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Comparison on Various Developing Method at Clean Track ACT 8 Based on 0.5um CMOS Technology.

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Abstract: Photoresist development is one of the critical steps in ensuring good critical dimension uniformity (CDU). In this paper, we demonstrate the methods by using 0.5um CMOS Technology Gate pattern. There methods used at our coater and developer system are standard, agitate and prewet. 25 pieces of 8 "dummy wafers were used for each method. All wafers were coated with 1.0um thickness of photoresist before we exposed it using Nikon stepper i14. Then the wafers were developed using different type of developing method at CLEAN TRACK ACT 8. These 3 batches of bare silicon wafers were run continuously in order to eliminate the variations of room humidity and temperature between runs.

13 wafers from each developing method we chosen as a sample to be measured at CD SEM system. 9 locations of CD measurement were measured in each wafer. CD vs. Wafer No graph were plotted in order to check the stability of CD measurement. Our finding from the study is that the agitation developing method gave the most stable and uniform CD measurement.

Keywords: Developing method, CD Sem, wafer, Coater, Stepper.

I. INTRODUCTION

Standard development method using E2 nozzle (Figure 1) in lithography term has been used since Fab 2 at Mimos Semiconductor qualification for years. E2 nozzle with standard development method is a conventional method in CLEAN TRACK ACT 8 developing process. During standard photoresist development method, developer solution is dispensed onto the wafer using E2 nozzle and then allowed to puddle. De-ionized (DI) water is then sprayed onto the wafer to rinse the developer solution away and to complete developing process. At the same time, DI water is sprayed on the wafer back to clean it. Finally, the wafer is spun dry for the next process. It is implemented to all patterns in lithography process for 0.5um CMOS technology.

Since the development process is necessary in considering CD (critical dimension) measurement uniformity, many ideas have come in order to improve the precision of development. Currently, we face a problem which is there is uniformity issue on CD within wafers. It can be seen clearly when we run 25 wafers in one lot. There is a big range between maximum and minimum CD measurement. These phenomena occurred on every pattern and product, even though on fresh dummy. This automatically eliminates factors such as resist thickness, topography or underlying process.

Besides standard development, other methods were explored to find the best results. The methods are agitation method and prewet method. In other fab, agitation method is reported as a good development method. While prewet method is another option to get better CD measurement uniformity but its consumed double quantity of developer solution.
In this paper, we will compare the result on CD measurement uniformity from different methods of developing process which are standard, agitation and prewet at CLEAN TRACK ACT 8 using gate pattern from 0.5um CMOS Technology.

II. EXPERIMENTAL

A. Procedure

3 boxes of 25 pieces fresh dummy is needed for this experiment. Every lot which is consists with 25 pieces of wafer will be used for each development method. For this purposes, 1.0 um resist thickness will be coated onto the wafer as this thickness is the standard thickness used for 0.5um gate pattern which is used in this experiment. These 3 lots must be run continuously in order to eliminate the variations of room humidity and temperature between runs

.Refer to Table 1 for experimental conditions. Below is the procedure of the experiment:

Lot 1- Standard development method

1. Coat 25 pieces of fresh dummy with 1.0um resist thickness
2. Expose the wafer with gate pattern,
    a. Reticle: 0028130A,
    b. Exposure dose: 170 mJ/ms ,
    c. Focus = -0.65 um.
3. Develop the wafer using standard development method.

Standard development method is a common method. At first, developer solution is dispensed onto the wafer, after a minute interval, DI water will rinse the wafer and the wafer is spun to remove excess DI water.

Lot 2 – Agitation development method

1. Coat 25 pieces of fresh dummy with 1.0um resist thickness
2. Expose the wafer with gate pattern,
    a. Reticle : 0028130A ,
    b. exposure dose : 170 mJ/ms ,
    c. focus =-0.65um
3. Develop the wafer using agitation development method.

For agitation method, after developer solution is dispensed onto the wafer, wafer is agitated for a second at certain second interval. This step is repeatedly for several times. After the last intervals, wafer will be rinse of using DI water as usual step before spinning as a last step.

