Recent Progress of *Negative-tone Imaging* with EUV exposure

Toru Fujimori, Toru Tsuchihashi and Toshiro Itani

Advanced Resist Research Department
EUVL Infrastructure Development Center, Inc. (EIDEC)

Introduction

Recently, some researchers concern about *the limitation of CAR's performance*, which mean, Resolution, Line width roughness (LWR) and Sensitivity (RLS) trade off.

New chemistry and new resist materials will be strongly required, but CAR materials still has the potential of the performance.

Especially, CAR *negative-tone imaging has high possibility* for next generation.

Agenda

Two topics, today !

1. **CAR extension** *(Chemical Amplified Resist)*

   CAR materials for Negative-tone imaging (NTI)
   (Using Organic Solvent Developer)
   => High Sensitivity and High Resolution !

2. **New materials**

   EIDEC Standard Metal EUV Resist
   => Ultra High Sensitivity !!

Agenda

Two topics, today !

1. **CAR extension** (Chemical Amplified Resist)

   CAR materials for Negative-tone imaging (NTI)

   (Using Organic Solvent Developer)

   => High Sensitivity and High Resolution !

2. **New materials**

   EIDEC Standard Metal EUV Resist

   => Ultra High Sensitivity !!

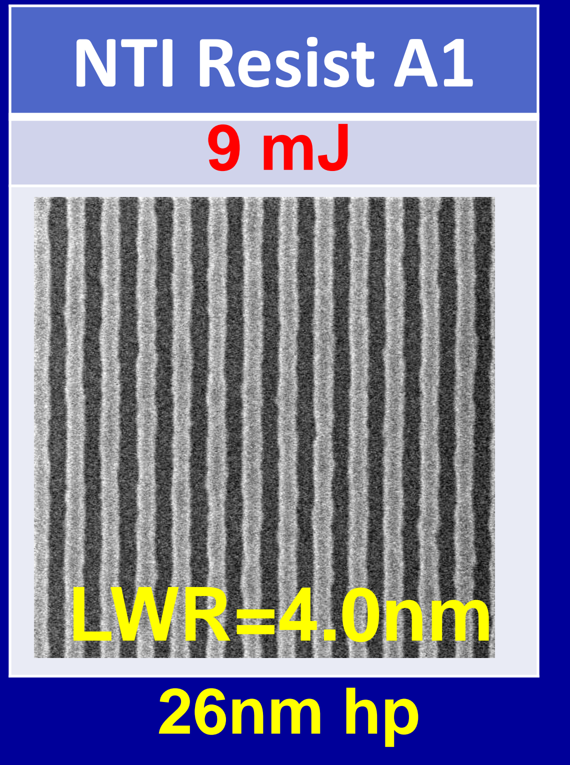
Sounds boring ?!

Keep continue to study CAR ?!

(Chemical Amplified Resist)

See this picture. *Still boring ???*
Looks quite good, right ?!

CAR Negative-tone Imaging



NTI Resist A2

13 mJ

LWR=3.8nm

22nm hp

Exposed with NXE 3100 (NA=0.25)

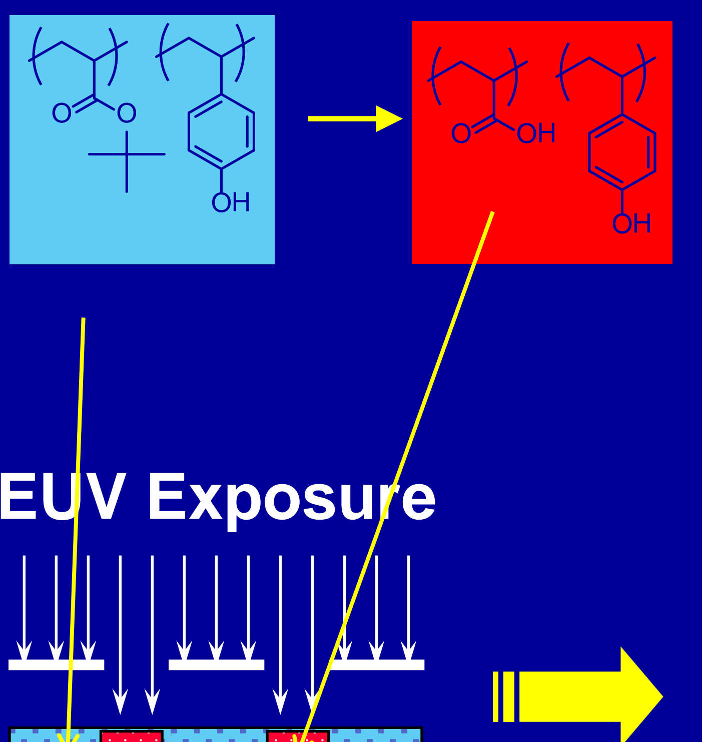
T. Fujimori et.al., 2014 International symposium on Extreme Ultraviolet Lithography

