Rounding of Wafer – Hole Corners in <100>-oriented Silicon Wafer by Anisotropic Etching

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SUMMARY

This paper presents investigation on the alteration of wafer – hole corners made in <100>-oriented silicon wafer by anisotropic etchings such as KOH or TMAH solutions. The holes are achieved by anisotropic etching in <100>-oriented silicon wafer. Two different techniques for corner alteration are compared for KOH (33wt%) and TMAH (25wt%) solutions. A very smooth shaped corner with very good surface quality is obtained by TMAH etching with respect to KOH.

Keywords: *wafer through-hole, micromachining, etching, corner alteration*

INTRODUCTION

The term bulk micromachinig always refers to etching structures from the backside of the wafer to form cavities or holes. Wet etching is mostly used for standard <100>-oriented wafer. When anisotropic etching is applied then the result is a cavity with <111>-oriented sidewalls having 54,7° angle to the surface. Such corner is rather sharp and for some applications is worth to be smoothed. Recently a new technique for wafer through-hole interconnections was suggested [1]. The interconnections has been formed by using electrodeposited photoresist, but after the photoresist prebake the photoresist at the corners is rather weak due to reflow caused by the surface tensions at the corners. Smoothing all corners for example would alleviate this problem. To find the best method two different techniques for anisotropic etching one with KOH (33wt%) and one with TMAH (25wt%) are compared.

PROCESSING

Fabrication

All microstructures are fabricated in <100>-oriented silicon wafer by anisotropic etching. We made two kind of structures. The first test structure was made with two masks – one for the holes and a second mask (fig. 1), which leaves only the area around the corners unprotected, for the anisotropic etch. The second test structure was prepared using one mask only (fig. 2). After the holes are etched the mask is removed and the whole wafer surface is left unprotected.

Experiments

We etched the structures shown in fig. 1 in 33wt% KOH at 70°C for 20min and also in 25wt% TMAH at 70°C for 20min. The structures shown in fig. 2 were etched in 33wt% KOH at 77°C for 15min and also in 25wt% TMAH at 69°C for 15min.

RESULTS

Fig. 3 shows the shape of wafer after it has been etched in KOH or TMAH applying the process flow from fig. 1. From the SEM pictures can be seen that when the process flow from fig. 1 is used second hole has been partly etched. Main problem with this process flow is the wafer alignment. The accuracy of the alignment given by the producer of the wafers is 0.5°. When wafer is anisotropically etched through a mask (fig. 1, step 3) a hole is observed which is aligned towards to the real crystal plane. The consequence of this is that the hole is rotated in relation to the second mask (fig. 1, step 4). This effect can be seen on fig. 4. Fig. 5 shows the shape of the wafer after it has been etched in KOH or TMAH applying the process flow from fig. 2. We observed very good surface quality for the structures etched with TMAH (fig. 6b) with respect to KOH (fig. 6a). A new plane is observed on the sample, which determines the shape between <100> and <111> planes in fig. 5, and between two <111> planes in fig. 3. The reason for the additional new plane is the absence of any masking layer and the

