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MASK ROUGHNESS EFFECTS ON PATTERN VARIABILITY (2)

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LBLN

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SEMATECH

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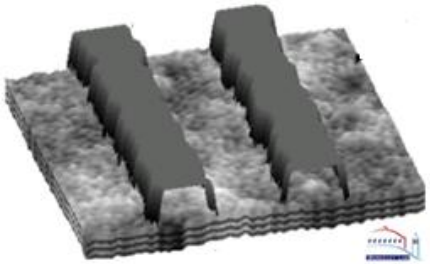
ASML, TEL USHIO NXE:3100 teams

- For keeping the tools up enough during night(s) and weekend(s)

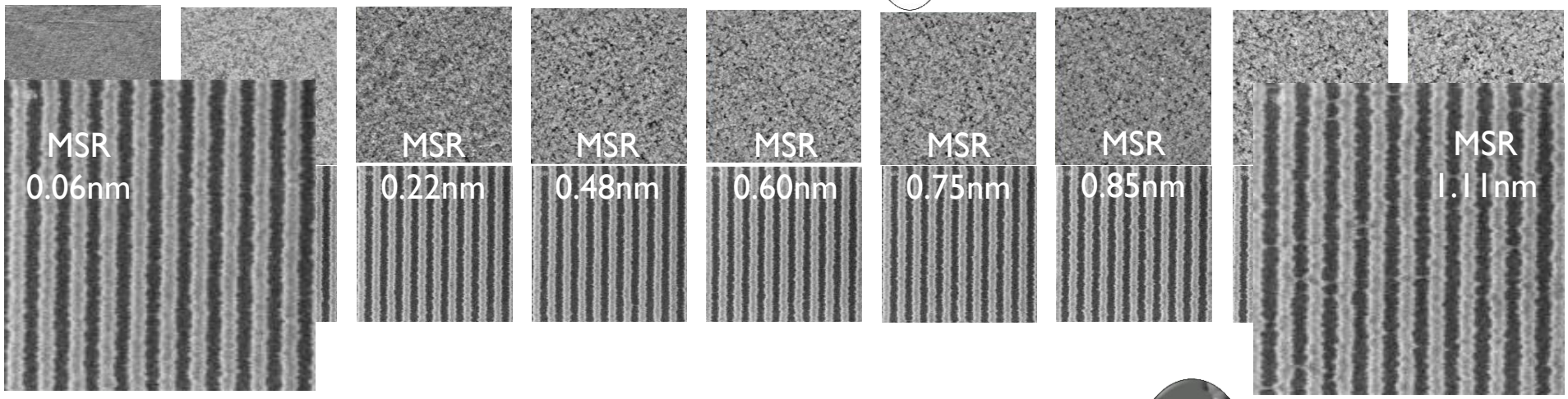
OUTLINE

- Introduction:
  - Mask surface roughness (Speckle)
  - Mask absorber LER/LCDU transfer
- Results & Discussion: NXE:3100 exposures @ imec
  - Mask absorber LER-LCDU impact on L/S-CH
  - Speckle impact on L/S-CH on multiple structures, multiple resists
  - Flare vs. Speckle
- Conclusions/Future work

