An all in one chamber approach for a shallow trench etching process in 130 nm node completely controlled by interferometry

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The shallow trench formation affects importantly electrical performance and yield of devices. Therefore, the requirements in terms of etch depth and profile uniformity, critical dimension (CD) control, slope of hard mask, profile and etch rate microloading, and RIE lag (ARDE) are very stringent. To accomplished these requirements, we have developed a stable whole process with hard mask opening (HMO) and substrate etching controlled by interferometry. The substrate etching was carried out over hard mask to minimize microloading and RIE lag.

Introduction

The etching of shallow trench completely in one reactor offers a couple of advantages. But such a process is challenging and manifold because of multiple etching steps sequence. [1]

The etching process is often divided into a nonselective main etch step (ME) to define feature size/shape and an overetch step (OE) highly selective to the underlying film. Etching steps stopped by time are often unsuitable to etch multiple film stack, because film thickness and etch rates are drifting with time. Therefore, optical emission spectroscopy is used to monitor the plasma changing when a layer has been cleared.

The etching requirements become challenging more and more with shrinking feature size. It is often necessary to remain a constant film thickness after ME to get the best etching performance. The interferometry is a suitable instrument to stop reproducible in film. [2]

Therefore, we have developed a very stable all in one chamber approach for the shallow trench etching process completely controlled by in situ thin-film interferometry.

Experimental

We used a commercial high-density plasma etching chamber with decoupled plasma source for 200-mm-diam wafers equipped with ceramic chuck (DPS$^+$, Applied Materials). An endpoint system (EyeD, Verity Instrument) was installed on the etch reactor for real time optical emission spectroscopy and interferometry.

The multiple film stack to be etched is illustrated in Figure 1.

Results and discussion

The nitride opening process was special designed. By using interferometric endpoint prediction, the nitride main etching was certainly stopped before reaching pad oxide. The remaining nitride was removed by overetch step with stop on underlying pad oxide. Figure 2 shows typical interferometric and optical emission traces from nitride ME and OE. The averaged CD was +/- 5nm from the target CD (Fig. 3).

To minimize microloading and RIE lag (Fig. 4), the shallow trench was etched over hard mask. The resist mask was removed after HMO by in situ O_2 plasma that cleaned the chamber wall simultaneously from fluorocarbon polymers generated during HMO to avoid F radical attacks at Si. The trench depth was also controlled by interferometry. Figure 5 shows the trend of normalized trench depths measured on 12 points/wafer.

Conclusions

The use of interferometry is a very powerful instrument to control etching processes of multiple film stack like shallow trench patterning. In combination with substrate etching over hard mask we got a very stable whole etching process with small wafer to wafer and lot to lot variation in CD and trench depth.

References

[1] N. Layadi *et al.*, J. Vac. Sci. Technol. **B 12**, 2345 (1999)

[2] S. J. Ullal *et al.*, J. Vac. Sci. Technol. **B 20**, 1939 (2002)

Figures

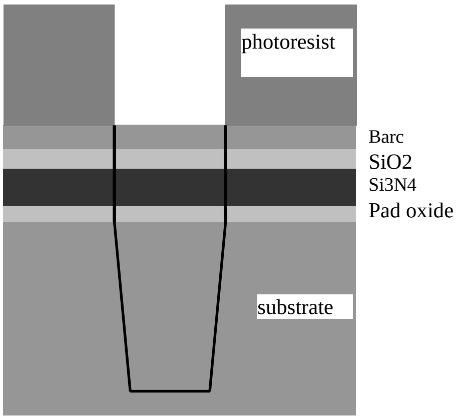

Fig. 1. Multiple film stack to be patterned in STI formation.

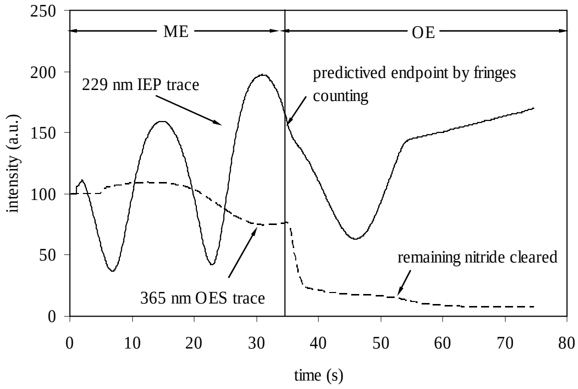

Fig. 2. Typical interferometric (IEP) and optical emission (OES) signals for HMO process (nitride steps).

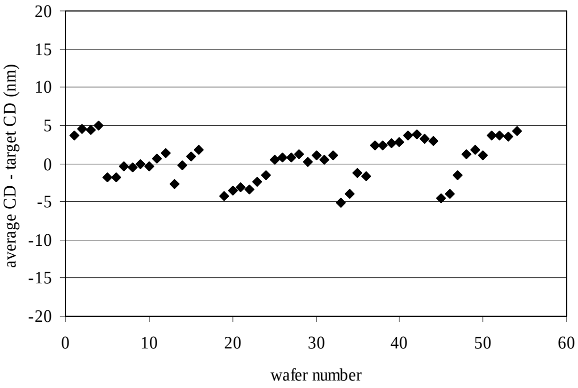

Fig. 3 Average CD subtracted from target CD measured on 4 wafers/lot.

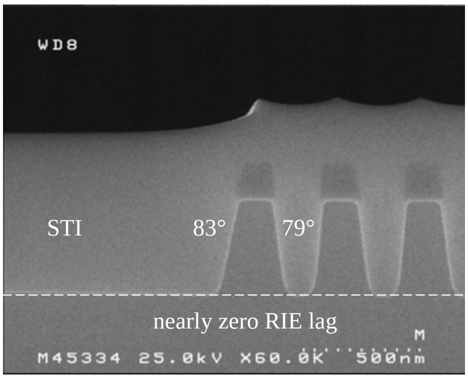

Fig. 4 X-section image of STI with nearly zero RIE lag.

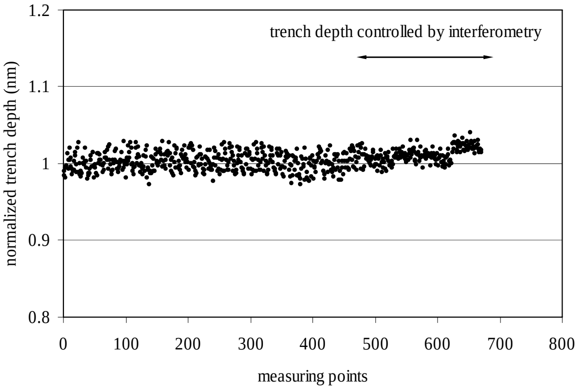

Fig. 5 Normalized trench depth (relating to target depth) measured on 12 points/wafer on 4 wafers/lot.