

7th International EUV Initiative Resist Technical Working Group

November 11, 2005

San Diego, California

Report to the IEVUI

Kim Dean, SEMATECH
Serge Tedesco, CEA/LETI

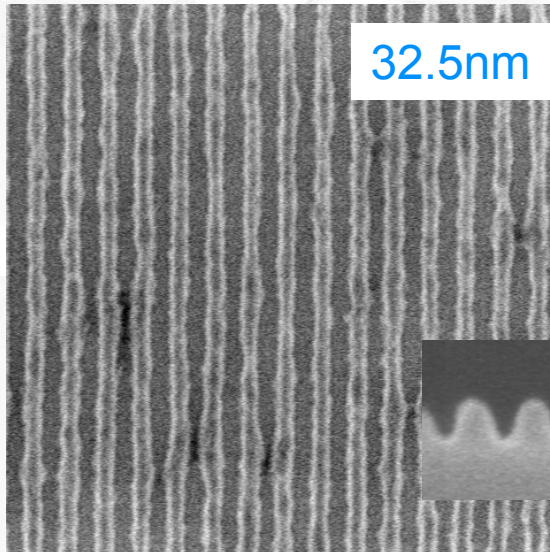


Accelerating the next technology revolution.

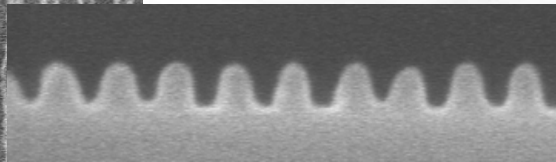
Goals and Objectives of Resist TWG

- Remove resist from #1 top critical issue!

EUV-25: $E_{\text{size}} \sim 7.5\text{mJ/cm}^2$



MEDEA results using
PSI Zurich interferometer



IEUVI Resist TWG Meeting November 10, 2005 San Diego, California

8:00	Breakfast	All
8:30	Welcome and Introductions Review of Charter and Goals for Resist TWG Review of Outgassing Round Robin Plans	<u>Kim Dean</u> , SEMATECH
8:45	Outgassing Round Robin Results (~15 min each)	SEMATECH/Dean, <u>Intel/Yeuh</u> , U.Hyogo/Watanabe, BOC Edwards/Keen, ASET/Oizumi, <u>Trieste/Dean</u> , <u>CEA/LETI/Vannuffel</u>
10:00	Discussion of Results	All
10:30	Break	
10:45	Resist Specification Roadmap; Review, Edit	<u>Kim Dean</u>
10:50	Update Japan/ASET	Hiroaki Oizumi, ASET
11:05	Update from More Moore	Serge Tedesco, CEA/LETI
11:20	Update from MEADEA/EXCITE	<u>Mieke Goethals</u> , IMEC
11:30	Update from US/SEMATECH	<u>Kim Dean</u>
11:40	New Areas for TWG Cooperation	Serge Tedesco
11:55	Wrap up, Plans for Next Meeting	Kim Dean
12:00	Lunch	All
13:00	Adjourn	

Top Four Issues for TWG Cooperation

- 1. What is a safe level of resist outgassing?**
 - Work together to determine specifications, include tool and resist suppliers
- 2. How is the resolution limits of chemically amplified resists understood?**
 - Provide enough tool time for cycles of learning
- 3. How can photospeed, LWR, shot noise, resolution be optimized?**
 - Provide enough tool time for cycles of learning
- 4. What are new ways for the TWG to cooperate?**



Outgassing Round Robin Background

- The IEUVI resist technical working group (TWG) has initiated an EUV resist round robin
- The goal is to compare results and develop standard methodology for resist outgassing
- Model resist was formulated by MIT LL (Ted Fedynyshyn) and shipped to researchers by SEMATECH

