NON-LINEARITY OF THE DISSOLUTION IN ADVANCED EUV PHOTORESIST

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INTRODUCTION

WHY IS THE DEVELOPMENT STEP SO IMPORTANT?

- Development is the step that reveals CD and LWR.
- In a pattern, there is a continuous change of solubility ranging from non-exposed to exposed polymer.
- At the edge of the pattern, small change in the concentration of protecting groups leads to a big change in solubility.
- Spatial fluctuation in the dissolution rate generates LER.

DISSOLUTION RATE MONITOR (DRM) TOOL

- Tool developed at imec in collaboration with TEL
- Resist coated on SiOx wafer
- 5 fields at different exposure dose
- Continuous measurement when in contact with controlled flow of developer

Apply developer flow in vertical mode

Good flow front
EXPERIMENTAL DETERMINATION OF DISSOLUTION RATE

Reflectometer records interference pattern every 10ms

Peaks of interference are translated into film thickness through time

A fitted linear slope determines the development rate for each exposure dose
RESULTS – NEGATIVE TONE DEVELOPMENT
VALIDATION OF THE SET-UP
WITH 193nm RESIST EXPOSED ON NXE1950

ArF – NTD resist
Dissolution curve

Contrast curve for ArF NTD resist

Set-up is validated
EUV RESIST - NEGATIVE TONE DEVELOPMENT

NON LINEARITY IS OBSERVED

We observe a progressive decrease of the dissolution rate with time (or resist depth)

Could it be caused by the resist thickness difference between 80nm ArF resist and 40nm EUV resist?
RESIST THICKNESS IMPACT

The top 15nm of resist dissolves similarly in all cases.

Non linearity of EUV resist dissolution ➔ Thinner resist has higher dissolution rate (but lower etch, abs,....)

Non linearity is linked to the EUV polymer formulation, and further research is needed to explain it.
RESULTS - EUV POSITIVE TONE DEVELOPMENT
POSITIVE TONE DEVELOPMENT

DISSOLUTION CURVE FOR DIFFERENT POLYMER TYPE

EUV PTD - Resist A

Polymer backbone A
Linear dissolution

EUV PTD – Resist B

Polymer backbone B – non linear:
Delay followed by a swelling then a quick dissolution

How does this influence lithographic performances?

Steeper contrast leads to better litho performances
RESULTS - EUV METAL OXIDE RESIST
EUV METAL OXIDE RESIST - NTD
LINEAR BEHAVIOUR

Dissolution curve for a metal oxide resist

Dissolution is relatively linear.

Development rate slows down near the substrate interface

Would this be due to interaction between Si oxide substrate and the resist?

Coated FT. 24nm
We tested MO resist on 3 substrates:
- Silicon oxide, thermal (SiOx)
- Organic underlayer (UL)
- Spin-on Carbon (SOC)

At the switching dose, we noticed a slight sensitivity shift (UL gives higher sensitivity than SiOx) and variation between substrates at the resist interface.

Impact is lower at lower exposure dose.
PLATFORM COMPARISON
We observe a trend between dissolution characteristics (Rmin, Rmax and contrast) and lithographic performances. More data is needed for quantified correlation.
CONCLUSION

- Dissolution Rate Monitor (DRM) is a relevant tool to capture variation in dissolution behaviour for different resist chemistry.

- For the resist tested, the tool permitted to identify:
  - Impact of thickness: non linearity increase for thicker EUV resist. Thinner NTD resist shows higher Rmax.
  - EUV resists show important difference between polymer families.
  - Substrate has a mild influence on the MO resist dissolution.

- We observed a link between lithographic performances and dissolution characteristics, but more data is needed to confirm a correlation.

- Different dissolution behaviour can be measured and taken into account into resist design for resist manufacturer (swelling,...).

- At imec, we hope that building more knowledge on resist dissolution can help to design low LWR EUV resist.
THANK YOU

I WOULD LIKE TO THANK, FOR THEIR FRUITFUL COLLABORATION:

- Stefan De Gendt [promotor] (Imec/KU Leuven)
- Danilo De Simone [supervisor] (Imec)
- Ivan Pollentier (Imec)
- Geert Vandenberghe (Imec)
- Grozdan Grozev (Fujifilm)
- Veerle Van Driessche (Fujifilm)
- Tsubaki Hideaki (Fujifilm)
- Kenta Suzuki (TOK)
- Tomohiro Oikawa (TOK)
- Takehito Seo (TOK)
- Satoshi Dei (JSR)
- Masafumi Hori (JSR)
- Michael Greer (Inpria)
- Mike Kocsis (Inpria)
- Michael Carcasi (TEL)
- Carlos Fonseca (TEL)
Questions?

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LINEARIZATION

HOW DID I CALCULATE DEVELOPMENT RATE FOR NON LINEAR DISSOLUTION?

In order to be able to represent in a contrast curve, DR is needed, therefore I have chosen, arbitrary, to calculate DR like this:

Ref. NTD – Relative thickness evolution

Ref. PTD – Relative thickness evolution

Rate at half thickness if below switching dose

Mean rate (total thickness/total time) for doses around switching dose