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Summary of European Workshop on Resist Limitations

February 27th, 2005; San Jose, CA

Sematech Resist Limitations Workshop

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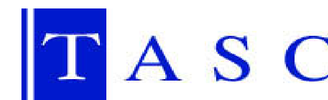
1st European Workshop on Resist Limitations

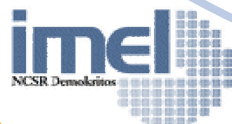
Erlangen, December 14, 2004

EXCITE

PHILIPS

ASML





Resist Limitations Workshop - General

- 24 participants from Europe (MEDEA ExCITe and More Moore), Asia (ASET, Osaka Univ.) and USA (Sematech)
- 3 general roadmap presentations by IMEC, ASML and Clariant
  - ITRS update 2004 and it's consequences for resist development
  - Tool roadmap for 193i and EUV
  - Resist roadmaps 193i and beyond
- 14 short presentations on physical, chemical and processing limitations of state-of-the-art resists were given by the participants
- Prioritization of Issues was done (mainly under the perspective of the european EUV community)
- Top 3 ranked Issues were discussed in detail in following breakout sessions

Prioritization of Issues

Items were collected after each presentation and clustered at the end of the presentation session;
Voting: each meeting attendee was allowed to allocate 3 points

Topic	Votes	In Detail
Line Edge Roughness	**19**	■ Shot noise & LER ■ LER transfer during etch ■ LER – sensitivity trade-off ■ Contact hole – LER ■ Molecular size distribution ■ Metrology
Chemical Amplification	**17**	■ LER ■ Diffusion ■ Secondary electron blur ■ Resolution vs. Diffusion ■ Acid nanospace control ■ CAR limit @ 35nm?
Defectivity & Outgassing	**17**	■ Defects ■ Surface defects ■ Interactions on interfaces resist-fluid-optics ■ Outgassing ■ Leaching (“Immersion Outgassing”)
Processing	**9**	■ Process complexity ■ Resist development ■ Pattern collapse ■ Thin resists
Optical properties of resists	**4**	■ CD control ■ Absorbance of resists ■ Refractive index ■ High-RI fluids and light propagation

Resist Limitations Workshop – Breakout Sessions

- Breakout Sessions on top issues were held to clarify:
  - is the problem fully understood (contributors, mechanisms, today's vs. future limits, intrinsic?
  - for which wavelengths and which node(s) will this issue become a problem?
  - what is the outlook for solving the problem (process trade-offs, work-arounds)?
  - research effort & who could play a major role in this research effort (consortia, universities, suppliers, IC manufacturers, …)

Some general conclusions

- Issues that require „standardization methodology“ can best be driven by consortia (e. g. Sematech)
- Issues that include decent „chemistry knowledge“ can best be pursued between supplier & institutes
- standardized methodology should asap be available for resist supplier to pre-check materials
- Top #3 Resist Limitations were:
  - LER – Shot Noise – Sensitivity
  - Diffusion - Resolution
  - Resist Outgassing
- Issues will be addressed at International SMT Workshop and follow-up MEDEA workshops

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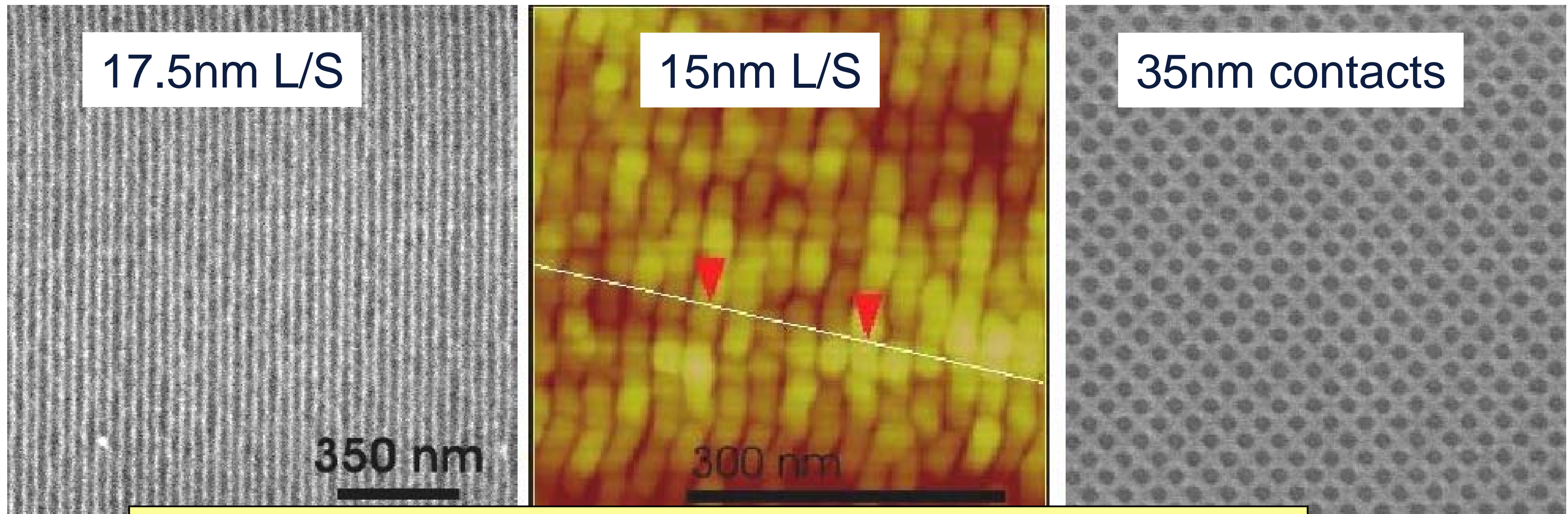
Statements on "Chemical Amplification Resists"