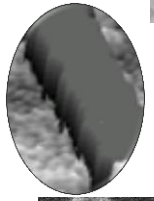
INTRODUCTION

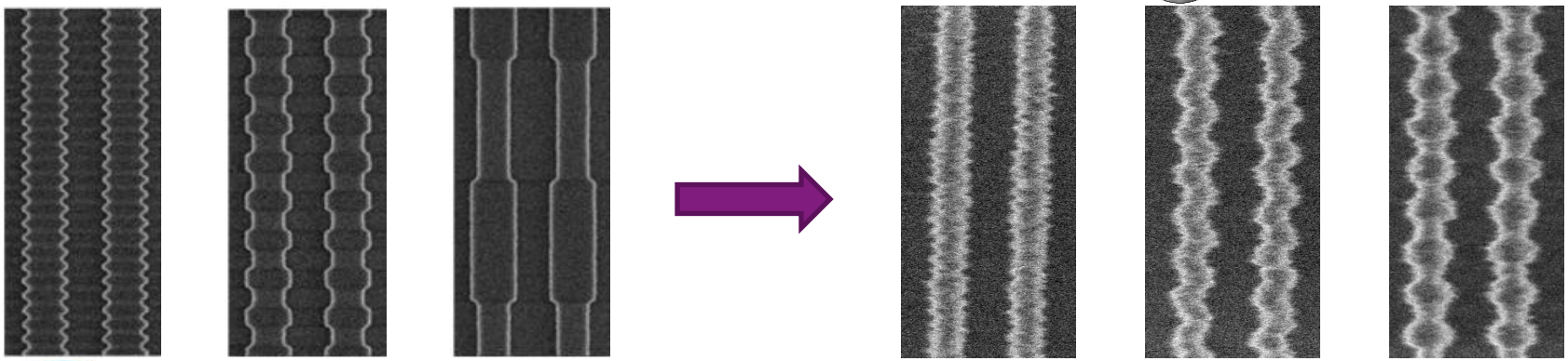


1. Surface roughness: Speckle effect

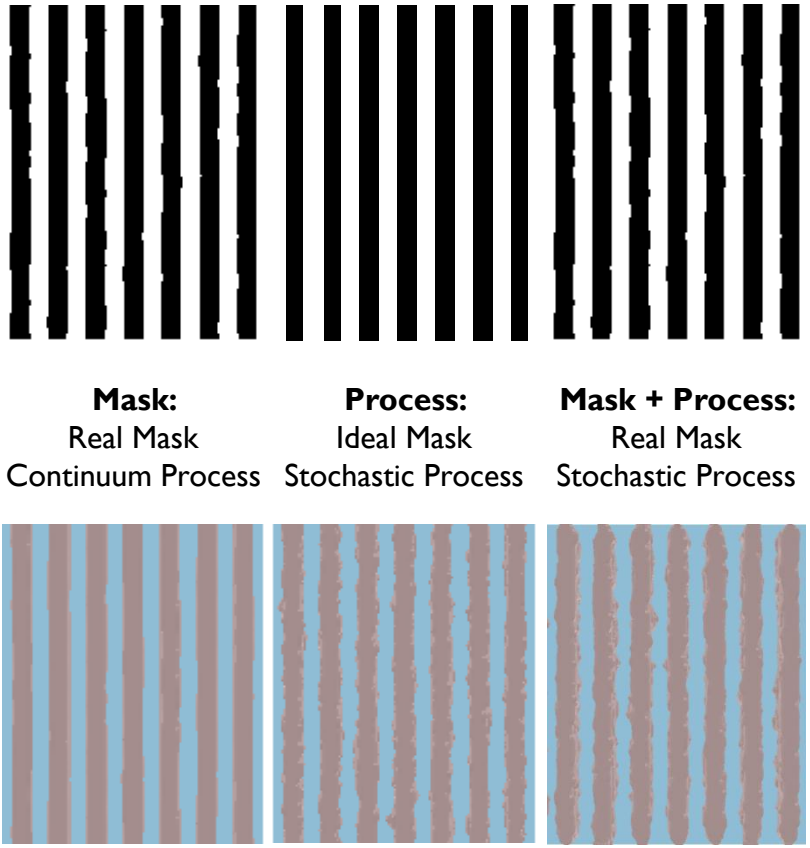


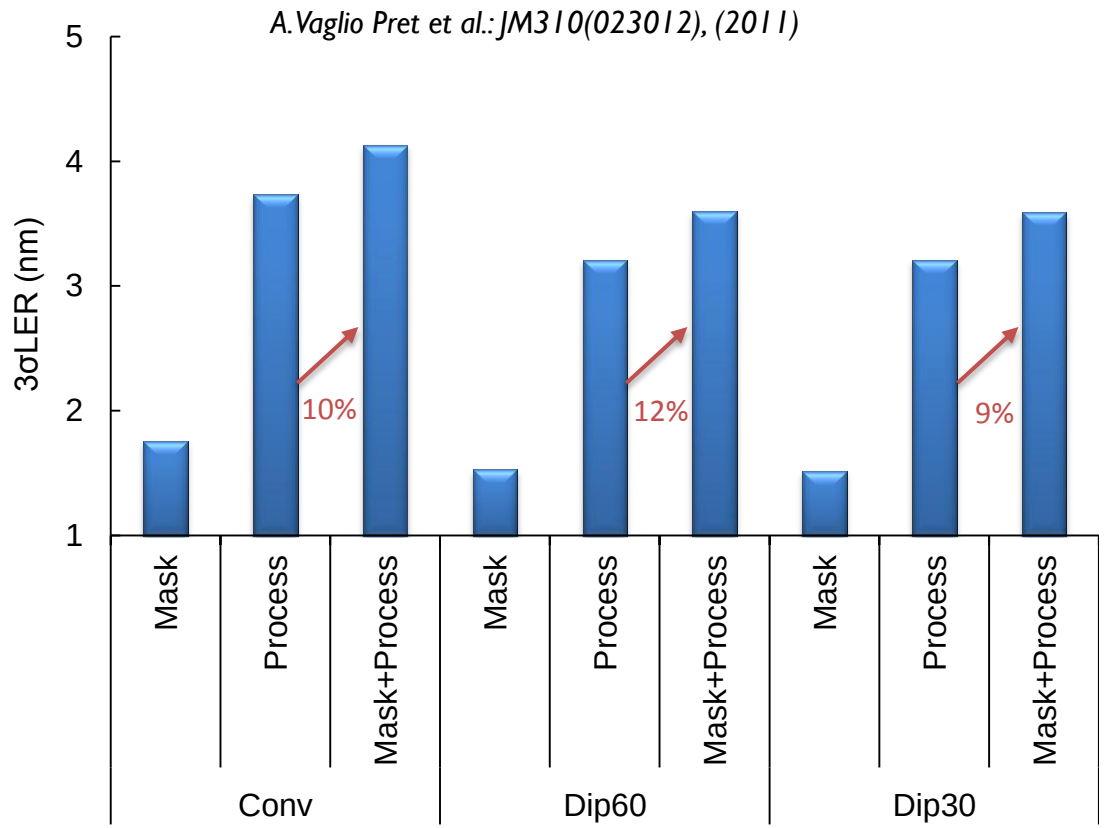
2. Absorber roughness: LER/LCDU transmission





MASK ABSORBER LER TRANSFER (1/3)