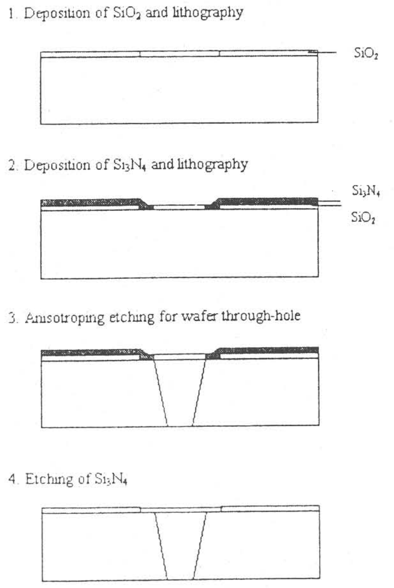


Fig. 1: Process flow for the first structure

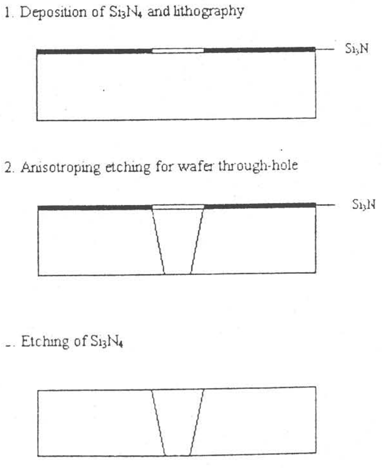
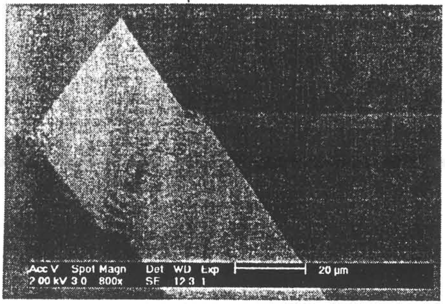
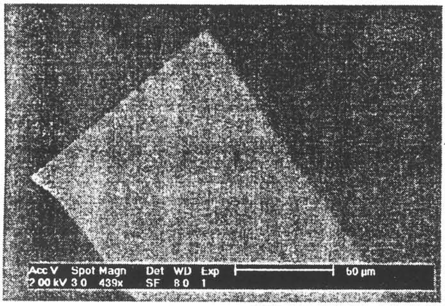


Fig. 2: Process flow for the second structure

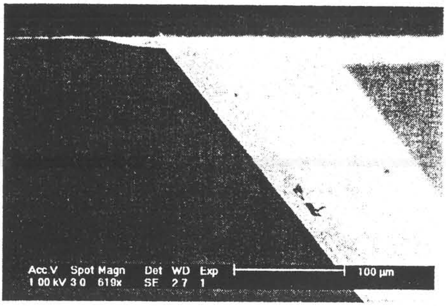


a) etched in KOH (33wt%, 70°C) for 20min

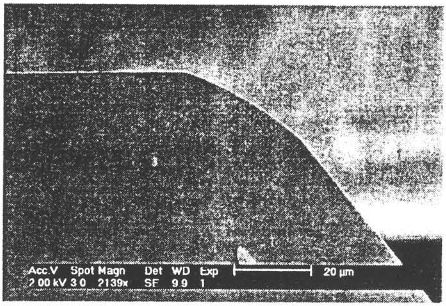


b) etched in TMAH (25wt%, 70°C) for 20min

Fig. 3: Cross-section of the altered first structure wafer through-hole edge



a) etched in KOH (33wt%, 77°C) for 15min



b) etched in TMAH (25wt%, 69°C) for 15min

Fig. 5: Cross-section of the altered second structure wafer through-hole edge

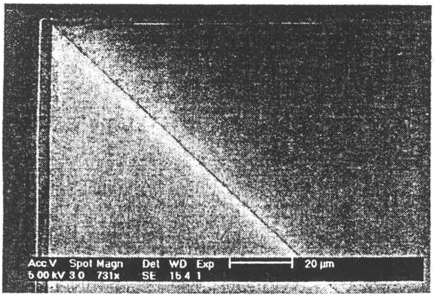
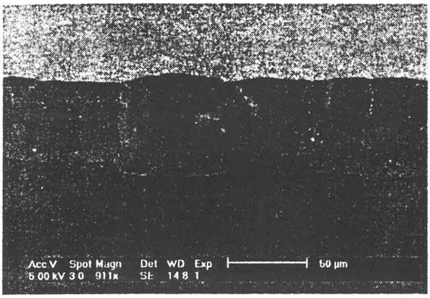
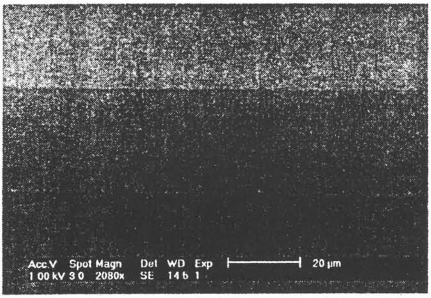