Lot 3 – Prewet development method

1. Coat 25 pieces of fresh dummy with 1.0um resist thickness
2. Expose the wafer with gate pattern,
    a. Reticle : 0028130A ,
    b. exposure dose : 170 mJ/ms ,
    c. focus =-0.65
3. Develop the wafer using agitation development method

For prewet method, DI water is dispensed onto the stationary wafer followed by developer dispense. The wafer is left stagnant for a few seconds and then spun for a while at certain spin speed. Next, developer solution is dispensed again onto the wafer. The next step is same as the agitation method. After that, DI water is dispensed to rinse the wafer and dry spinning will follow to dry the wafer.

B. Measurement

CD Measurement of the wafers was done using S8840 (Hitachi) scanning electron microscope (SEM). For every lot, wafer no 1,2,3,4,11,12,13,14,21,22,23 and 24 will be measured. This specific wafer numbers were chosen to represents the whole lot. CD measurement will be done at 9 points (Figure 2) at product area. The pattern measured is 0.5um width gate pattern (Figure 3 and Figure 4). All wafers must be measured on the same day to prevent from pattern shrink problem caused by temperature and humidity influence.

III. RESULTS AND DISCUSSION

From the plotted graph (Figure 5), we can see CD measurement of standard development method for each wafer. The CD measurement range between the maximum and minimum value is 0.0255um (Figure 8). Even though this range is still within technology specification, we are looking to improve the process window.

During development process, the developer concentration will reduce as it dissolves photoresist causing the development rate to reduce with time and to differ depending on the density of pattern or the amount of photoresist it dissolves. In this standard development method the developer solution is stagnant. Thus not all photoresist patterns are developed at the same rate. Larger area to develop will have less “active” developer necessary to dissolve the photoresist. As a result, this variation of “active” developer caused the critical dimension (CD) for each wafer differs slightly.

Figure 6. CD range measurement range for agitation method is 0.013um. It shown a smaller range compared to standard method. It also gives a stable measurement for all 25 wafers. Even though the mean of CD is slightly higher, we are not looking at the mean, only the stability and uniformity.
The agitation promotes better developer distribution into the photoresist pattern. Each movement will give every places of photoresist pattern “active” developer solution.

For prewet method (Figure 7), the CD range is 0.017um, slightly higher than the agitation method but still gives a good uniformity. As stated before, even though the mean of CD is slightly higher, we are not looking at the mean, only the stability and uniformity
The introduction of DI water before developer is to wet the photoresist pattern. Photoresist pattern is very dry and exhibit hydrophobic (expel water) characteristic. This wetting process is to induce the reaction between developer and photoresist. The combination of the DI water prewet and agitation give stable CD measurement but the appearance of the second developer solution after the first dispense is consuming more developer solution, thus not very cost effective.

Beside the development method, cycle time, type of developer, developer flow rate, developer volume and type of resist may change the result even though agitation method is used. If different condition is used in this experiment, the result might be differing.

IV. CONCLUSIONS

From the study, it shows that photoresist development process at CLEAN TRACK ACT 8 for 0.5um CMOS Technology using agitation and prewet methods give better CD uniformity if compare with standard method.
By implementing agitation development method, it didn't gives any disadvantage as there is no major change done from the current development which is standard method except the movement of the wafer.

For prewet development method, even though it shows stable CD uniformity but it is not practically to be implemented because double volume of developer solution is consumed and that brings to the economical issue.

REFERENCES

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Table 1 . Experimental conditions

Coat/Develop process	TEL CLEAN TRACK ACT 8
Substrate	Si (bare)
Resist	TDMR AR 3100 8cP
Solvent	EBR 70/30
Resist Thickness	10300 Å
Film thickness measurement	Nanospec 8000X
Exposure	Nikon NSR 2205i14 series
Exposure layout	See Figure 2
Reticle	0028130A
Development	AZ 726MIF
Development nozzle	E2 nozzle
Development flow rate	1.8l/min
CD measurement SEM	Hitachi S8840

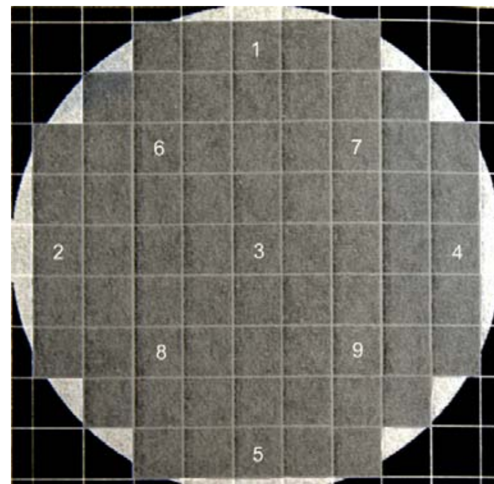

Figure 2. CD Measurement location on pattern wafer.