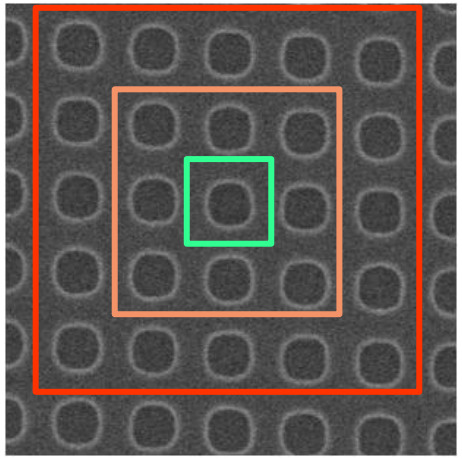




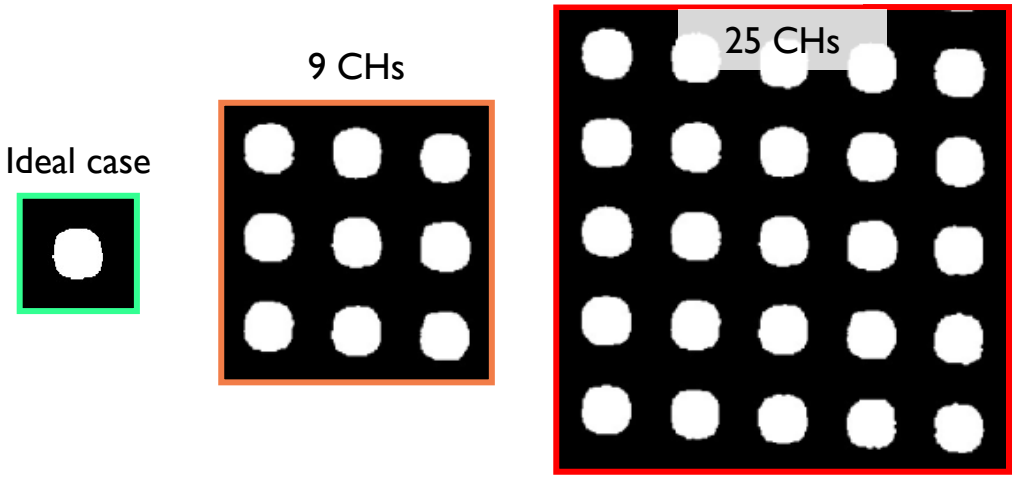
- Mask Absorber LER transfer: 10%
- Tanabe/Gallagher/Naulleau: 9-13% *E. Gallagher et al.: Proc. SPIE, vol. 7969(79690W-1), (2011)*
- Mack: 12% *Chris A. Mack: Proc. SPIE, vol. 7488(748828), (2009)*

