A study of the profile of high aspect ratio structures made in silicon by a Bosch type etch process

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Bosch type of etch processes are commonly used in silicon processing for making high aspect ratio structures [1]. The switching between a deposition step and and etch step offers a high selectivity towards the masking layer. On the other hand the profile obtained shows often scalloping as well as some etching underneath the masking layer, the latter referred to as undercut. In this study deep trenches as well as deep vias with an opening of 2 micron and a typical depth of 25 micron using are investigated. The effect of the time ratio between the passivation step and the etch step, the top power, the bias and the pressure on the profile, performance is investigated. At the end it this proven that undercut and scalloping at the top can be avoided by combination of a continuous etch and a Bosch type etch.

Introduction

For etching deep structures into silicon a Bosch type etch approach is often used [1]. With this technique a large variety of structures can be made. In this study we focus on trenches as well as via's with a diameter of 2 micron with an oxide hard mask and a typical depth of 25µm. The aim is to investigate the profile, scalloping, as well as the undercut underneath the oxide hard mask. In order to allow a voidless conformal filling, the shape of the structure itself plays a major role.

Therefore different process variations and approaches are evaluated to see the impact on the undercut and the profile of the trenches and via's.

Experimental

The experiments are carried out on 200 mm Si wafers. The wafers receive a 2µm TEOS hard mask. By means of Iline lithography and etching the pattern is transferred into the oxide layer down to the silicon substrate. Subsequently the wafers are stripped to remove the photo resist. After patterning, 86% of the wafer surface is covered with the oxide hard mask and 14% is trench or via area.

The deep silicon etch is carried out on a LAM TCP9400SE that is converted to a LAM DSiE chamber. The etching consists of alternating a deposition step and an etching step. The deposition step is based upon a carbon rich chemistry while the etching is based upon a fluor rich chemistry. Only one parameter is varied each time starting from a standard recipe. The impact of the top power, bottom power, pressure, time ratio of the etching and the deposition step on the profile is evaluated by secondary electron microscopy (SEM). After patterning the wafers are broken and the cross section profile of the trenches/via's is evaluated using SEM. The wafers are evaluated without any clean.

Results and discussion

As depicted in fig. 1, the time ratio can be used to tune the slope of the trench. At higher pressures more slope is obtained. Bias voltage (bottom power) and top power on the other hand can reduce the scalloping fig 2 and fig. 3. None of the above tuning resulted in a zero undercut. As shown in fig. 4, an approach that starts off with a continuous trench etch SF_6/O_2 followed by a Bosch type of processing resulted in a near zero undercut and avoids scalloping. The profile is bowed.

Conclusions

The influence of process parameters on the profile of Si structures etched by a Bosch type process is investigated. A reduction of the undercut can be achieved by using a two steps process while the scalloping is sensitive to the top and bottom power.

References

[1] Kitt Wai Kok *et al.*, J. Vac. Sci. Technol. B **20**, 1878 (2002)

Figures

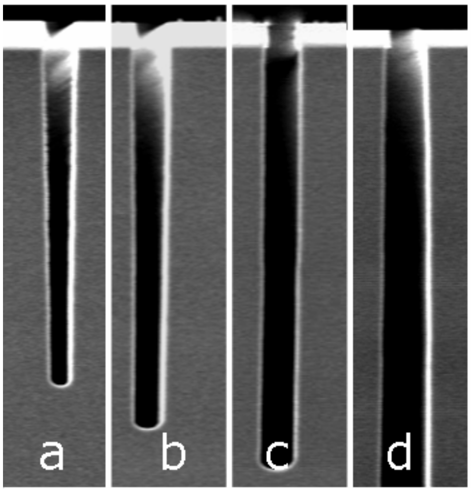

Fig.1 The etch time/deposition time increases from a) 0.4 to d) 0.7 allowing to go from a sloped profile to a straight profile. The undercut is more pronounced in d. The ratio has a strong impact on depth of the trench as well as selectivity. The pictures are taken at the same magnification. The proposed model is that because a longer deposition time a thicker polymer is grown resulting in more selectivity, slope and less isotropic etch.

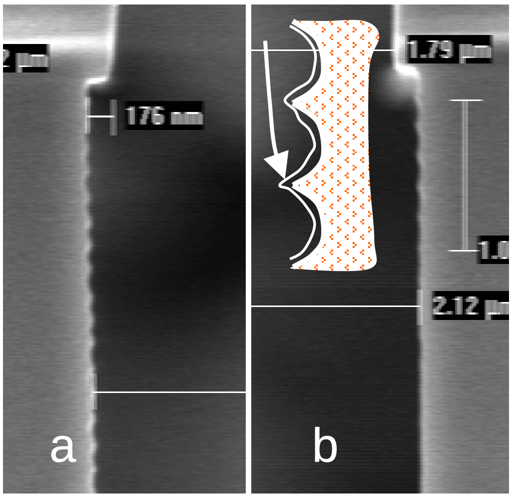

Fig. 2 The Bias during the etch step is 1.8 times larger in b) than a) resulting in a smoothening of the scalloping. The model is that at higher bias the parts of the scalloping that stick out most, are etched away by the deflected ions. The effect is less pronounced 1µm below the hardmask.

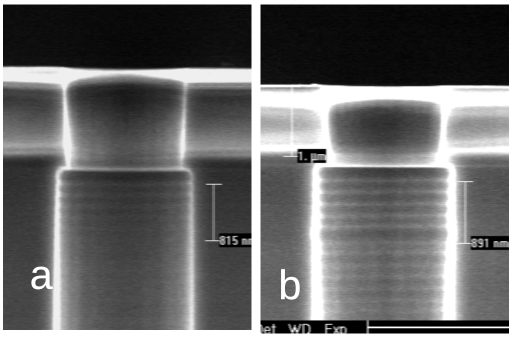

Fig. 3 Shows a study on via's. The top power during the etch step is 1.8 times larger in b) compared to a). Scalloping is more pronounced in b) than a). The proposed model is that at higher top power the plasma is more dissociated and thus more reactive. The undercutting is present and nearly not influenced.

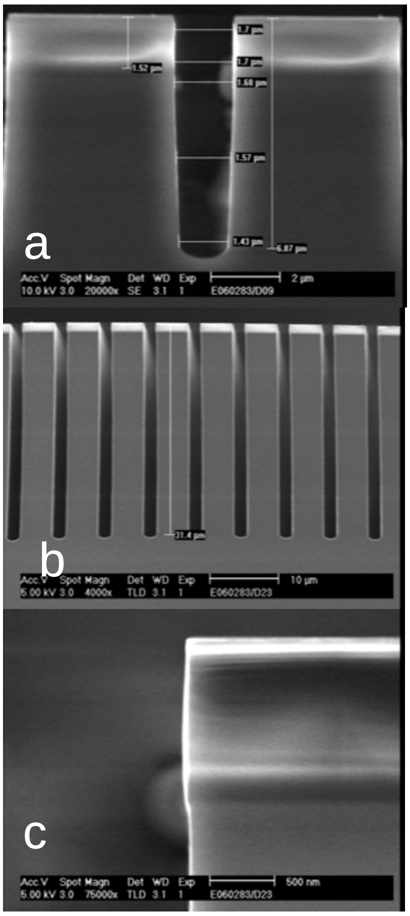

Fig. 4. In a) the profile is shown after the continuous trench etch. In b) shows the total trench after the additional Bosch processing. Figure c shows that scalloping and undercut at the top can be avoided. The proposed model is that the oxide type of passivation during the continuous etch resists the Bosch etching.