Shrink and Control Critical Dimension Using Dielectric Etch Chamber for 45nm Technology and Beyond

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Critical dimension (CD) shrink was performed using the capacitive coupled plasma etcher with high frequency source on in-situ hard mask open and dielectric etch process. Two frequencies (<100MHz vs >100 MHz) source power with different plasma densities were compared. It was found that the CD shrink was related to the CF_2 species that were excited from source power and >100 MHz source power showed the strong control knob on CD shrink comparing to <100MHz. Chemistry selection and process control knobs have been evaluated and it was found that the CD shrink was basically controlled by pressure, polymer gas, and source power. A maximum >60nm CD shrink bias was obtained when profile and final CD range was maintained in the spec. Repeatability tests demonstrated the production worthy performance on CD shrink and tight CD range control.

Experimental

All experiments were done in Enabler Dielectric Etch™ chamber with two different frequency source powers. The chamber configuration consists of both low and high frequency bias power is used to control the incident ion energy to the wafer for versatile process applications. An amorphous carbon layer (Advanced Patterning Film: APF) mask pattern wafers with BARC/DARC layers were used to be evaluated.

Results and discussion

(1) High frequency and their comparison on CD shrink

CD bias comparison on the BARC open process step with and without source power shows source power strong effect on CD shrink as in Figure 1. The CF_2 radical emission in etching plasma were collected by the optical emission spectroscopy (OES) as shown in Figure 2 and 7 to evaluate the difference on the CD shrink with different process parameters. It was found that the >100 MHz source provided the efficient generation of CF_2 radical density that resulted in more CD shrink as shown in Figure 3. The high frequency source power provided the CD shrink capability was believed due to high ion density in Figure 4 and low voltage between high frequency source and low bias power very well controlled the etch direction.[1] The CD shrink varied with different source power for both frequencies and it showed the more CD shrinks with high source power in Figure 5. The CF_2 species density without source power showed lowest signal and the strongest emission with the high source power, which was pretty much consistent with the wafer results in Figure 7.

(2) Other CD shrink control knobs

CHF_3 flow on BARC open was evaluated at different pressure and the high CHF_3 gas flow and low pressure were showing strong knobs on CD shrink control with source power in Figure 6. It was known that CF_2 was one of many species from CHF_3 dissociation during the plasma etch and more CF_2 has been generated with high frequency power, which deposited on the sidewall to protect the isotropic etch and therefore made the top CD shrink.[2,3] With the lower flow CHF_3, the CD shrink range was much bigger than high CFH_3 flow with pressure change. The function of low pressure shrink CD was believed due to the ion or flux etched down to the contact hole much more than other directions because of high plasma density caused by high V_{dc}. A summary of CF_2 species density with pressure, gas flow, source power was in Figure 7. The CF_2 species density explained why high source power and low pressure as the knobs on CD shrink control. Figure 9 showed the results of final CD shrink.

(3) Productivity capability

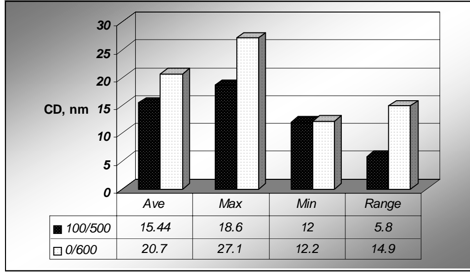
The production-like runs on patterned structure wafers were tested with two different source powers and both showed CD shrink consistently repeatable in Figure 8. The high frequency source power provided the high plasma density as the strong knob for CD shrink and meantime allowed the high efficiency wafer-less dry clean, which benefited APF etch clean mode requirement.

Conclusions

With high frequency source power, low pressure and polymerized gas addition in a dielectric etch chamber, APF hardmask open etch with the following dielectric etch demonstrated the production worthy performance on CD shrink and tight CD range control.