MASK ABSORBER LCDU TRANSFER (2/3)

Mask CD-SEM image



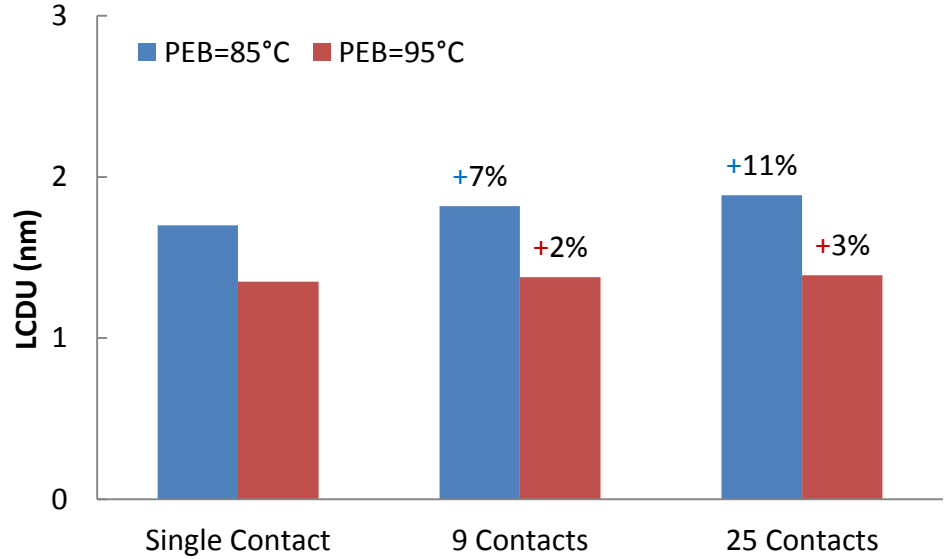
Prolith Mask modeling



Mask contribution evaluated simulating

1. 1 "real" CH (ideal case) x 250
2. 9 "real" CHs x 28
3. 25 "real" CHs x 10

for 85° and 95° PEB



- Mask CH LCDU impacts is ≤ 11% and PEB dependent

SPECKLE: MASK INFORMATION (1/2)

Blue area: Graded Cr mask (aggravated MSR)

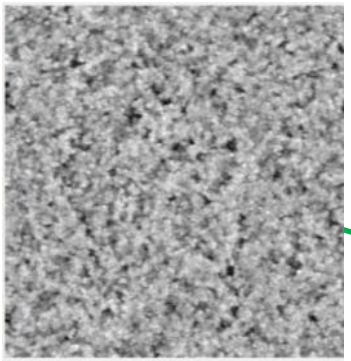


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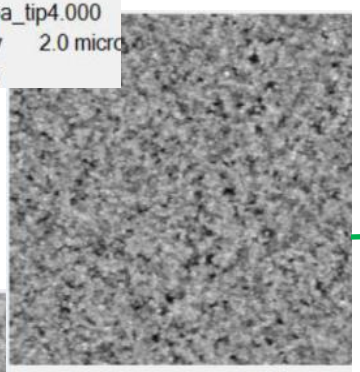
Image size = 2.0 by 2.0 micro
Raw RMS = 1.111 nm



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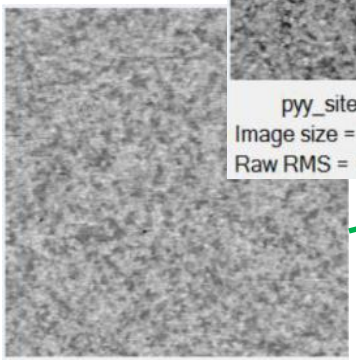
Raw RMS = 0.749 nm