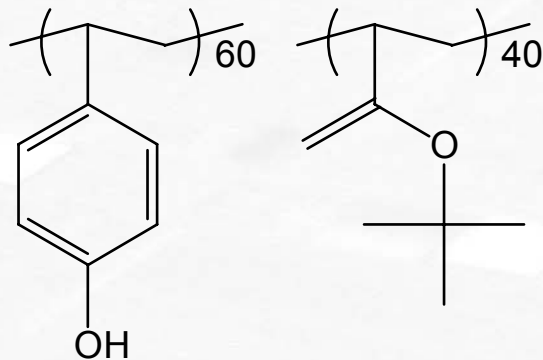
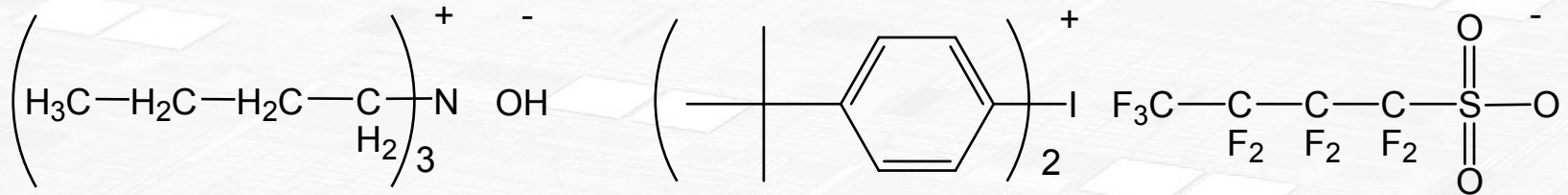


Resist Outgassing Researchers (7)

- **Intel**
 - Synchrotron source, desorption tubes, ongoing
- **Trieste**
 - Synchrotron source, mass spec, ongoing
- **SEMATECH**
 - Synchrotron source, desorption tubes, ongoing
- **ASET**
 - Synchrotron source, mass spec, ready mid-2005
- **CEA/LET**
 - Standalone source, mass spec, controlled contamination studies, ready mid-2005
- **BOC Edwards**
 - Standalone source (borrowed), mass spec
- **University of Hyogo**
 - Synchrotron source, mass spec, ongoing



Round Robin Resist Structure LUVR-99246*



Polymer:	0.940
PAG:	0.060
Base:	0.010
Calculated EUV base 10 absorbance =	$2.01 \mu\text{m}^{-1}$

*Resist provided by MIT LL, Ted Fedynyshyn

SEMATECH Round Robin Results

- Tests carried out at University of Wisconsin using thermal desorption tubes and GC/MS
- Total outgassing = $3.9\text{E}+13$ molecules/cm²
- Outgassing Rate = $2.6\text{E}+12$ molecules/cm²-sec
- Outgassing products:

Peak #	R.T.	Area %	ID
1	4.89	2.09	Isobutane
2	5.09	87.57	1-Propene, 2-methyl-
3	9.52	3.37	Acetone
4	21.95	3.34	Benzene, tert-butyl-
5	32.43	3.64	Methylstyrene

Resist Outgassing Results

- Five groups reported values, the other two will report at February 2006 meeting
- Outgassing rates varied between E+11 and E+13 molecules/cm²-sec, a huge variation in results!
- Different methods were used, group discussed ways to better compare results
- Much discussion of ASML specs and what is really important, hydrocarbons or heteroatoms, low or high molecular weights?

Resist Outgassing Discussion

- In the future, everyone should report
 - Total pressure rise
 - Outgassing rates for the following ranges: 1-30amu, 30-44amu, >44amu
 - Total outgassing rate
- Mass range should include 1-200 amu
- Is power level a problem or not? Preliminary BOC data shows outgassing scales with flux
- Should use 3XEzero for dose for future testing
- Should use negative mass spec for negative ions? Cl-? F-?
- Are F/Cl a problem for optics contamination? ASML's specs are tighter for F/Cl than hydrocarbons.
- BOC results, $5E+13$ rate for 44-200amu
- Coorelate resist loss to outgassing for cheaper screening

Next Steps

- **Results will be compiled and compared**
- **The TWG will develop areas of improvement in outgassing measurement techniques**
- **The TWG will also review outgassing specifications**
- **Ru-capped multilayer samples available for contamination experiments**

Exposure Tool Availability--Update

- **MET at ALS Berkeley:** operations continue into 2006
- **Exitech Intel:** operational; for Intel development
- **HiNA3 ASET:** operational; available, but limited throughput (2 wafers per day)
- **PSI Zurich interferometer:** operational; available for others, pay per shift
- **Exitech Albany:** operational;
 - open to all with established priority
- **ASML alpha tools:** scheduled operational late-2006; tools located at Albany and IMEC



EUV Resist Specification Roadmap (revised)