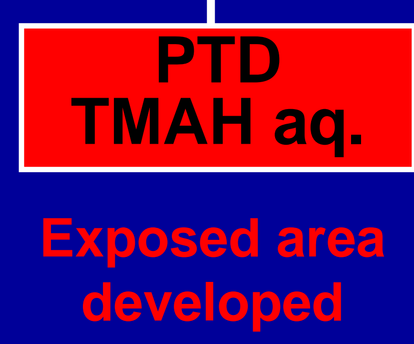
NTI process overview

NTI (Negative-tone Imaging) = Using Organic Solvent developer

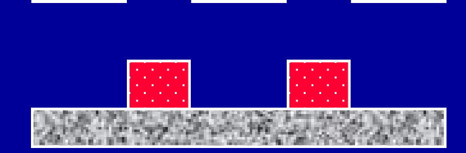
Process flow

Coat & exp. ➡ Bake (Reaction) ➡ Development





Non-exposed area developed



1. CAR extension - Why CAR negative-tone imaging ? -

CAR Negative-tone imaging (NTI, using organic solvent based developer) provided low swelling and smooth dissolving behavior.

CAR Negative-tone imaging with EUV exposure (EUV-NTI) has huge advantages for the performance, especially for improving LWR, which will be expected to resolve RLS trade off.

Also, outgas study of CAR Negative-tone imaging materials already have been studying for a long time.

1. CAR extension *- Development behavior PTD vs NTI -*

Development behavior

By using in situ High Speed-AFM

Development Time
0 sec.

Positive-tone

Negative-tone

No swelling
Dissolving

Swelling

Dissolving

Negative-tone: No swelling, Dissolving smoothly

T. Fujimori et.al., International Symposium on Semiconductor Manufacturing 2014

1. CAR extension *- Typical example of LWR advantages -*

	Positive-Tone	Negative-Tone
Resolution	45 nm hp	45 nm hp
LWR	4.8 nm	**3.0 nm**
Sensitivity	14 mJ / cm^2	14 mJ / cm^2
L / S (Line / Space) 1:1		

Exposed with EUV light on SFET (NA=0.30)

T. Fujimori et.al., 2013 International symposium on Extreme Ultraviolet Lithography

1. CAR extension - Resolution performance on CAR EUV-NTI -

hp size (nm)	13 mJ	18 mJ	33 mJ
24 nm hp	LWR=3.9nm	LWR=3.9nm	LWR=3.0nm
22 nm hp	LWR=3.8nm	LWR=3.7nm	LWR=3.8nm

Exposed with EUV light on NXE3100 (NA=0.25)

1. CAR extension *- Resolution capability of CAR EUV-NTI -*

Resolution capability by using EB lithography tool

20 nm **17.5 nm** **16 nm** **15 nm**

14 nm **12.5 nm**

14nm line was resolved !

CAR NTI => High potential.

Exposed with EB-lithography tool (Vacc = 125 keV) at NIMS

Agenda

Two topics, today !

1. CAR extension (Chemical Amplified Resist)

CAR materials for Negative-tone imaging (NTI)
(Using Organic Solvent Developer)
=> High Sensitivity and High Resolution !

2. New materials

EIDEC Standard Metal EUV Resist
=> Ultra High Sensitivity !!

2. EIDEC Standard Metal EUV Resist (ESMR)

[Background]

Negative-tone imaging (NTI, using organic solvent based developer) provided low swelling and smooth dissolving behavior.

Organic solvent based developer is very useful for organic materials, inorganic materials and organic/inorganic hybrid materials, because of a wide variety of solubility.

New chemistry and new resist materials will be strongly required.

2. EIDEC Standard Metal EUV Resist (ESMR)

[Background]

Chemical Amplified Resist (CAR) using positive-tone development (PTD) is still one of the strongest candidates for EUV lithography realization for sub-10 nm generation.

However, some researchers have reported *concerns* on the *limitations in the performance of PTD-CAR*.

Consequently, there is critical need for new chemistry and development of new resist materials, like 'non-CAR' materials.

The developments of new resist materials have been just started to study for improvement of sensitivity using *'metal containing non-CAR materials'*.

2. EIDEC Standard Metal EUV Resist (ESMR)

EIDEC has just started to study
EIDEC original metal containing resists

Keyword

1) With organic solvent development
2) Metal containing
   organic/inorganic hybrid materials
3) Study of process conditions
   Under layer, Bake conditions,
   Development conditions, and so on.

Just show preliminary results
with EB lithography tool

Summary

1. CAR extension (Chemical Amplified Resist)

=> CAR negative-tone imaging has high possibility for next generation.

High Sensitivity and High Resolution !

2. New materials

EIDEC Standard Metal EUV Resist (ESMR)

=> achieved Ultra High Sensitivity

Very high potential in the form of extremely high sensitivity with high resolution

Acknowledgement

This work is supported by
New Energy and Industrial Technology Development Organization (NEDO).

A part of this study was supported by
NIMS Nanofabrication Platform in Nanotechnology Platform Project sponsored by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

The authors would like to thank

- EIDEC research members
- EIDEC member companies, especially, FUJIFILM Corporation

Thank you for your kind attention.