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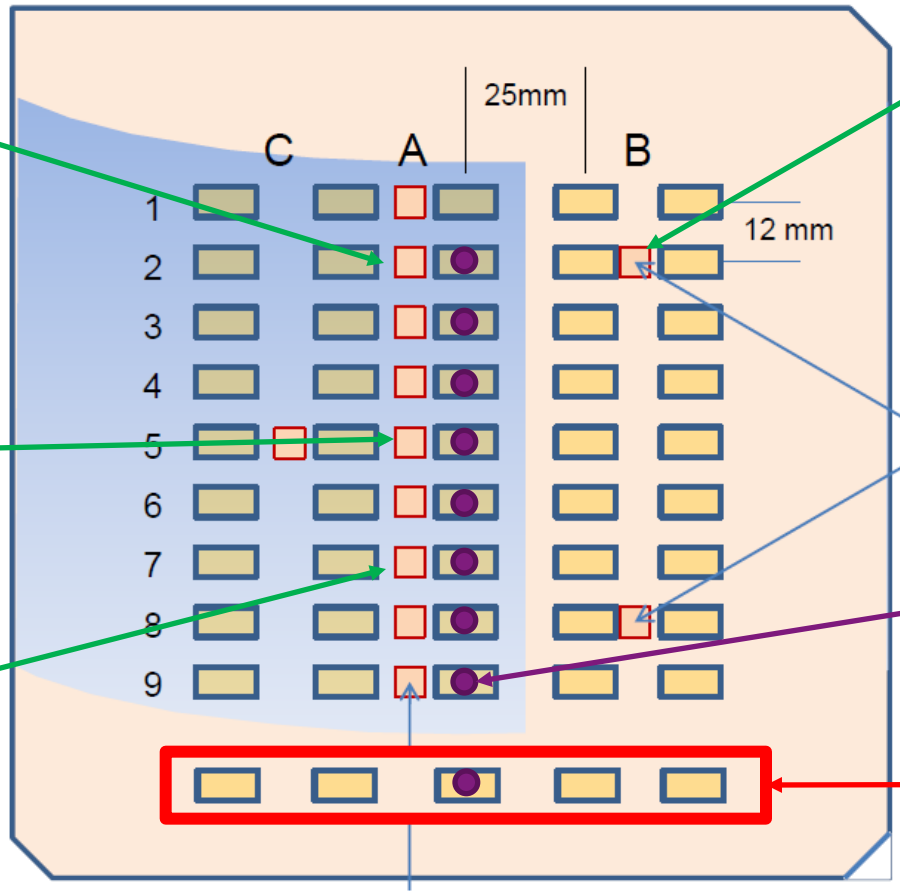
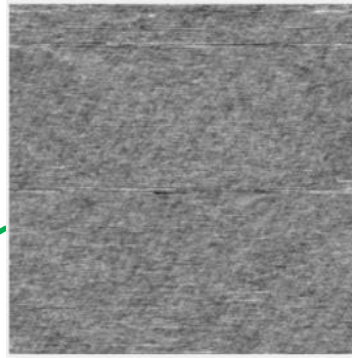
Raw RMS = 0.229 nm





pyy_site_b8_tespa_tip4.000
Image size = 2.0 by 2.0 micro
Raw RMS = 0.063 nm

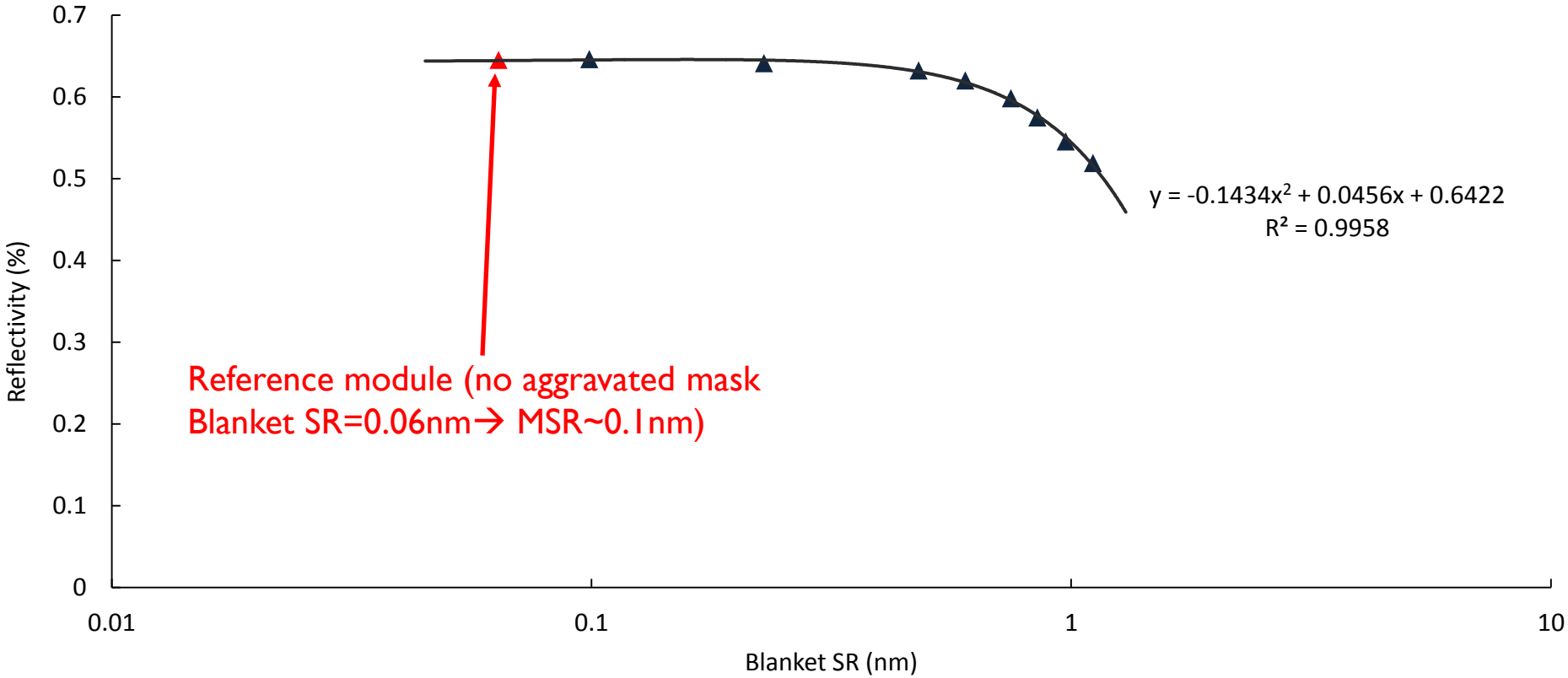
AFM Measure of Substrate ($10x10\mu m^2$)

