Extreme Ultraviolet Lithography (EUVL): Novel Patterning Materials, Progress and Challenges

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12th September 2017
XVI SBPMAT
Gramado Brazil
Brief Outline

- Semiconductor IC fabrication technology/HVM
- Lithography- prospect and technical challenges for EUVL
- Resolution-LWR-sensitivity trade-off/CARs
- Process flow layout of resists for NGL/non-CARs
- Resist materials challenges for sub-7 nm EUV lithography
- Metal oxide resists
- Routes to achieve future technological EUVL nodes
- Development of indigenous resist technologies
The semiconductor industry is approaching $400B/yr in sales

- Computers 42%
- Communications 24%
- Data networks?
- Internet of ”things”?
- Transportation 8%
- Autonomous vehicles (Artificial Intelligence)?
- Consumer Electronics 16%
- Medical &Health
- Industrial 8%
- Military 2%
Improvements in IC performance and cost have been enabled by the steady miniaturization of the transistor.

**Smaller is Better**

Intel continues to predictably shrink its manufacturing technology in a series of "world firsts."

- **45 nm with high-k/metal gate in 2007**: Single core Intel Atom™, dual core Intel Pentium®, Intel Core i7,i5,i3 processors with six cores, and even eight core Intel Xeon® processors.

- **32 nm with high-k/metal gate in 2009**: $\text{Eq.T}_{\text{ox}}$ of high-k reduced from 1.0 nm (45 nm) to 0.9 nm (32nm), gate length ~ 30-32 nm. (Enables a >22% gain in terms of drive current & tightest gate pitch reported in the industry).

- **22 nm with the world's first 3D transistor** in a high volume logic process beginning in 2011.
Foundry Futures: TSMC, Samsung, Global Foundry & Intel (Invidia, AMD?)

Gear Up for 7 nm and Beyond tools

- Intel: Launching 10 nm technology node based for mobile market. *While desktop will remain on 14 nm technology node.*

- TSMC planning a quick transition from 10 to 7 nm technology node in 2018.

- In contrast Samsung planning to hold at 10 nm technology node for multiple products and planning to introduce 8 nm node with conventional immersion and 7 nm with EUV 2019-2020.

*Ref: https://www.extremetech.com/computing/237781-samsungs-10nm-node-soxs-now-in-mass-production*
Next Generation Lithography (NGL)

- Multiple exposure lithography (ArF-iMPT)
- Extreme ultraviolet lithography (EUVL)
- Electron beam lithography (EBL)
- Ion beam lithography (IBL)
- Nano imprint lithography (NIL) & related nanofabrication technologies
- Directed Self Assembly (DSA)
Roadmap for Lithography: Driver for Scaling of IC Technology

- To achieve the required market it’s important to update lithography process and compatibilize it for sub 10nm level patterning.
GLOBAL PROJECT: Multi-disciplinary & Multi-Institutional

- FIB/EBL CBPF Brazil
- Photodynamics UFRGS Brazil
- EUV MET LBNL USA
- INUP IIT Bombay India
- IMEC Belgium EUVL Stepper
- HIM NTU Taiwan
- Industry Intel, Dow, SRC, SCL
- SOTON UK EBL/ HIM

IIT Mandi Design and Synthesis of Resists
**Photoresists**

- Light-sensitive:
  - polymers/macromolecules/molecules/hybrids/inorganics

- Changes in their chemical structure when exposed to radiation/UV-light.

- Contain light-sensitive chemical functionality - allow image transfer onto a silicon wafer.

