# **HSQ Experiment**

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# Experiment summary

- 1. vary post apply bake temperatures (slides 4-16)
- 2. developer concentration conditions for 30 nm dots (slides 17-23)
- 3. developer concentration effect on large 50 um features (slides 24-26)
- 4. dose optimization on line width and pitch using low concentration developer (slides 27- 38)
- effect of delay between exposure and develop (slides 39 42)

### HSQ Post Apply Bake Experiment

# HSQ Post Apply Bake Experiment

- Purpose
  - To identify, and confirm the effect of different post apply bake conditions for HSQ

# **Process Condition**

- XR-1541 (HSQ) 6% on a 1" square silicon substrate piece
- Spin conditions = 5000 rpm, 2500 rpm/s, 60 sec
- post apply bake (various conditions)
- average resulting thickness (pre-develop) ~ 116nm
- Develop: MF-319 for 70 seconds, DI water rinse for 60 seconds, nitrogen blow dry

# Experiment 1

- 3 post apply bake conditions
  - 80 C 4 min
  - 150 C 2 min
  - 250 C 2 min







### Summary of different bake conditions



| bake         | highest dose with<br>no residue<br>(μC/cm²) | thickness<br>(nm) | pre-develop<br>thickness<br>(nm) |
|--------------|---|-------------------|----------------------------------|
| 80 °C 4 min  | 550   | 100               | 116                              |
| 150 °C 2 min | 550   | 99                | n/a                              |
| 250 °C 2 min | 300   | 81                | n/a                              |

 small difference in thickness vs. dose for the various bake conditions at lower doses (left graph)

• difference in residue around 50 x 50 um feature with different bake conditions (see right table)

• lower bake temperature can achieve a higher post develop resist thickness without residue by using higher dose (see right table)

# Experiment 2

• Purpose

- see if experiment 1 is repeatable
- evaluate no bake









#### Summary of different bake conditions



- some differences to experiment 1 but general trend is repeatable
- there is no significant difference in thickness vs. dose for the various bake conditions (left graph)
- BUT, there is a difference in residue around 50 x 50 um feature with different bake conditions (see right table)
- lower bake temperature can achieve a higher post develop resist thickness without residue by using higher dose (see right table)

### HSQ Dots Experiment

# **Process Condition**

- •HSQ 6% on a silicon substrate
- •Spin conditions = 5000 rpm, 2500 r/s<sup>2</sup>, 60 sec
- •Bake= 80 °C for 4 minutes
- •Resulting thickness ~ 119nm
- •CAD File = 30 nm squares on 100 nm pitch

### dots with 2.3% TMAH (MF-319) developer



#### VERY SMALL PROCESS WINDOW

- at 1000 uC/cm2 all dots just starting to print
- at 1100 uC/cm2, only 100 uC/cm2 greater dose, residue starts to form between dots



Develop process:

- MF-319 for 70seconds
- DI water rinse for 60 seconds
- Nitrogen blow dry

## dots with 25% TMAH developer



#### WIDE PROCESS WINDOW

- the process window is much larger using the higher concentration developer
- dots look very uniform at 3000 uC/cm2 and residue does not form between dots until 6800 uC/cm2



Develop:

- TMAH25% for 30seconds
- DI water rinse for 60 seconds
- Nitrogen blow dry

## HSQ dots made using 30nm squares pattern

| <ul> <li>ο</li> <li>ο</li></ul> | 6400μC/cm <sup>2</sup> | 6600μC/cm <sup>2</sup> | 6800µC/cm <sup>2</sup> | 7000µC/cm <sup>2</sup> |
|---|------------------------|------------------------|------------------------|------------------------|



At dose  $6600\mu$ C/cm2, residue around the dots starts to appear.



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## Diameter = 0.0067 \* Dose + 7.026



Selected values of the linear trend line above is shown on the chart. 23

# Side Experiment

Compare the effect of developing with :

- 1. MF-319 for 70s
- 2. TMAH25% for 30s
- 3. TMAH25% for 7s







TMAH25% for 30s

•Development process using TMAH25% for 30s shows better contrast than using MF-319 for 70s



**HSQ Lines Experiment** 

# **Process Condition**

- •HSQ 6% on a silicon substrate
- •Spin conditions = 5000 rpm, 2500 r/s<sup>2</sup>, 60 sec
- •Bake= 80 °C for 4 minutes
- •Develop = MF-319 for 70seconds, DI water rinse for 60 seconds, nitrogen blow dry

### 20 nm lines with 1:5 line and spacing ratio



Actual line (exposed region) width:

- Lines are falling over



Actual line (exposed region) width:

- Over exposed



Actual line (exposed region) width:

- Over exposed

### 50 nm lines with 1:2 line and spacing ratio



Actual line (exposed region) width: Mean = Can not determine



Actual line (exposed region) width: Mean = 31.7 nm



Actual line (exposed region) width: Mean = 32.53 nm

### 50 nm lines with 1:2 line and spacing ratio



Actual line (exposed region) width: Mean = 46.3nm



Actual line (exposed region) width:

- Over exposed



Actual line (exposed region) width:

- Over exposed

#### 100 nm lines with 1:1 line and spacing ratio



Actual line (exposed region) width: Mean = 64.1nm



Actual line (exposed region) width: Mean = 86.36nm

### 100 nm lines with 1:1 line and spacing ratio



Actual line (exposed region) width: Mean = 78.24 nm



Actual line (exposed region) width:

- Over exposed



Actual line (exposed region) width:

- Over exposed

### 100 nm lines with 1:2 line and spacing ratio



Actual line (exposed region) width: Mean = 38.39nm



Actual line (exposed region) width: Mean = 63.37nm



Actual line (exposed region) width: Mean = 71.41nm

### 100 nm lines with 1:2 line and spacing ratio



Actual line (exposed region) width: Mean = 71.52nm



Actual line (exposed region) width:

- Over exposed



Actual line (exposed region) width:

- Over exposed

#### 100 nm lines with 1:5 line and spacing ratio



Actual line (exposed region) width: Mean =23.24 nm



Actual line (exposed region) width: Mean = 38.055 nm

### 100 nm lines with 1:5 line and spacing ratio



Actual line (exposed region) width: Mean = 33.83nm



Actual line (exposed region) width: Mean = 54.02nm



Actual line (exposed region) width: Mean = 72.41nm

#### 100 nm lines with 1:10 line and spacing ratio



Actual line (exposed region) width: Mean = 32.05nm



Actual line (exposed region) width: Mean = 43.92nm HSQ Time Experiment

# Procedure

 ~1" piece is coated with HSQ and baked at 80C for 4 minutes.

- Loaded piece is exposed for the first time approximately 30minutes after coating.

- The piece is exposed with the exact same pattern with different offsets after 1 hour, and after 2 hours.



The highest dose squares at different time

 Small difference in the size of residue around the squares (the size of the residue decreases as the time after spin coating increases)

# Thickness vs. Dose

