A STUDY OF MINIMUM ISO-DENSE ETCHING CD BIAS LOADING PERFORMANCE ON ADVANCED LOGIC TRENCH PROCESS

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ABSTRACT

Iso-dense loading including critical dimension (CD), depth and profile etc. is becoming a challenge for both Logic front-end-of-line (FEoL) and back-end-of-line (BEoL) patterning due to the need to scale the pitch [1-2]. In this paper, trench process iso and dense CD performance had been evaluated for both devise and reliability uniformity window. By using AppliedPRO™ [3], a systemic investigation was performed to find the tuning knobs of iso to dense etching CD bias loading. Based on DOE and tuning knob window split, our results indicate that iso to dense CD bias loading can be tuned. This study demonstrates efficient way to find the tuning knob and develop relative etching recipe.

Keywords - Tri-layer patterning, Trench etch, ML etch, Iso-dense loading.

INTRODUCTION

Tri-layer mask scheme has been designed with increasing demand for pitch down scaling on advanced logic node. Therefore, iso-dense CD loading control faces significant challenges. Due to lithography limitation, iso pattern always has equal or even larger CD than dense pattern, and shows taper profile after lithography exposure (Figure 1). Hence, etch solution on dense to iso CD loading control becomes more and more critical. In this work, etch solutions has been evaluated by constructing a virtual design of experiment (DOE) using AppliedPRO™.

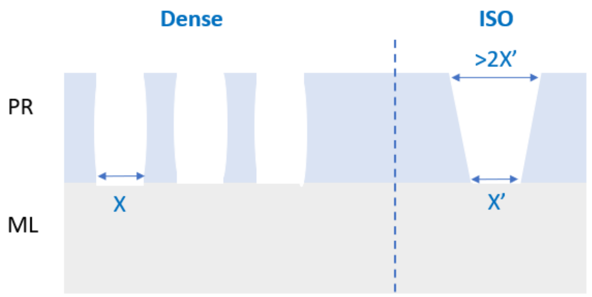

Figure 1: Schematic of dense and iso performance post lithography exposure.

EXPERIMENT DESCRIPTION

In our experiment, typical trench film stack has been built with photoresist (PR), Si based anti-reflection middle layer (ML), carbon based bottom layer (BL) and patterning layer (PL) to study iso-dense CD loading (Figure 2).

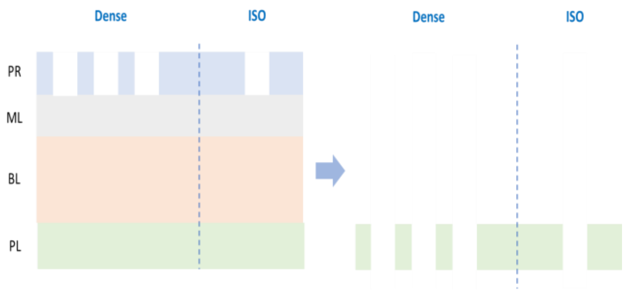

Figure 2: Schematic of typical structure.

CD determinate step is usually ML etch step for most of tri-layer trench etch. To explore the sensitivity, ML etch recipe DOE including special gas T flow, bias power and CHF3/CF4 flow ratio as tuning knobs was created by using AppliedPRO™ software (Figure 3) and etched by Applied Materials Inc. Sym3™ etching system.

DOE	Special Gas T Flow	Bias Power	CHF3/CF4 Flow Ratio
1	Low	Low	High
2	Low	High	Low
3	High	High	Low
4	Medium	Medium	Medium
5	Low	Low	Low
6	High	High	High
7	High	Low	Low
8	Low	High	High

Figure 3: DOE of etch recipe by AppliedPRO™.

RESULT AND ANALYSIS

Except incoming effect as mentioned before, another failure cause of iso-dense CD loading comes from fluorine radicals not being balanced between these two sections at ML etch. There are more fluorine radicals at iso section, and it leads to more PR consumption resulting in larger iso CD (Figure 4).

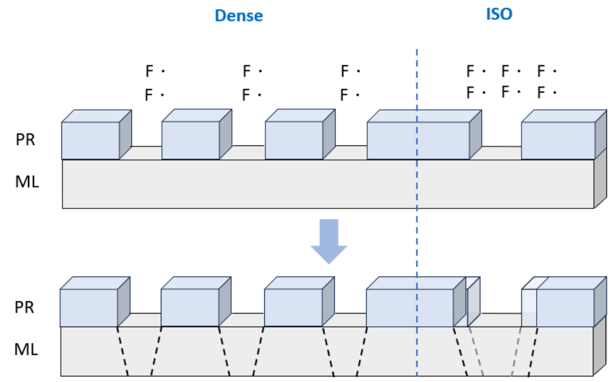

Figure 4: Schematic of ML etch.

In most cases iso-dense CD loading was defined at ML etch step and was tuned by controlling the amount of polymer deposition (Figure 5). Normally to achieve less CD loading amount, it requires more deposition amount at iso section. However, there is limitation to achieve both CD targeting and trench open window at the same time.

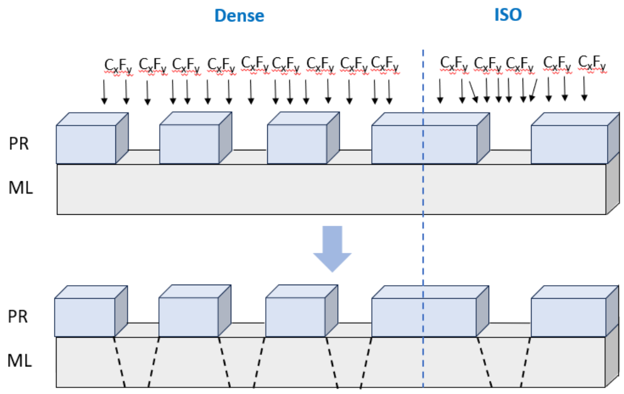

Figure 5: Schematic of ML etch.