- Two types: positive and negative
Photo Resists Materials Roadmap: Current status and challenges

*Competing Options*

- **Chemically Amplified (CA) Polymeric Resist**
  
  Diffusion is a challenge: E size trends UP

- **Non-CA /Inorganic/Semi-Inorganic Resist**
  
  Developer: Aqueous, Solvent(s), Alcohols/Blends
  
  Patterning can be + or – tone depending on resist

- **Under Layer**
  
  - Emphasis on bi-layer {SSQ (silsesquioxane) resist on organic hard mask}/ tri-layer (SSQ resist/Spin on Glass)/ on organic hard mask materials
  
  - Inorganic resists might be patterned directly as hard mask

*DSA*

  Extensions from 193nm or new concepts applicable to EUV

- **Top Coat**
  
  Improve E size; Reduce LWR; Abate outgassing impacts to patterning?

All material options are on the table / under evaluation; Esize improvements needed
1. PAG generates Acid Catalyst

CHEMICALLY AMPLIFIED RESISTS (CARS)

2. Catalytic Deprotection
WASH w/ Aqueous Base Developer

PAG

PAG

PAG
Resolution-LWR-sensitivity trade-off

\[ \text{LWR} = \sqrt{2} \cdot \text{LER} \]

As local variation of the line width and the distance between lines is linked to higher failure rate for the transistor and, thus, poorer device functionality, it is of the foremost importance to improve the LER performances.

The present sub nanometer technology demands novel EUV resist materials that are directly sensitive to radiation even without using the concept of chemical amplification (CARs).

Challenges in chemical amplified (CARs) resist materials:

- Acid diffusion
- Sensitivity
- Post exposure instability
- Line width roughness (LWR)
- Line edge roughness (LER <1.5 nm) etc.
PAG (Gonsalves et al.*) bound methacrylate resin has been developed by DOW for EUVL because of their following advantages:

- The use of acrylate monomers allows a plethora of chemistry options for dialing in properties, such as developer selectivity, etch resistance, low outgassing, and secondary electron yield.

- The attachment of the PAG anion to the resist polymer affords a very low acid blur, necessary for the high resolution required.

- The use of chemical amplification is necessary to increase resist sensitivity.

Gonsalves PAG patents US 8685616,7833690,7776505,7008749
Process Flow Layout of Resists for Next Generation Lithography

Synthesis of Resists
- Synthesis of Monomers
- Polymerizations

Characterization
- NMR, IR, GPC, TGA, DSC, and XPS
- Thin Film Formation

EBL Exposure
- Spin coat (thickness <40 nm)
- Pre Bake
- Sub 20 nm L/S patterns
- Post Bake
- TMAH Development

Processing the Resist Selected for Optimization

Data Analysis
- HRSEM Imaging
- AFM-Measurement

Photodynamics UFRGS

EUVL for sub-20 nm (L/S) patterns

Data Analysis

Synthesis of Resists

Characterization

EBL Exposure
1. No PAG is Required

**Non-CHEMICALLY AMPLIFIED RESISTS (n-CARS)**
WASH w/ Aqueous Base Developer
Photoresists with sulfonium trflate group

- Sulfonate triflate groups
  - Highly Sensitive to UV Photons
  - Upon irradiation, hydrophilic sulfonium triflates convert to hydrophobic sulfide units

- Monomer
  - Sulfonium functionality one end and polymerizable MMA (methylmethacrylate) other end

Gonsalves et al., *J. Mater. Chem. C.*, 2014, 2118-2122
AIBN

MAPDST Homopolymer

\[
\begin{align*}
\text{H}_2\text{C} &= \text{C} \\
\text{CH}_3
\end{align*}
\]

\[
\begin{array}{ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccs

NRT Curve

![Graph showing NRT Curve for MAPDST-Homopolymer and MAPDST-MMA Copolymer.
Sensitivity = 5.25 μC/cm² (γ) = 3.6
Sensitivity = 2.06 μC/cm² (γ) = 1.8

EBL Evaluation

<table>
<thead>
<tr>
<th>Resist</th>
<th>20 nm Isolated lines pattern at dose 40 μC/cm²</th>
<th>20 nm with L/S lines patterns 40 μC/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAPDST-Homopolymer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAPDST-MMA Copolymer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16 nm lines with L/S patterns