Specifications	Alpha (2005)		Beta (2007)		Gamma (2009)	
	Spec	Current**	Spec	Comment	Spec	Comment
Resolution 1:1	45nm	35nm/45nm (C/S)	32nm		32nm	
Resolution contacts	55nm	TBD	45nm		40nm	
Resolution Isolated Lines	32nm	30nm/40nm (C/S)	22nm		18nm	
Depth of Focus	200nm	100nm for 35-nm 1:1 200nm for 50-nm 1:1	225nm	Dense and isolated; DOF at 10% exposure latitude	225nm	Dense and isolated; DOF at 10% exposure latitude
Photospeed (mJ/cm ²)	10 mJ/cm ²	21mJ/cm ² E-size @ 50-nm 1:1	7mJ/cm ²	Assuming ~30 wph	5mJ/cm ²	Assuming > 100 wph if 5 mJ/cm ² , 115W intermediate focus
Line Edge Roughness (3 σ)	< 4 nm	~4 nm @ 50-nm 1:1 ~7 nm @ 35-nm 1:1	< 3nm		< 1.4 nm	LWR < 8% etched gate length; gate length = 18 nm
Wall Profile Angle	>85°	80° @ 50-nm 1:1	> 85°	Measure cross-sections	> 85°	Measure cross-sections
Outgassing	4.7E13 molecules/cm ² -sec	1.60E+13	TBD		TBD	
Pattern Collapse	>3	None observed	>3	Aspect ratio 3:1 for all structures	>3	Aspect ratio 3:1 for all structures
Unexposed Film Thickness Loss	< 10%	10nm	< 5%		< 5%	
PEB Sensitivity	< 2.5 nm/deg C	TBD	<1.5 nm/deg C		< 1 nm/deg C	
Delay Stability @ < 1ppb amine	30min	TBD	30 min	a) pre-exposure, b) under vacuum, c) post-exposure	30 min	a) pre-exposure, b) under vacuum, c) post-exposure
Etch Resistance	Similar to novolak	TBD	Similar to novolak		Similar to novolak	

**Measured top down values for Rohm and Haas resist MET-1K.

C/S=cross section **Green** = spec is met, **Orange** = spec is not met

Model for EUV Resist Development Acceleration

- Regions focus on their primary strength
 - Basic resist performance data are shared between regions (use specification table as a template, details to be determined)
 - US provides access to exposure capability
 - AP and EU encourage resist suppliers to expose best candidates on US tools
 - EU provides resist modeling support
- Next to focus on sharing resources/activities in primary strength
 - Regions coordinate efforts in secondary & tertiary strength to avoid duplication of efforts
 - General coordination/exchange about fundamental resist development activities to avoid duplication

Resist: Consortia Core Capabilities

US

Asia/Pacific

Europe

Access to Exposure Capability*

Fundamental Resist Development

Resist Modeling

Fundamental Resist Development

Access to Exposure Capability*

Fundamental Resist Development

Resist Modeling

Resist Modeling

Access to Exposure Capability^

Strength

- ❑ US: Very strong access to exposure capabilities (e.g., SEMATECH)
- ❑ Asia/Pacific: Consortia/institutions with strong working ties to resist companies (e.g., ASET, Hyogo University)
- ❑ Europe: Strong resist modeling expertise (e.g., IMEC)

*) Small field exposure tools, ^) Interferometric imaging



TWG Response to Proposal (I)

- EXCITE suggested the TWG move on to cooperate on 22nm HP development
- TWG suggested we clarify access and cost to exposure tools, define “open access”
- IMEC offered to help LER/acid diffusion modeling if experimental results were provided

TWG Response to Proposal (II)

- Resist suppliers were asked what they need to accelerate EUV resist
 - Need more cycles of learning, example: one supplier has tested ~5000 immersion samples this year, few 10s of EUV samples tested
 - 10X more people working on immersion than EUV
 - Most suppliers have easy access to 193nm immersion photons, not EUV photons
 - Need reliable tools, suppliers already observing tool differences, using time to calibrate tools
 - What is the real insertion point?
 - Motivation lacking, need more customer pull
 - Resist suppliers make money 10 years after technology is inserted



More TWG Comments

- Most felt that, given enough cycles of learning, current platforms will work at 32 nm half pitch
- Not all agreed, some felt a breakthrough is necessary
- All agreed 22nm HP will require new approach
- Two companies expressed an interest in building stand alone tools to measure contrast curves, outgassing, interference lithography (AIXUV and Energetiq)
- ASML Alpha tools are not capable of 32nm imaging



TWG Actions

- Clarify access and costs for SEMATECH MET at Albany
- At next meeting, ask TWG to bring more resist screening data
- At next meeting discuss how TWG can cooperate on 22nm HP development
- Present availability and performance of MET tools (tentative)