Fig. 4: SEM picture of disaligned wafer

anisotropic etching characteristic of the silicon wafer [2]. We tested to etch the silicon also for 60 minutes and 120 minutes, but when this long etch time with TMAH is applied the surface quality is preserved, but hillocks are observed on the high – index plane (fig. 7). One of the theories explains the hillocks with the etching mechanism of the silicon in anisotropic solution where hydrogen is released. This hydrogen sometimes sticks to the silicon surface preserving the silicon from etching resulting in appearance of pyramidal structures – hillocks. Fig. 5a shows very nice round corner with TMAH. Because the corner is smoothed it should present better photoresist coverage when the wafer is covered with photoresist. With the presented method could be fabricated unique structures on <100>-oriented silicon wafer [3].



a) etched in KOH



b) etched in TMAH

Fig. 6: Front – view of the new high-index plane

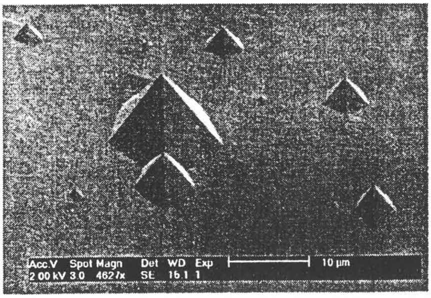


Fig. 7: SEM photo of hillocks observed on the new high-index plane when the wafer is etched with TMAH (25wt%,69°C) for 60 min

CONCLUSIONS

Method for rounding all corners of anisotropically etched through – hole in <100>-oriented wafer is presented. Two anistropic etchants are tested – 33wt% KOH and 25wt% TMAH. All obtuse corners could be smoothed very nicely due to the high etch rate at these corners. KOH solutions introduce very high roughness, sometimes exceeding 10µm, with respect to TMAH, which makes TMAH more attractive than KOH. Recommended conditions for TMAH etch following the process flow from fig. 2 are temperature around 70°C and etch time of 15 minutes. When these conditions are fulfilled the new – index plane has an angle of around 27 degrees to the surface. Therefore TMAH could be used, for example, to smooth all sharp corners of the through-holes and in this way to improve the local photoresist coating uniformity by reducing all problems connected with the surface tensions at these corners. Fig. 8b shows the advantage of such corner rounding. The photoresist coating at the corner is uniform and there is no danger for photoresist break up [4]. Moreover, although that TMAH is more expensive than KOH it is becoming in the last time more popular due to the compatibility with the clean rooms and because of the absence of metal ions.

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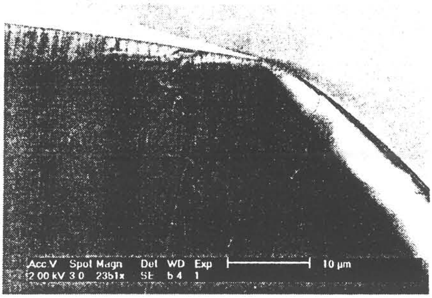
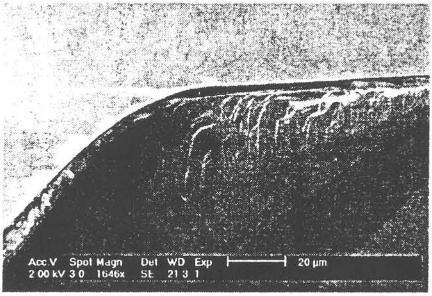


a) without corner rounding



b) with corner rounding

Fig. 8: Corner coverage with photoresist

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