Advances in Directly Patternable Metal Oxides for EUV Resist

Andrew Grenville
Conventional Photoresists
Stretched to the Limit

Resolution

Line Width Roughness

Pattern Collapse
Patternable Metal Oxides

Resolution & LWR
Etch Selectivity
Low Blur
EUV Absorbance

Goal: Design photoresists with small, inorganic building blocks
Gen 1 Materials: EUV Imaging

8 nm l/s
LWR 1.5nm

10 nm l/s
LWR 0.7 nm
Inpria Generation 1 EUV Photoresists

**Image Fidelity (res & LWR)**

**Etch Resistance**

**High EUV absorbance**

**Instability: shelf life and process**

**High Developer Concentration**

**High Imaging Dose**

**10 nm l/s, 0.7 nm LWR**

Competing condensation and dehydration processes
New Platform Solves Key Challenges

**Gen 1**
- Image Fidelity (res & LWR)
- Etch Resistance
- High EUV absorbance
- Instability: shelf life and process
- High Developer Concentration
- High Imaging Dose

**Gen 2**
- Image Fidelity (res & LWR)
- Etch Resistance
- High EUV absorbance
- Shelf stable and vacuum stable
- Standard Developers
- Path to required dose
Inpria’s Patterning Mechanism

Bake

Metal hydroxo clusters

Dense metal oxide film

Develop

Exposure generates high solubility contrast in developer

New molecular oxide clusters and ligand chemistries adopted for Gen 2 materials

L* = radiation sensitive ligand
Gen 2 E-Beam Baseline: YA Series

26nm hp

9/17/2013 7:17:28 PM
dwell 150 ns
HV 5.00 kV
HFW 695 nm
WD 3.9 mm
mag 298 060 x
tilt 47°

18nm hp

9/17/2013 7:19:03 PM
dwell 150 ns
HV 5.00 kV
HFW 511 nm
WD 3.9 mm
mag 405 099 x
tilt 47°

n-BA develop
20nm FT, ~1100μC/cm²
Gen 2 E-Beam Baseline: YA Series

16nm hp

14nm hp

12nm hp

 inpria
Shelf-Life >3 Months @ RT

18nm hp by EB

Stored at room-temperature

No systematic performance degradation observed over 15 weeks
BMET EUV Imaging: YA Series

22nm hp

100 mJ/cm²

Dose reduced 40%

18nm hp

57 mJ/cm²

18nm dipole; Developer: n-BA

Formulation & process optimization
PSI EUV Imaging: YA Series

Organic developer, 20nm FT, 150C PEB, dose: ~90 mJ/cm²

Unoptimized process
PSI EUV: TEM x-section of 22hp

Pt layer for TEM

Inpria resist

Si substrate

Native SiO2
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Ligand Selection Key Lever

Radiolytic efficiency modulated as predicted by chemistry of ligand sequence. Demonstrates control over an important component of improving sensitivity.

* Relative FTIR absorbance
Path to Improved Sensitivity

Stability

High Imaging Dose

Standard Developers

Maximum Sensitivity

- Remove background condensation from development rate equation
  - High EUV absorbance, tunable M-L radiolysis platform to maximize or amplify photo-efficiency
  - Leverage strength of polarity change/solubility on oxide formation to limit threshold dose

Have stable, fab compatible platform: critical baseline for testing design modifications
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Typical EUV Litho Module

- Thick Spin On Carbon (SOC) often required for device stack
- Opening the SOC requires use of Si-HM (thickness/selectivity)
- Drives higher aspect ratio resist: can lead to pattern collapse
Simplified EUV Pattern Transfer

- Process simplification
  - Need <20nm of resist – mitigates pattern collapse
  - Eliminates need for Si-HM: reduces coat/etch steps
  - Allows higher SOC thickness

>38:1 selectivity to SOC using O₂:N₂ open
Spin-On-Carbon Open

High selectivity provides large process window for SOC open

20 nm Inpria Resist

100 nm SOC

EB expose, no hard bake

O$_2$:N$_2$ etch
Pattern Transfer & Resist Strip

Inpria Resist
20nm
SOC
50nm
Si

SOC open
O2:N2 (300W)

Si etch
C4F8:Ar (35W)

SOC strip
After O2 (10W)

Resist consumed during etch
Summary

• New metal oxide resist platform developed
  – High resolution (12nm hp by EB)
  – Improved dose
  – Stable
  – Compatible with standard developers

• High etch selectivity and pattern transfer demonstrated

• Path identified to improved sensitivity and contrast
Acknowledgements

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