CD-SEM Measurements

Reference Structures

A.Vaglio Pret et al.: Proc. SPIE, 8322(83220N), (2011)
S.A.George et. al.: JVSTB, 28(6), (2010)

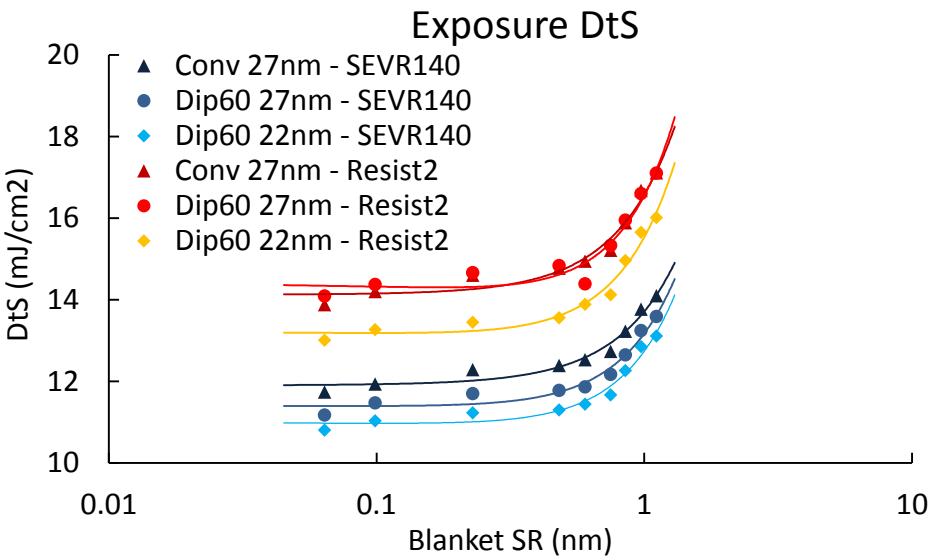
SPECKLE: MASK INFORMATION (2/2)