Process Optimization

- Thin film formation (Photoresist spin coating)
- Pre-bake conditions
- Post exposure bake
- Development conditions
- Dose Sensitivity etc

Centre of Excellence in Nanoelectronics (CEN) facilities at IIT Bombay, India
Conclusions

- The CH₃SCH₃ group sensitive to the irradiation.
- Irradiation at 103.5 eV produced fragments (SO₂, SO and CF₃).
- XPS, NEXAFS and QMS techniques confirms that low stability of the triflate group.
- We hypothesize that the neutral sulfide Ar-S-CH₃ is formed during the post exposure bake and development processes.

High-resolution XPS spectra of the C 1s (left) and S 2p (right) envelope of the MAPDST homo-polymer films before irradiation and after 1 and 5 min of SR irradiation at 103.5 eV.

This study was performed at the Brazilian Synchrotron Light Source (LNLS) Campinas-Prof. Weibel UFRGS
EUV Exposure of MAPDST Homopolymer Resist @ Berkeley MET Lab

EUV Exposure Details

Substrate: 4 Inch P-Type Silicon
Under Layer: HMDS
Resist: MAPDST-homopolymer (Negative tone Resist)
Thickness: 45.68 nm
PEB/T: 90/90 °C/Seconds
PAB/T: 100/90 °C/Seconds
E₀ Dose: 30mJ cm⁻²
Mask: IMO228775
Field: R4C3 (LBNL low-flare bright-field)
Developer: TMAH-1/18/10DIW

SEM Images of MAPDST Homopolymer Resist EUV Exposed @ Berkeley MET USA Lab

Exposure dose 113.7 mJ/cm²

a=25 nm L/S lines patterns
b=20 nm L/S lines patterns

**Figure:** complex nanofeatures of poly-MAPDST: a) 100 nm dots; b) 50 and 60 nm dot; c) star elbow connections; d-e) nano dots; f) nano-boats/waves/line-elbows; g) nano-ring; h-i) line features
Figure: Complex nanofeatures of poly-MAPDST: a) 100 nm dots-2D view; b) 100 nm dots-3D View; c) 50 nm dots 3-D view; d) 100 nm star-elbow connections.
LER/LWR Calculation of MAPDST Copolymer Resist EUV Exposed @ Berkeley MET Lab

**MAPDST-Homopolymer**

<table>
<thead>
<tr>
<th>Feature (nm)</th>
<th>LER (nm)</th>
<th>LWR (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 nm</td>
<td>1.6±0.2</td>
<td>2.1±0.3</td>
</tr>
<tr>
<td>25 nm</td>
<td>1.8±0.4</td>
<td>2.3±0.1</td>
</tr>
<tr>
<td>20 nm</td>
<td>2.0±0.3</td>
<td>2.8±0.1</td>
</tr>
</tbody>
</table>

**Achievement:**
LER/LWR values meet the ITRS requirements for 20 nm Node
Incorporation of high EUV absorb SbF₆ in the Poly-MAPDST structures

- Antimony has high EUV optical density (8-10)
- Hexafluoroantimonate (sensitivity enhancer).
- Sensitivity for 20 nm (L/2S) features is 24.5 mJ/cm². Roughly four times more sensitive than Poly-MAPDST.
- Collapse free nano patterns/complex features have been achieved.
- Improved nano-mechanical properties (Modulus and adhesion).

