Mimicking very low energy secondary electron (< 20 eV) interactions with novel photoresists

Aniket Thete
Nanophotochemistry
ARCNL
Work Groups Network

Nanophotochemistry (ARCNL)

Prof. Fred Brouwer
Bruno Rocha Martins
Jarich Haitjema
Yu Zhang
Robbert Bloem
Lotte Metz
Sander van Leeuwen
Aniket Thete

Condensed matter physics

Dr. Sense Jan Van der Molen
Daniël Geelen
Prof. Rudolf M. Tromp
LEEM for EUV lithography research

- Lower energy secondary electrons (LEE)
- Line edge roughness (LER)
- Mimicking LEE
Low-energy Electron Microscopy

- low energy electron source
- tunable energy
- spectroscopy
Typical experiment

- Contrast curve – vary dose and energy
- Electron energy loss spectrum (landing energy)

Electron objective lens

Resist

substrate

-15kV + V_E

Electron Energy

0 1 2 3 18 19 20 30 70 80 90

Dose 

\( \mu C/cm^2 \)
First results on PMMA

Electron Energy

0 1 2 3 18 19 20 30 70 80 90

Dose μC/cm²

Optical image

PMMA

10eV 15eV 20eV 90eV

14eV

H₂C

C

C=O

O

CH₃

50μm
Electron Energy loss spectrum

$E_0 = 14\text{eV}$

$E_0 = 15\text{eV}$

$E_0 = 20\text{eV}$

$E_0 = 30\text{eV}$

PMMA

$\begin{array}{c}
\text{H}_2\text{C} \\
\text{CH}_3 \\
\text{\text{C=O}} \\
\text{O} \\
\text{O} \\
\text{\text{CH}_3} \\
\text{x}
\end{array}$
Energy loss data PMMA (no graphene)


Current flowing through the resist

Net beam current

\[
\frac{I(V)}{I_0} = \pm g_0 V^2 = 1 - \left(\frac{E_0 - V}{E_1}\right)^\alpha
\]
Sn(oxo)-X (EUV –absorbing material)
Charging when $E_0 < 15$ eV

$E_0 = 10$ eV  \[\downarrow\]

$V = 10$ V

$E_{\text{eff}} = 0$ eV
Summary and conclusions

• Positive /negative charging/ LEE interaction threshold
• Model has been formulated
• Charging control- Graphene
• Resist reaction with low energy electrons (< 5 eV)
• Resist charging relevant in EUV exposures(?)
• Effect on Line Edge Roughness
Thank you!

Monday 26\textsuperscript{th} 4:40 pm

\textbf{10583-6} Zr- and Hf-based molecular hybrid materials as EUV photoresists
Supporting info.
If we are at positive charge (red plus), then we will suddenly drop to negative charge (red circle) as conductance increases, and the s-curve shrinks. We then have a sudden drop in $E_{\text{land}}$. 

$$0.0025V^2 = (1 - c \sqrt{E_0 - V}) \times 1.85$$

Or sample becomes more conducting:

$$0.0025V^2 = (1 - c \sqrt{E_0 - V}) / 2$$

$$0.0025V^2 = (1 - c \sqrt{E_0 - V}) / 4$$

$$0.0025V^2 = (1 - c \sqrt{E_0 - V}) / 40$$