Ultra low-k dielectric etching and stripping processes

Blaschta, Frieder; Schulz, Stefan E.; Rennau, Michael
Chemnitz University of Technology, Faculty for Electrical Engineering and Information Technology,
Center for Microtechnologies

1 Introduction

Although the debate still rages about the materials used, we will report essentially about the patterning and stripping of SiO_2 aerogel and MSQ based ultra low-k dielectrics. Common to both is that there is porosity in the dielectrics. This means, that all processes must be carefully adapted to this fact.

2 Experimental

In general, the patterning processes of dense SiO_2 are transferable to low-k. However, the layer stack, mask material and strategy have to be modified. Always one must consider the large inner surface of the dielectrics because of the porosity. Moreover, low-k material demands an additional cap layer, which simplifies patterning. In connection with this, the concept of single and dual hard masks was introduced to etch the low-k materials and to strip the necessary photoresist afterwards.

Fig. 1 shows the scheme of a single and dual mask stack.

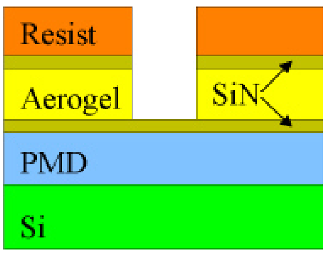

Fig. 1a: Single hard mask

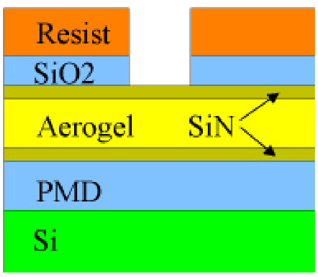

Fig. 1b: Dual hard mask

In general, after 500nm PECVD SiO_2 / 50 nm PECVD SiN deposition on a Si (100) substrate, an about 500nm thick porous layer of low-k material was deposited. Normally, a cap layer of SiN (Hardmask HM1, 50 - 400nm thick) was deposited on it. In case of dual hard mask additionally a PECVD SiO_2 layer (HM2) of about 500nm thickness was used.

The patterns of vias and lines were formed by conventional i-line photolithography and e-beam lithography in some cases.

The reactive ion etch (RIE) with inductively coupled plasma source (ICP) has been carried out in an equipment of Oxford Instruments.

First trials with a conventional gas mixture of $CHF_3/CF_4/O_2$ showed adhesion failures at the interface between SiN and aerogel (Fig. 2).

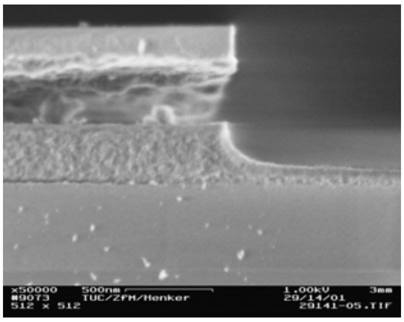

Fig. 2: Adhesion failure at single hard mask caused by oxygen containing etch processes.

By eliminating oxygen in the etch processes the adhesion could be improved and at the same time the damages of low-k materials were reduced. In this way we were able to etch sensitive low-k materials, like aerogel [1].

Fig. 3 demonstrates the successful patterning using a CF_4/Ar mixture.

The advantage of a dual hard mask was used to remove the photoresist without impacts on porous low-k and hardmask / aerogel interface with an intermediate etch stop after etching the hard mask HM2.

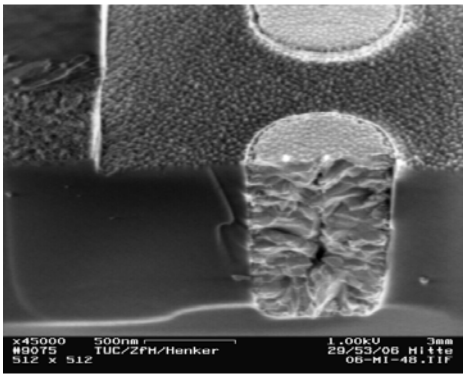

Fig. 3: Patterning with dual hard mask

In the following, a hydrogen based resist removal has to be performed in order to minimize the impact on low-k materials. A suitable H_2-plasma strip was developed at an AMAT ASP chamber, using a downstream microwave discharge. Remaining impact of hydrogen ashing process on low-k materials, like aerogel, porous MSQ and non-porous Black Diamond™ was investigated. In order to simulate the worst case of impact, plasma treatments were done at blanket wafers with the above mentioned materials. The relative change of thickness and the k-values were investigated.
Fig. 4 shows the relative change of thickness in dependence of time of plasma treatment.