MAPDSA-MAPDST hybrid copolymer

Gonsalves et al., Indian Patent appl. 2016-11022219
Optical Density of the Elements
EUV Lithography for MAPDSA–MAPDST Copolymer resist

EUV exposure details

Substrate: 4 inch p-type silicon
Costing solvent: 3 wt % resist in acetonitrile
Thickness: 45 nm
prebake: 60 ºC/ 60 sec
Post bake: 60 ºC/ 60 sec
E₀ Dose: 11 mJ cm²
Sensitivity: 24.5 mJ/cm²
Mask: IMO228775
Field: R4C3 (LBNL low-flare bright-field)
Developer: TMAH /12 Sec/DIW/10 Sec

MAPDSA-MAPDST (2.15:97.85)

Mw =~8,441 g/mol

Gonsalves et al, Indian Patent application. 2016-11022219
FE-SEM images of various nano-line features obtained from MAPDSA-MAPDST resist (dose: 33 mJ/cm²)

Fig a) High resolution 20-90 nm lines with L/5S characteristics; (b) Higher magnification 20-40 nm lines with L/5S.
HR-AFM images of complex nano-features and 20 nm L/5S-L/2S features obtained from the MAPDSA-MAPDST resist (Dose: 24.5 mJ/cm²)

Fig a) line-elbow connection; (b) nano-dots; (c) nano-rings; (d) star-elbow features; (e) 20 nm line features with lines with L/5S-L/2S characteristics.

Gonsalves et al., Indian Patent application, 2016-11022219
Nano-mechanical properties measurements

Due to incorporation of SbF₆ content in poly-MAPDST resist structures, enhanced nano-mechanical properties (modulus and adhesion) were observed.

Table 1. The DMT modulus (GPa) and adhesion (nN) values for 20, 22 and 28 line features of 1.5% and 2.15% resists with different line/space characteristics in the range L/2S-L/5S.

<table>
<thead>
<tr>
<th>Feature Size</th>
<th></th>
<th>(L/5S)</th>
<th>(L/4S)</th>
<th>(L/3S)</th>
<th>(L/2S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SbF₆</td>
<td></td>
<td>DMT Modulus</td>
<td>Adhesion</td>
<td>DMT Modulus</td>
<td>Adhesion</td>
</tr>
<tr>
<td>20 nm 1.5%</td>
<td></td>
<td>3.6±0.25</td>
<td>30±3</td>
<td>3.4±0.14</td>
<td>31±4</td>
</tr>
<tr>
<td>2.15%</td>
<td></td>
<td>5.2±0.12</td>
<td>38±2</td>
<td>5.1±0.18</td>
<td>36±2</td>
</tr>
<tr>
<td>22nm 1.5%</td>
<td></td>
<td>3.9±0.30</td>
<td>30±5</td>
<td>3.75±0.25</td>
<td>30±3</td>
</tr>
<tr>
<td>2.15%</td>
<td></td>
<td>5.1±0.11</td>
<td>40±3</td>
<td>5±0.19</td>
<td>41±6</td>
</tr>
<tr>
<td>28 nm 1.5%</td>
<td></td>
<td>4.2±0.13</td>
<td>35±4</td>
<td>4±0.11</td>
<td>38±3</td>
</tr>
<tr>
<td>2.15%</td>
<td></td>
<td>5.0±0.10</td>
<td>50±2.5</td>
<td>5.11±0.15</td>
<td>51±4</td>
</tr>
</tbody>
</table>

Interestingly, even at lower feature sizes such as 20, 22 and 28, the modulus and adhesions values of the 2.15 % resist patterns are higher as compared to those of the 1.5 % resist. All these results confirm a better performance of the 2.15% resist in terms of the nano-mechanical properties of its high resolution patterns as compared to those of the 1.5% resist patterns.

Photodynamics: for MAPDSTA–MAPDST Copolymer resist (Prof Weibel UFRGS)

