameter and distance between the holes. It was found that the smallest hole can be created with the diameter of 6.1-6.5 µm in diameter and with the closest center-to-center distance of 25 µm.

2. 実験（Experimental）

【利用した主な装置】

スピンコーター、マスクレス露光装置、酸アルカリドラフトチャンバー、反応性イオンエッチング装置 (RIE)、多目的エッチング装置(ICP-RIE)、短波長レーザー顕微鏡[OLS-4100]、プラズマアッシャー

【実験方法】

The fabrication process composed of 2 main steps, etching of the square window on the back side and etching of the circle pattern array on the front side of the silicon wafer. For the back side, since the square pattern size of as large as 4x4 mm^2, cleanroom sticker for dicing saw technique was used for oxide removal prior to the wet etching. In contrast, patterning the front side was created by maskless exposure on PR film before the oxide removal and deep RIE etching subsequently.

Detail of the overall process is as followings

1. Thermal silicon oxide with the thickness of 1 µm was deposited on 2 inches silicon wafer.
2. On the back-side of the wafer, cleanroom sticker (for dicing saw cutting) with ‘square’ cut pattern was attached to the surface to be used as a mask in RIE step.
3. Thermal oxide on the back-side was removed by RIE technique.
4. The wafer was wet-etched in TMAH solution at 90℃ for 6-7 hours until the remaining thickness of the wafer is 20-40 µm.
5. PMER P-HA1300PM was deposited on the front-side of the silicon wafer using spin-coating technique. Prior to the coating of the photoresist, the silicon wafer was soaked in HMDS vapor for 1 min. The spin coating was performed by ramping from 0 to 500 rpm in 5 sec before keeping steady at 1250 rpm for further 30 sec. The PR film was subsequently pre-baked at 110℃ for 10 min.
6. Patterns were created on the PR film by maskless exposure and developed twice in PMER P-7G for 1min before stopping in water for 1-2 min. The film was then post-baked at 110℃ for 6 min.
7. Thermal oxide on the front side of the wafer was removed by RIE technique using O_2:CF_4 17:54 SCCM, power 80 W, and pressure 5 Pa for 60 min.
8. After the oxide removal, the silicon was etched using Bosch process 60 cycles for 2 times.
9. The sample was cleaned by plasma asher at 300 W for 30 min.

3. 結果と考察(Results and Discussion)

Considering etching on the back side of the silicon wafer, after 6 hours of the wet etching by TMAH at 90℃, square window with the depth of around 260 µm was obtained, corresponding to the etching rate of 43.3 µm/h. It was observed that the edge of the square may vary among them which is due to the variation of the hand-cutting. Despite this non-perfect shape, it still proved that the sticker can be successfully used as a mask for oxide removal especially for the large pattern whose perfect shape is not necessary. This helps reducing the coating and patterning steps of the PR on the back side.

For the front side etching, it was found the pattern size affect both the depth and the width of the resulting holes. Results obtained by using 240 cycles of Bosch process revealed that the pattern diameter of 5, 10, 25, and 50 µm yielded the depth of 36.2, 44.0, 55.0, and 60.0 µm, respectively. This suggested the larger pattern diameter allows the etching depth to be deeper that the smaller one.

When considering the hole width, the results showed that the larger pattern led to the larger hole as the pattern diameter of 5, 10, 25, and 50 µm caused the hole width of 10.8, 23.0, 45.0, and 73.0 µm respectively. According to the width and the depth of the etching hole, we can concluded that the size of the pattern has an influence on aspect ratio of the resulting hole. The larger pattern diameter provided to the smaller aspect ratio.

Apart from the pattern diameter, the other key parameter is the distance between the patterns. As discussed above, after undergone deep RIE, the width of the pattern increased to a certain value. Hence, if the distance between the patterns was smaller than the increasing width, it would cause the structure to collapse as shown in Figure 1C.

According to the results above, it was assumed that to obtained a relatively small hole, we need to use a smaller pattern diameter to compensate the effect of width broadening of the hole. Therefore, we tried to use the pattern diameter as small as 3.0 µm and could obtain the hole with the width as small as 6.1-6.5 µm.

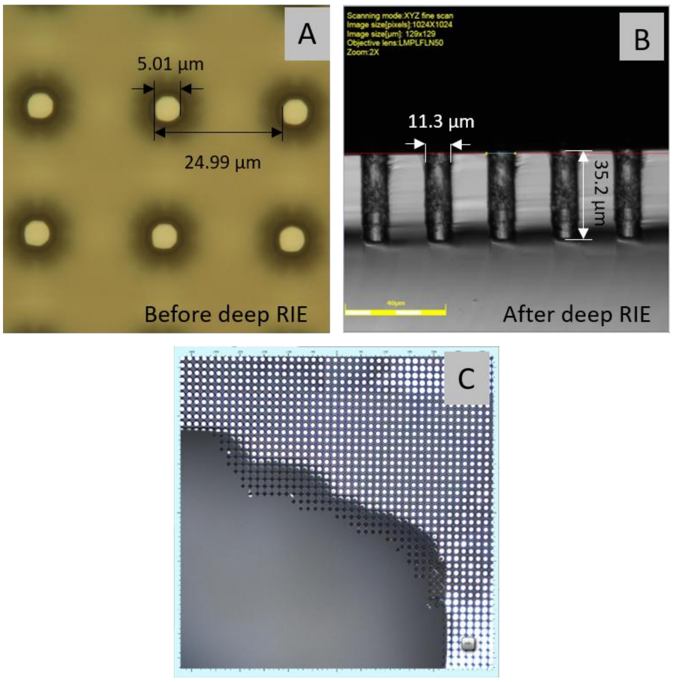

Figure 1: A) Optical microscope of the pattern after oxide removing step, B) picture from 3D optical microscope of the hole after 240 cycles of Bosch process with the starting pattern diameter of 5 µm, C) example of the collapse membrane due to the close distance between each circle pattern.

4. その他・特記事項(Others)

なし

5. 論文・学会発表(Publication/Presentation)

なし

6. 関連特許(Patent)

なし