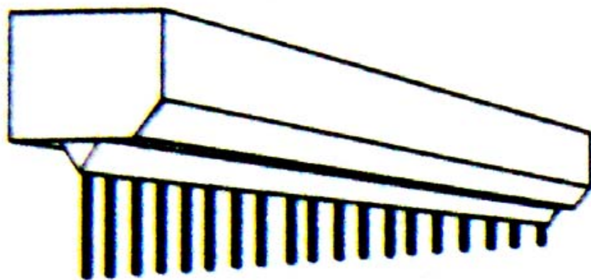

Figure 1. E2 Nozzle

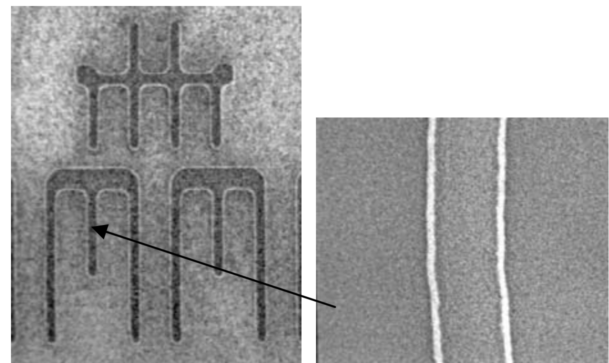

Figure 3 and 4 . Gate pattern line width ,0.5um
Note: For figure 4, the image is slightly distorted, this is the effect of the reversible CD sem image. In real pattern, the profile is actually straight.

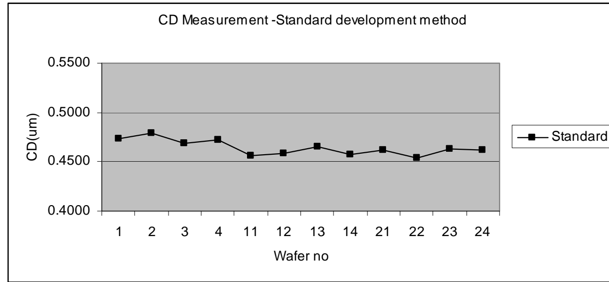

Figure 5. CD Measurement for lot using standard development method

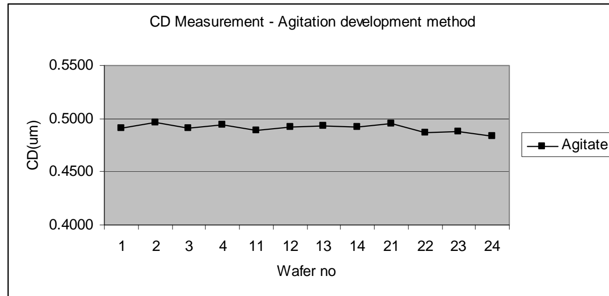

Figure 6. CD Measurement for lot using agitation development method

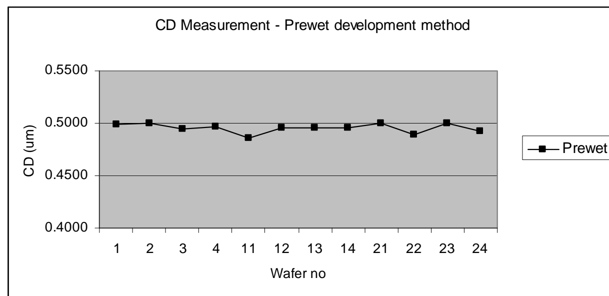

Figure 7. CD Measurement for lot using prewet development method

Development Method	CD Range (um)
Standard	0.0255
Agitation	0.013
Prewet	0.017

Figure 8 . CD Measurement range for each method.

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