- An initial photodynamic study was carried out using SR as an excitation source as well as high surface sensitive analytical tools (NEXAFS and XPS spectroscopy). The investigation clearly showed a fast decomposition rate of the radiation sensitive sulfonium triflate followed with important changes in the ester group. Sulfur L-NEXAFS spectra of the 2.15 % MAPDSA-MAPDST copolymer resist thin films showed that irradiation at 103.5 eV led to a general decrease in signals, except one signal at about 164.8 eV. This transition was assigned to a CH$_3$-S- group bonded to the phenyl ring. This result confirmed the polarity switching mechanism from hydrophilic sulfonium triflates to hydrophobic aromatic sulfides due to EUV radiation especially on post baking.
- The detailed HR-XPS results on the energy regions of F 1s and O 1s indicated the potential important role of the inorganic SbF$_6$ moiety during irradiation. The results obtained indicate that the inorganic SbF$_6$ group may have an effect on the sensitivity as observed from the exposure doses of the 2.15% MAPDSA-MAPDST (33mJ/cm$^2$) copolymer versus the pure MAPDST homopolymer (113 mJ/cm$^2$). The inorganic SbF6 is hypothesized as contributing to the enhanced sensitivity due to the higher OD of the Sb.
- Further analysis is in progress to be reported shortly by the Weibel group UFRGS Brazil.
He-ion active Poly-MAPDSA-MAPDST hybrid resist-sub-20 nm patterning (NTU Taiwan)

<table>
<thead>
<tr>
<th>DOSE (μC/cm²)</th>
<th>Helium ion microscope (HIM) images</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 (μC/cm²)</td>
<td><img src="image1" alt="Image of patterned lines at 110 μC/cm²" /></td>
</tr>
<tr>
<td>120 (μC/cm²)</td>
<td><img src="image2" alt="Image of patterned lines at 120 μC/cm²" /></td>
</tr>
</tbody>
</table>

**FIG**: He-ion exposed 20 nm (L/4S) line patterns of 2.15%-MAPDSA-MAPDST resist (100Xmagnification): a) At a dose 110 μC/cm², b) At a dose 120 μC/cm².

**FIG**: AFM topography of 20 nm (L/4S) line features of the 2.15%-MAPDSA-MAPDST resist at the dose 110 μC/cm².

Gonsalves et al., AIP Adv., 2017, 7, 085314
He-ion active Poly-MAPDSA-MAPDST hybrid resist-sub-20 nm patterning

**FIG:** Cross sectional view of 20 nm (L/4S) features at a dose 110 μC/cm² (Magnification: 300X), b) Thickness measurements of 20 nm line features by tilting the line patterns at 45° angle (Magnification: 200 X, Dose: 110 μC/cm²).

K. E. Gonsalves, *AIP Advances*
MAPDST-ADSM hybrid co-polymer resist for higher resolution e-beam/Helium ion beam lithography applications

![Chemical structure of ADSM-MAPDST (10:90 feed ratio) hybrid co-polymer]

**Lithography parameters**

- Substrate: 2 inch p-type silicon
- Solvent: 2.5 wt % resist in acetonitrile
- Thickness: 30 nm
- Prebake: 80 ºC/ 60 sec
- Post bake: 60 ºC/ 60sec
- Developer: TMAH /20 Sec/DIW/10 Sec

- Weight average molecular weight = 8221 g/mol⁻¹; Poly Disparity Index = 1.51
- Calculated x and y composition from NMR analysis is : 3.8 : 96.2
MAPDST-Tin hybrid co-polymer resist for higher resolution e-beam lithography

Resolution of poly-MAPDST was increased by incorporation of hybrid inorganic tin monomer.

After e-beam exposure, the Sn-C bonds and sulfonium trilfates of the polymer undergoes photo cleavage and leads to the structural conversion.

The designed resists are able to pattern 10 nm isolated lines under e-beam conditions at the dose 700 uC/cm²
Helium Ion (He⁺) Active Novel Hybrid n-CAR MAPDST-ADSM copolymer resist for Sub-10 nm Technology Node

Fig. (a) Chemical structure of MAPDST-ADSM copolymer resist

Fig. (b) He⁺ studies for dose estimation on developed hybrid MAPDST-ADSM copolymer resist

Fig. (c) & (d) He-ion exposed 10 nm line patterns on MAPDST-ADSM copolymer resist at the dose 50.6 pC/cm²
Molecular resists for lower nodes
Global photoresists market size

3.2 Billion Dollars

- 2015
- 2016
- 2017
- 2018
- 2019
- 5.0 Billion Dollars

It’s time to meet National demand by developing indigenous resists.

