Measurement of latent image in resist using scanning probe techniques

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Motivation

Exposure

Bake

Final Resist Structure

Dissolution
Motivation

Exposure

Bake

Metrology Black Box

Dissolution

Final Resist Structure
Experiment

Expose

EUV CAR
26nm thickness
100 keV
500 µC/cm^2

SEM Final Structure
2 kEV

Bake

110°C
60s (POR)

Develop

2.3% TMAH
30s Puddle

AFM

Cypher VRS
AM Tapping Mode

Diode
Surface Roughness

RMS roughness: 0.3 nm

What does this say about AFM resolution?
Radial Autocovariance Function

Autocovariance measures correlation of image pixels vs shift distance.
Radial Autocorrelation Function

\[ L_c = \sqrt{r_{tip}^2 + l_{polymer}^2} = 3.1\text{nm} \]

\[ r_{tip} \leq 3.1\text{nm} \]
Patterned CAR (POR)

High quality AFM image of photoresist shrinkage
Other bake times

- 6.5s
- 11s
- 16s
- 30s
- 45s
- 60s
- 120s
Thickness Histograms
Thickness Histograms
Thickness Histograms

Probability

Thickness (nm)

16s
11s
6.5s
Unexposed

×10⁻⁹
Thickness Histograms
Thickness Histograms

![Thickness Histograms](image-url)
Thickness Histograms
Thickness Histograms
Thickness Histograms

increasing bake time
Critical Dimension (CD)

CD measured via photoresist shrinkage matches expected trend for developed lines
Line Width Roughness (LWR)

Rapid drop at short bake time
Reaches plateau
~7.5 nm
LWR Power Spectral Density (PSD)

Power spectrum represents frequency breakdown of LWR
LWR Power Spectral Density (PSD)

Correlation length is a measure of underlying blur processes

$L_c = 14.35 \text{ nm}$
Correlation Length

Diffusive trend in correlation length
On a normalized scale, the thickness profile is a proxy for the chemical profile.
This profile can be used to assess the chemical slope.
Chemical Slope

Thermal process *increases* chemical slope
-> Evidence of nonlinear bake dynamics
Chemical Slope

$LWR \propto \frac{3 \sigma}{\text{slope}}$
Reduction in LWR can be attributed to improved chemical slope.
Latent vs Developed CD

CD trend is consistent between latent and developed structure.
Latent and developed LWR similarly follow similar trends.
Latent vs Developed $L_c$

Better SEM data needed, but initial $L_c$ trend shows possible development-induced blur.
• CAR has been reasonably well studied over the years
• More work needed to characterize chemical propagation in non-CAR resists
• Taken some preliminary data on a metal-based resist
Non-CAR Resist
Conclusions

• Atomic force microscopy represents a promising technique for measuring intermediate photoresist processes

• Photoresist shrinkage appears to be a good proxy for underlying photoresist chemistry
  • CD, LWR, and (maybe) $L_c$ trend similarly in latent AFM images and post-develop SEM
  • Could be used to measure development-induced blur

• Preliminary work suggests technique is applicable to types of resist
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