Plans for Next TWG Meetings

- **SPIE, February 23, 2006**
 - Finish outgassing round robin
 - Discuss tool access
 - Discuss 22nm HP development

- **Mid-year teleconference 2006**

- **EUVL Symposium October, 2006**
 - **Barcelona, Spain**

Backup Slides





Y monopole enables definitive resist-resolution limit testing

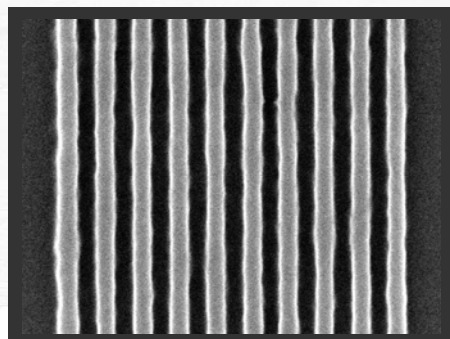
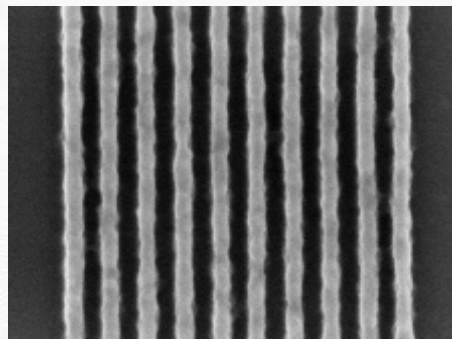
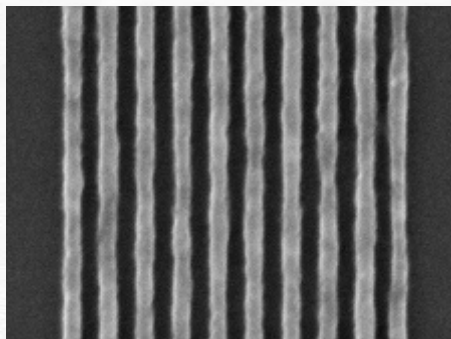
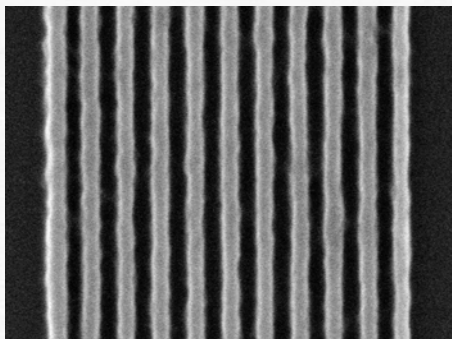
KRS

MET 1K

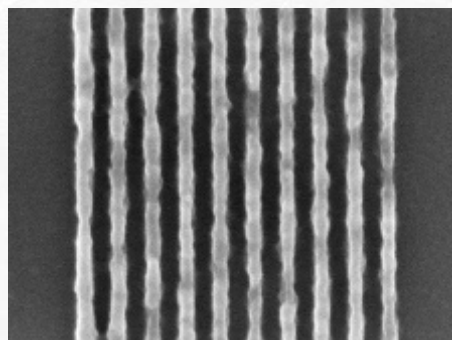
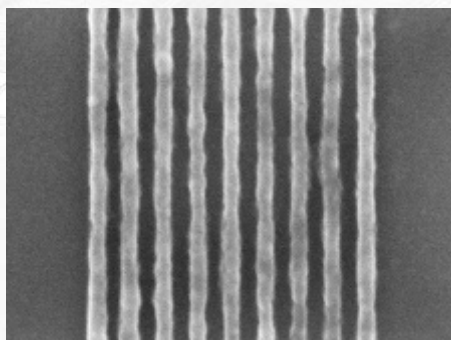
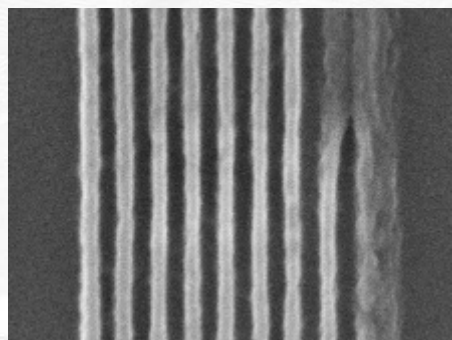
Supplier A

Supplier C

35-nm



32.5-nm



30-nm