But, no indigenous resists technology exists particularly for 180 or beyond nodes.

Current Photoresists Market Size to Meet Indian Requirements:
~ Rs. 1 Crore/year

Projected Photoresists Market Size to Meet Indian Requirements: ~ Rs. 300 Crores(by 2020)/year

SCL
BEL
SITAR
GATEK

R&D in Academic Institutions

DUV Resists (248 nm)
i-Line Resists (365 nm)
Innovative resist formulation with intrinsic photoacid generation capability

Proof of concept for DUV and E-beam resists developed @ IIT Mandi.

Incorporation of photoacid generator (PAG) into resist backbone to control acid diffusion, and thus to improve LER/LWR of developed patterns.

Very recently, we have developed few chemically amplified resists which are sensitive to DUV photons as well as e-beam radiation. Using these resists we have successfully patterned 170 nm L/S patterns with low LER.

DUV Resists (few examples):
Patterns generated by E-beam lithography

150 nm lines with 300 nm space (L/2S)

170 nm lines with 170 nm space (L/S)
i-Line resists for Indian semiconductor industries

i-Line (365 nm) resists are generally a combination of Novalac resin and photoacid compound (PAC). Novalac resins are prepared by the condensation of o-/m-/p-cresols and formaldehyde, and the PACs are DNQ derivative.
Commercialization: Technology Transfer and Bulk Production

- Reproducibility of R&D Sample in Industry
  - Preparation of resist material in multi-gram scale (<100 gm)
  - Process development in Kilo gram scale (100-1000 gm)
  - Bulk production of resist material
    - Resist Formulation
      - Packaging & Storage
      - Dispatch to the Customer

- Characterization
  - Process development in Kilo gram scale (100-1000 gm)
    - Bulk production of resist material
      - Resist Formulation
        - Packaging & Storage
        - Dispatch to the Customer

- Performance determining parameters:
  - Resolution (line and space)
  - Sensitivity
  - Etch stability
  - Depth of focus (line and space)
  - Depth of focus
  - Dense/Isolated
  - Exposure latitude
  - Line edge roughness (LER)
  - Thermal stability
  - Post-exposure delay stability
  - CD Stability
  - Shelf life
  - Anti reflective coating agent
    - PAG bound base resists
    - Dissolution inhibitors
    - Solvent
    - Amines as acid scavanger
    - Surfactant
Conclusion

- Polymeric resists for 20 nm node or beyond technology with low LER/LWR
- Molecular resists for 16 nm or beyond node
- Enhancing sensitivity by incorporating inorganic materials with high EUV absorption cross section
- DUV and i-line resists for Indian semiconductor industries
- Bulk scale production, formulation and commercialization of indigenous resists to meet national requirements
Acknowledgments

Co-PIs IIT Mandi
Dr. Subrata Ghosh (organic chem)
Dr. Pradeep Parameswaren (inorganic)
Dr. Satinder Sharma (electrical engg)

Postdoctoral Researchers
Dr. Jyoti Shankar Borah
Dr. Mingxing Wang
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Mr. Pravind Yadav
Ms. Reetu Yadav

Facilities

- Indian Nanoelectronics Users Program (INUP), IIT Bombay for e-beam facility
- LBNL Berkeley USA, and IMEC Belgium for EUV exposures

Collaborators

- Prof. Daniel E. Weibel
  Chemical Institutes, UFRGS, Porto Alegre, Brazil
- Prof. Nikola Batina
  UAM Mexico
- Prof Rubem Sommers
  CBPF Rio de Janeiro
- Prof. Tsai, NTU
  Taiwan

Funding agencies

- The Department of Science and Technology (DST) & Semiconductor Lab/ISRO MHRD (UAY scheme), India
- Intel Corp USA /SRC USA
- DOW Corp USA