References

[1] Peter Ventzk *et al*., Dry Process Symposium (1999) III-23, p 203
[2] G.S Ochrlein *et al*., J. Vac. Sci. Technol. A12(2), Mar/Apr (1994) 323
[3] Y Chinzei *et al*., Dry Process Symposium V-6. p. 267-269 (1997)



	Ave	Max	Min	Range
100/500	15.44	18.6	12	5.8
0/600	20.7	27.1	12.2	14.9

Figure 1. CD shrink with and without source power

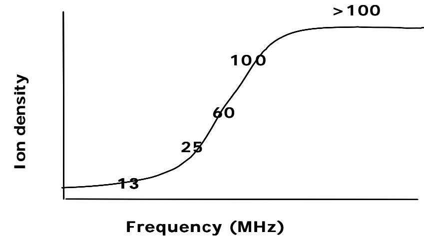


Figure 4. Ion density vs power frequency

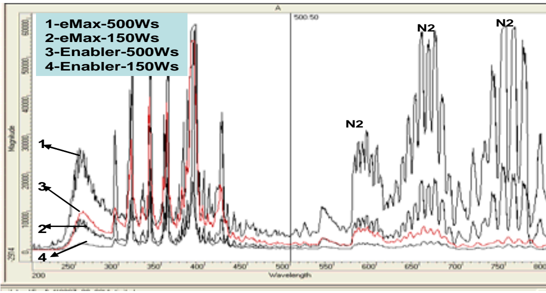


Figure 2, CF2 emission with diff frequency and Ws

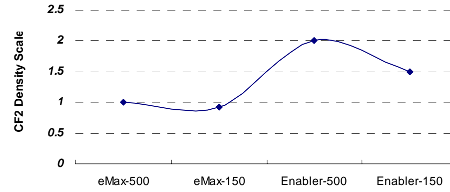


Figure 3, CF2 density with diff frequency and Ws

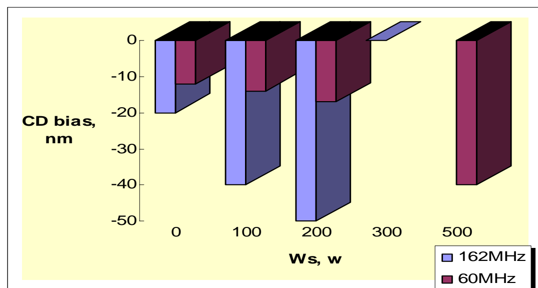


Figure 5, Two frequencies comparison on CD shrink

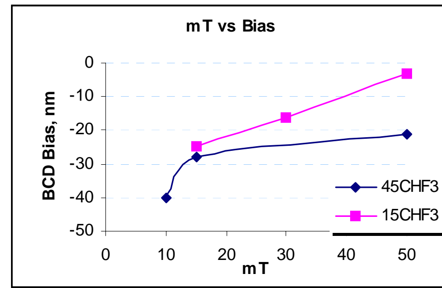


Figure 6, CD shrink with CHF3 and mT

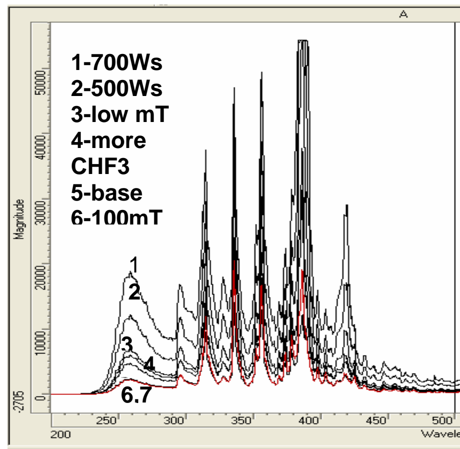


Figure 7, CF2 emission VS. Ws, mT, CHF3

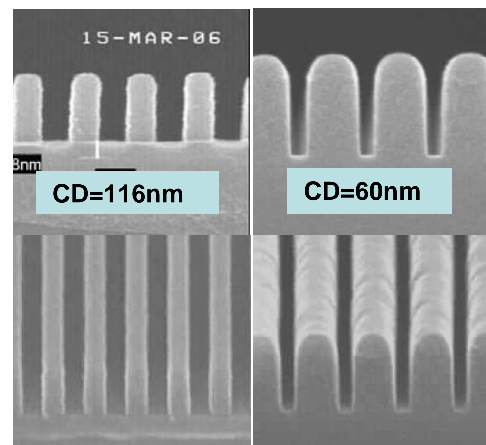


Figure 9, CD shrink SEM

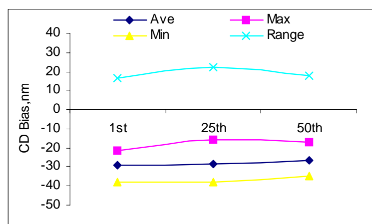


Figure 8, Repeat test data with 60 and 162 MHz