Development of Under Layer material for EUV Lithography

Nissan Chemical Industries, LTD.
Optical Lithography (with g-line, i-line, KrF, ArF)

Reflectivity control is the key factor. BARC material is necessary for Optical Lithography.

EUV Lithography (with 13.5nm)

Because EUV light is absorbed or path the layers, it does not need the reflectivity control. However, UL is used as adhesion and LWR reduction purpose.

NISSAN CHEMICAL INDUSTRIES, LTD. Electronic Materials Research Laboratories.
SEMATECH IEUVI resist TWG, 2011-02-27
RLS trade off

R: Resolution
L: Line-Edge-Roughness
S: Sensitivity

To apply the functional Under-Layer (UL) to minimize the trade off RLS
Requirement for EUV UL material

Requirements for EUV Under-layer

- High adhesion with PR
- Block the contamination from substrate (Barrier film)
- Good performance with thin film (~20nm)
- Good etch performance with fast etch rate or thin FTK.
- No out-gassing
- **resolution enhancement (pattern collapse)**
- **Reduce LWR, LER**
- Enhance Sensitivity

Stack structure:

<table>
<thead>
<tr>
<th>P.R.</th>
<th>Under-layer</th>
<th>Substrate</th>
</tr>
</thead>
</table>

NISSAN CHEMICAL INDUSTRIES, LTD. Electronic Materials Research Laboratories.

SEMATECH IEUVI resist TWG, 2011-02-27
Pattern Collapse
Pattern Collapse

SFET (Small Field Exposure Tool): NA0.30, σ0.7/0.3

Optimized UL had capability for below 30nm HP.

Conv. KrF-BARC (narrow collapse margin)

Optimized UL for EUV-PR

NISSAN CHEMICAL INDUSTRIES, LTD. Electronic Materials Research Laboratories.
SEMATECH IEUVI resist TWG, 2011-02-27
Pattern Collapse

UL could help resist to increase Pattern Collapse window

Introducing High adhesion unit into base Polymer of UL.

EUV-PR resin

PR

NCX (U.L.)

HM-layer

Silicon

High density unit

High polarity unit

NISSAN CHEMICAL INDUSTRIES, LTD. Electronic Materials Research Laboratories.

SEMATECH IEUVI resist TWG, 2011-02-27
Pattern Collapse

The comparison of pattern collapse margin.

Exp: MET, EUV-PR

UL-A (Polar unit)

UL-B (Polar unit)

Achieved ~20nm size Pattern at over dose condition.
Line-Edge-Roughness
NISSAN CHEMICAL INDUSTRIES, LTD.  Electronic Materials Research Laboratories.

SEMATECH IEUVI resist TWG, 2011-02-27
Line-Edge-Roughness

Material Concept for profile control

Top down  X section

Concept-1
High film density (Physically barrier)

Concept-2
Enhancement of Acid generation efficiency at interface between UL and PR.

NISSAN CHEMICAL INDUSTRIES, LTD. Electronic Materials Research Laboratories.
SEMATECH IEUVI resist TWG, 2011-02-27
High Density UL material

SFET (Small Field Exposure Tool): NA0.30, $\sigma 0.7/0.3$

- **Si-Sub./HMDS**
- **Acrylate**
- **High-density**

### HP 45
- Taper/Footing profile

### HP 35
- Taper/Footing profile

### HP 32
- Vertical profile


NISSAN CHEMICAL INDUSTRIES, LTD. Electronic Materials Research Laboratories.

SEMATECH IEUVI resist TWG, 2011-02-27
Photo-sensitivity

Keep the performance of Pattern Collapse & LER, but enhance the photo-sensitivity of EUV resist
Sensitivity

Acid Generation Mechanism

RH : Resin
MX : PAG
RH \dagger: Radical cation of resin
R • : Radical of resin
RH(H) +: Protonated resin
M : decomposition of PAG
X - : Counter anion of PAG

prof. Tagawa, Kozawa, et al

NISSAN CHEMICAL INDUSTRIES, LTD.   Electronic Materials Research Laboratories.
SEMATECH IEUVI resist TWG, 2011-02-27
Sensitivity

SFET (Small Field Exposure Tool) : NA0.30, σ 0.7/0.3

12.53mJ/cm²  11.68mJ/cm²
hp 45nm

12.96mJ/cm²  11.98mJ/cm²
hp 35nm

13.21mJ/cm²  12.25mJ/cm²
hp 32nm

Si-Sub. (O.D.=1.7) (w/ HMDS)  UL-H (O.D= 13.3um-1) (w/ Chromophore)

Sensitivity enhanced
~10% by Underlayer

2nd electron concept can enhance photospeed and also make pattern profile More vertical!

NISSAN CHEMICAL INDUSTRIES, LTD.  Electronic Materials Research Laboratories.
SEMATECH IEUVI resist TWG, 2011-02-27
Type B resin used UL can improve sensitivity, and pattern space area is more clear than type A resin from top view.

⇒ Type B resin generated more electron by EUV.

UL can control PR sensitivity and litho profile by control 2nd electron gen.
Conclusion

1. The key parameter for EUV-UL development are Outgassing control, strong adhesion with PR and LWR control and less LER.

2. The pattern collapse margin was improved by introducing polar unit into base polymer of UL.

3. High density UL could make resist profile more vertical and less LER.

4. The result of acid generation efficiency at UL surface was roughly correlated with actual PR photo-speed. (But need to confirm some other resist platform)