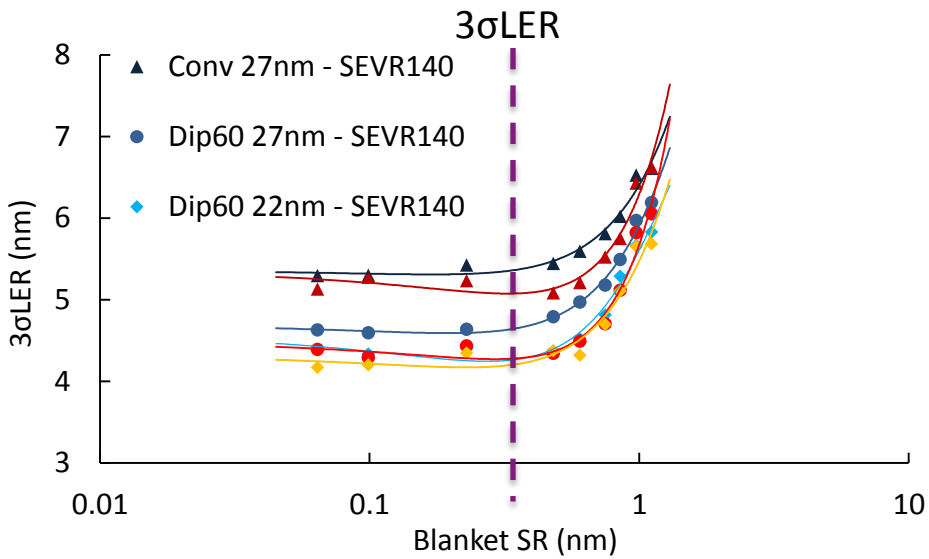


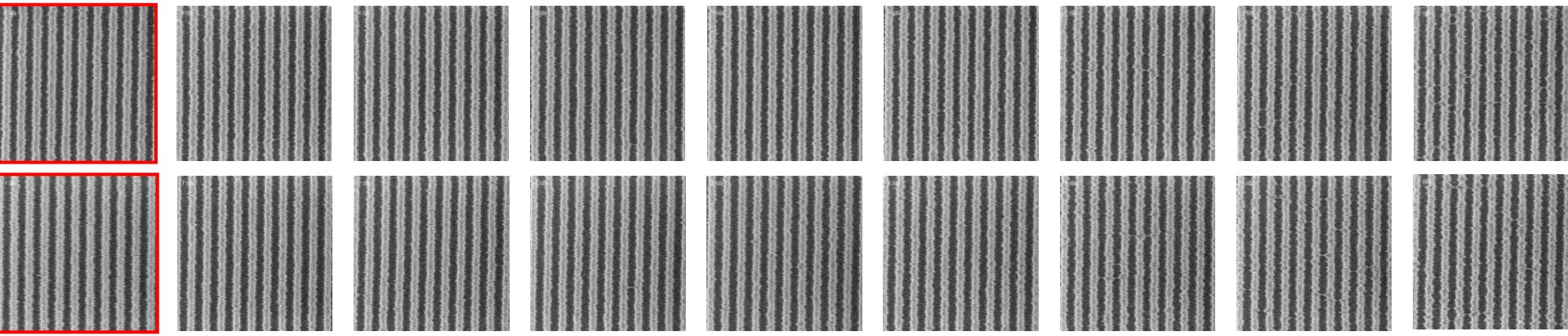
S.A.George et. al.: JVSTB, 28(6), (2010)

- (ML) Reflectivity drops upon mask surface roughness

L/S RESULTS (1/4)