- Non-local exposure at EUV;"secondary electron blur" (TNO)
- EUV shot noise prevents 40nm resolution (Freescale)
- "some modulation" down to 30nm HP already seen in EUV resist (AZ)
- no reasonable resist profiles obtained so far, how to deal with "flare"?
- polymer side reactions (radical formation, crosslinking, scissioning,..) which will take place due to high photon energy (IFX)
- "diffusion trade-off": "short" supports resolution, "long" smoothens LER (Freescale)
- "Confinement effects", e.g. non-linear behaviour of water uptake, diffusion vs. resist thickness (AZ)
- Experimental evidence that acid diffusion viz. image blur causes a significant decrease in EL (Philips)
- The acid diffusion length must scale down with the pitch, just as λ/NA (Philips)
- "nanospace reactions" (acid diffusion between exposure and PEB) add to image blur effect (Osaka Uni)

Statements on "Chemical Amplification Resists"

- resolution limited to 30-35nm half pitch due to acid diffusion; compare: 35 nm HP (7.1 nm LER, 11 mJ/cm²) vs. 17.5 nm HP (2.5 nm LER, 50 – 100 mJ/cm²) (IMEC)
- Confinement: LER and outgassing is related to resist components (size, aggregates) and to the imaging mechanism (CARs, chain scission etc) (IMEL)
- high resist absorbance at EUV (2-3/um; no significant progress)
- Key question: how to optimize Sensitivity, LER, Diffusion, Resolution simultaneously
- Fundamental limits LER: molecule size (0.7nm, 3 sigma: 2.1 nm)
- Not wavelength specific problem, but EUV / EB appears worse than 193nm; 193nm is worse than 248nm
- Problem seen for 45nm HP and below

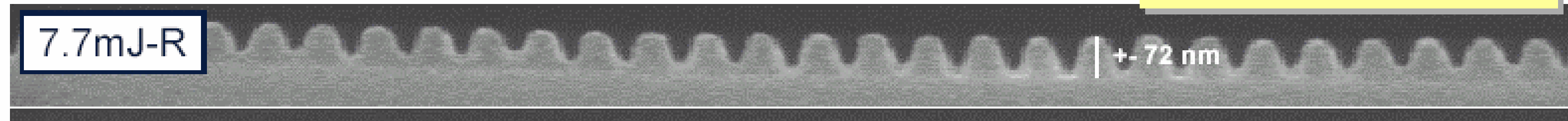
PMMA (non-CA resist) imaging at PSI



Best resolution obtained with optical lithography so far

Resist Performance Screening by EUV Interference Lithography: **Resolution no longer limited by tool, but by resist** (3rd Int EUV Symp.; Miyazaki)

40nm in CA-resist



General statements on roadmap issues

- ITRS completeley “red” for 45 nm and below
- EUV inserted at 32nm HP (k1 = 0.59!), extended for several generations
- 193i possibly down to 32 nm HP
- Resist suppliers need significantly more and regular tool time
- 35 nm HP feasible; intrinsic limits of CA resists seen at 20-25 nm
- Specific EUV sensitivity vs. LWR is central problem. Experimental evidence that ultra-low LER and low sizing dose cannot be achieved simultaneously
- Exposure tools available that run into CAR limit: EUVL (e.g. interference printer, MET); 193 immersion (e.g. hyper-NA interference printer); E-beam lithography

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These are the Roadblocks

- secondary electron blur is not as big as diffusion but might add up to 8nm
- shot noise limit for EUV photons limits low-sensitivity to ~ 4-5 mJ/cm2
- LER limit by molecular contributions is > 2nm
- Resolution Limitation by Diffusion ~ 20 – 25 nm
- outgassing in EUV is high and might prevent low-Mw resists

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Workshop Summary

- ITRS resist roadmap completely “red” for <45nm, i.e. no fundamental understanding of issues and no solutions visible yet to achieve targets on time (e.g. < 1.6nm CD control)
- The intrinsic trade-off between sensitivity, LER and resolution is the fundamental problem to be solved
- Fundamental and new limits are visible and require critical review of targets; e.g. molecule size of 2.1 nm or “non-linear” thin film behaviour
- Metrology needs to be developed and w/w standardized (e.g. LER, outgassing, leaching); early agreement on targets required to support resist development
- Follow-up WS’s (Sematech, 2/05; Medea, fall 05)