In order to find efficient tuning knobs, etch DOE had been designed by AppliedPRO^{TM} and results are shown as Figure 6. It indicates that special gas T is a powerful knob to fine tune iso-dense loading. The gas T will generate T' segment under plasma and it will not only react with C* to form CxHyT' polymer but also react with F* to form volatile T'F. Hence, iso section CD could be controlled and it even becomes possible to achieve iso CD smaller than dense CD. However, it slightly impacts line width roughness (LWR) as indicated by DOE result and etch stop was found under some conditions when implementing special gas T.

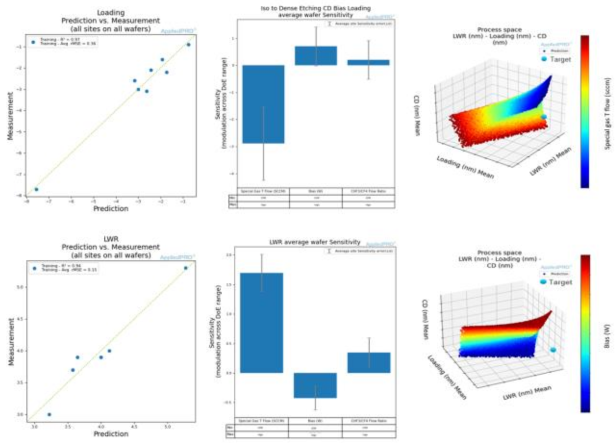

Figure 6: DOE result by AppliedPRO^{TM}.

Post ML etch partial has been checked to understand the root cause of LWR worsening and etch stop failure mechanism while implementing special gas T (Figure 7). ML etch partial results show there is PR shrinkage under plasma, which induces LWR worsening if ML etch step has high OX to PR selectivity. Moreover, etch stop happened at worse case due to polymer clogging at PR top.

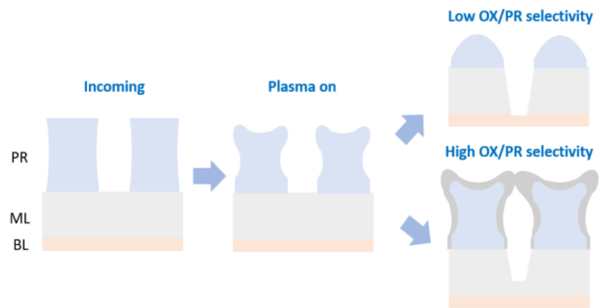

Figure 7: Schematic of PR under plasma and post ML etch.

Special gas T and CHF3/CF4 flow ratio has been further evaluated with bias power split to break through iso-dense loading trade-off with etch stop window. Window split results show that high OX/PR selectivity can be achieved by higher special gas T flow or lower CHF3/CF4 flow ratio, but both knobs have etch stop risk. Higher bias has benefit for etch stop window, but CD will be larger (Figure 8).

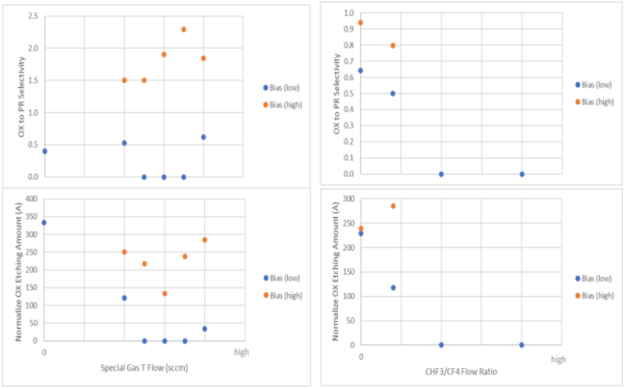

Figure 8: Window split on special gas T flow and CHF3/CF4 flow ratio.

To further improve LWR with CD tuning knob, special gas T flow was combined with bias power to find best window (Figure 9).

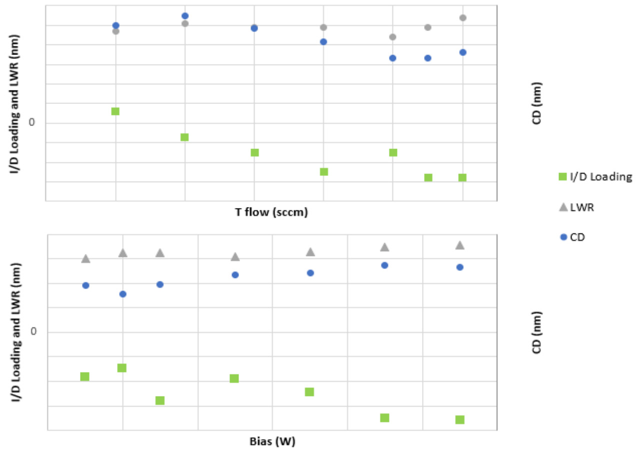

Figure 9: Window split on special gas T flow and Bias.

CONCLUSION

In this paper, the typical trench process has been designed to study iso-dense CD loading behavior. By using AppliedPRO^{TM} DOE function, both iso-dense loading and LWR tuning trend were simulated. The best process regime was found by combination of window split. Our study reveals that iso-dense loading could be tuned by implementing special gas T flow, but PR behavior under plasma need to be considered as well, therefore further fine tuning on bias, gas flow and gas ratio etc. is also needed.

REFERENCE

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