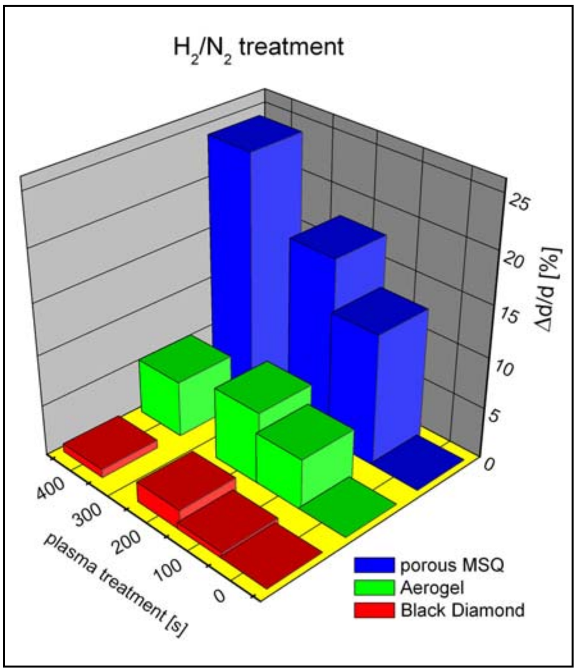

Fig. 4: Thickness change after plasma treatment of low-k materials

It is obvious that porous material suffer the most impact of stripping. That means the ashing process should be reduced to minimum with respect to damages of low-k materials. A similar situation was found by measuring the k-values. Fig. 5 confirms the impact of ashing on porous materials, again.
The nonporous material is nearly unchanged.

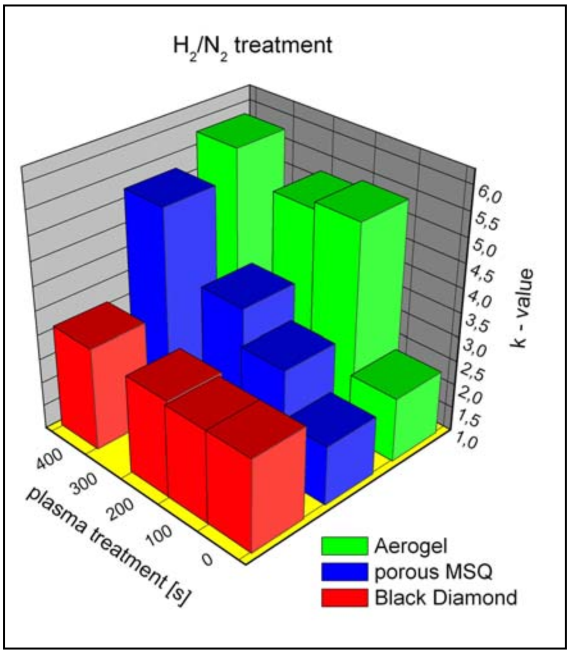

Fig. 5: k-values of plasma treated dielectrics

3 Summary

The concept of single and dual hard mask was studied with respect to etching and stripping. Both procedures have pros and cons.
It was found common to both, that oxygen must be excluded in all cases.
The stripping by means of hydrogen plasma is most promising, but further optimization is needed.

4 References

[1] Blaschta, F.; Schulze, K.; Schulz, S.E. and Gessner, T.: *SiO_2 aerogel ultra low k dielectric patterning using different hard mask concepts and stripping processes.* Microelectronic Engineering Vol. 76, (2004), 8-15

Acknowledgement

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