An Overview of EUVL Related R&D in Taiwan
Investigations on extreme ultraviolet lithography –
from beamline construction, masks, materials,
processes, to reliability of nano devicesa

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EUVL: Three-Year Project

Budgets

- **2008/08 ~ 2011/07**
  - 1st year: ~ US$191 K
  - 2nd year: ~ US$191 K
  - 3rd year: ~ US$90 K
    (overhead excluded)

- **Currently available EUV beamline @NSSRC**
  - 08A1 – LSGM
  - 21B2 – U9-CGM

- **Hardware construction**
  - Resist outgassing chamber (**QMS**)
  - Metrology tool (**EUV reflectometer**)
  - Resist imaging (**Interferometric exposure platform**)

- **Ten researchers, twelve graduate students involved.**
EUVL: Three-Year Project

Research Topics

Group (1) Fundamentals

- Resist outgassing: optics contamination
- EUV photochemistry

Group (2) Optics & Metrology

- EUV reflectometer: $n, k, T$ measurements
- EUV interferometric Litho.: resist imaging
- EUV simulation: zone plate for mask inspection, EUV proximity correction, photon scattering, multilayer simulation

Group (3) EUVL Applications

- EUV detector
- EUV radiation damage and ARC
- Mix & match lithography
- EUVL patterning for nano-optical devices
Current Results and Status - Outgassing Chamber

Designed and constructed an evaluation chamber with QMS for the resist outgassing study

- An dedicated vacuum system for the evaluation of resist outgassing will be completed in July, 2010.

10” new chamber to reduce background outgassing

Qualitative, quantitative evaluation of outgassing and exposure kinetics using quadrupole mass spectrometer (QMS)

14” old chamber

TSMC supported turbopump

NSC EUVL and personal, Nissan supported QMS

Delivery date: 2010/07/06
New EUV exposure kinetics successfully explain all experimental observations found in our outgassing works.

\[
\begin{align*}
M_j & \xrightarrow{k_{j,1}} M_j^* \\
M_j^* & \xrightarrow{k_{j,-1}} M_j \\
M_j^* & \xrightarrow{k_{j,2}^+} P_j^+ \\
M_j^* & \xrightarrow{k_{j,2}^{\text{neutral}}} P_j
\end{align*}
\]

\[
\frac{d \ln(\text{Ion intensity})}{d (\text{dose})} = \frac{d \ln([M_j])}{d (\text{dose})} = \frac{(k_{j,1} / \text{photon flux}) k_{j,2}}{(k_{j,-1} + k_{j,2})} = -C_j
\]

- The detail will be given by Prof. Grace H. Ho in the contamination section of this workshop.

Joint development projects on resist outgassing

- Nissan Chemical Industries: Outgassing Evaluation for Nissan EUV Underlayer Materials
- TSMC: Quantitative and Qualitative Evaluation of Outgassing from EUV Photoresists
Current Results and Status - nkt measurement platform

Establish a nkt measurement platform of thin films @EUV

(a) The thin-film reflectivity can be precisely measured and analyzed.

(b) In agreement with the results determined by other facility.

<table>
<thead>
<tr>
<th>MAX. sample size</th>
<th>20 x 20 x 2 mm</th>
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<tbody>
<tr>
<td>Polarization geometry</td>
<td>s only</td>
</tr>
<tr>
<td>Base pressure</td>
<td>2 x 10^-8 torr</td>
</tr>
<tr>
<td>Angle of incidence</td>
<td>1°–85°</td>
</tr>
<tr>
<td>Sample, Rotation θ</td>
<td>360°/0.001°</td>
</tr>
<tr>
<td>Detector, Rotation 2 θ</td>
<td>360°/0.0036°</td>
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• Results from collaboration with Nissan Chemical Ind., Ltd. (Reported in Japan’s 先端技術セミナー2009)
In situ n,k,t measurement

- In-situ n,k,t measurement
- Real-time inspect the changing (photo ablation) of resist thickness under EUV irradiating (the first time ever reported!!)
- the resist thickness changing is very important for lithography quality.

Current Results and Status - Exposure Platform

Exposure Platform with EUV Interferometric Lithography

- Can be used to expose 1D or 2D grating, mimicking line/space, holes patterns.
- Platform to investigate the EUV exposure capability, and to evaluate the EUV resist / material.
- Continuing to shrink the exposed pattern dimension.

Exposure chamber

Light source: 21B2 beamline @ NSRRC

Preliminary 1D exposure result on PMMA: 75nm half-pitch
Current Results and Status - Simulation

EUVL related analysis and simulation

- **EUV Zone Plate Manufacturability Analysis**
  - Fresnel zone plate manufacturability analysis for direct-write lithography by simulating focusing and patterning performance versus fabrication errors
    (Japanese Journal of Applied Physics 49, 06GD08, 2010)

- **EUV Proximity Effect Correction**
  - A fully model-based methodology for simultaneous correction of extreme ultraviolet mask shadowing and proximity effects
    (Journal of Micro/Nanolithography, MEMS, and MOEMS, in revision, 2010)

- **Stochastic EUV Photon Scattering Simulation**
  - Stochastic simulation of photon scattering for EUV mask defect inspection
    (Advanced Lithography 2010 -- Proc. SPIE 7636, 763624, San Jose, California, USA, Feb. 2010)

- **EUV Multilayer Simulation**
  - Using modified transmission line theory to calculate equivalent refractive index of multilayer structures in EUV mask for efficient scattering simulations by finite-difference time-domain method
    (Journal of Micro/Nanolithography, MEMS, and MOEMS, in revision, 2010)
Current Results and Status - **EUV radiation damage**

EUV Exposure Induced Damages on Non-Volatile Memories

- **EUV light source at NSRRC**

- **Device structure**

  - SONOS memory
  - Nano-crystal memory

  - NC memories exhibit much better EUV radiation tolerance than SONOS memories.
  - The EUV lithography could be a potential solution for advanced NC memories.

B.Y. Tsui
Future Perspectives

• Ready & open to all!
  – Outgassing chamber
  – nkt measurement platform

• Next step
  – International and domestic collaboration
    • The collaboration with TSMC & Nissan Chem. Ind., Ltd. is in progress currently.
  – EUV Interferometric exposure platform (in developing)
  – EUVL dedicated beamline
  – Next project