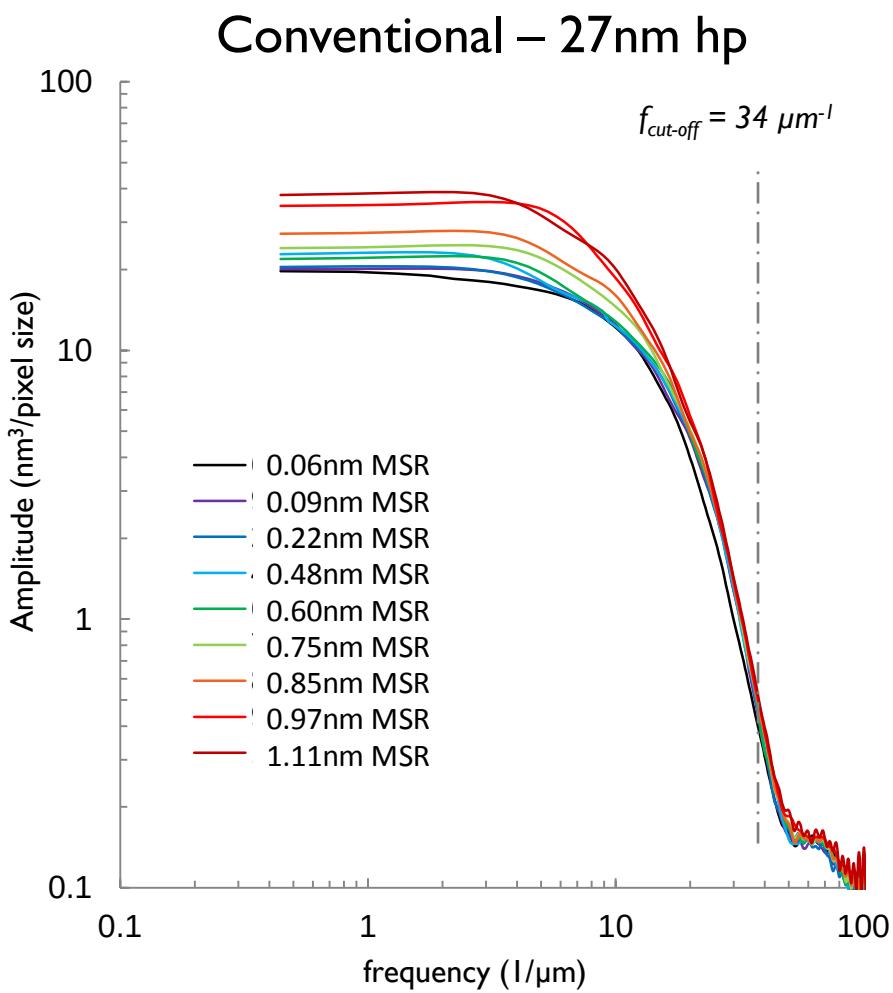


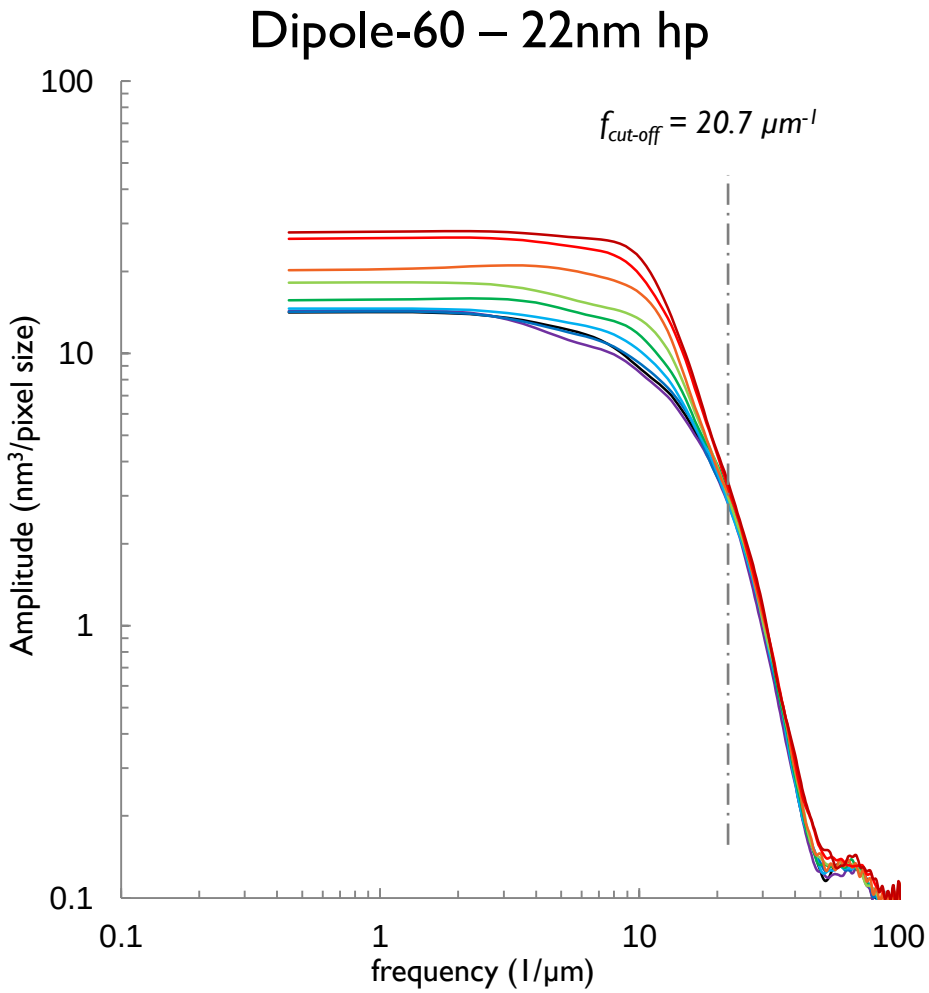




- 3σLER worsening for MSR > 0.3 nm

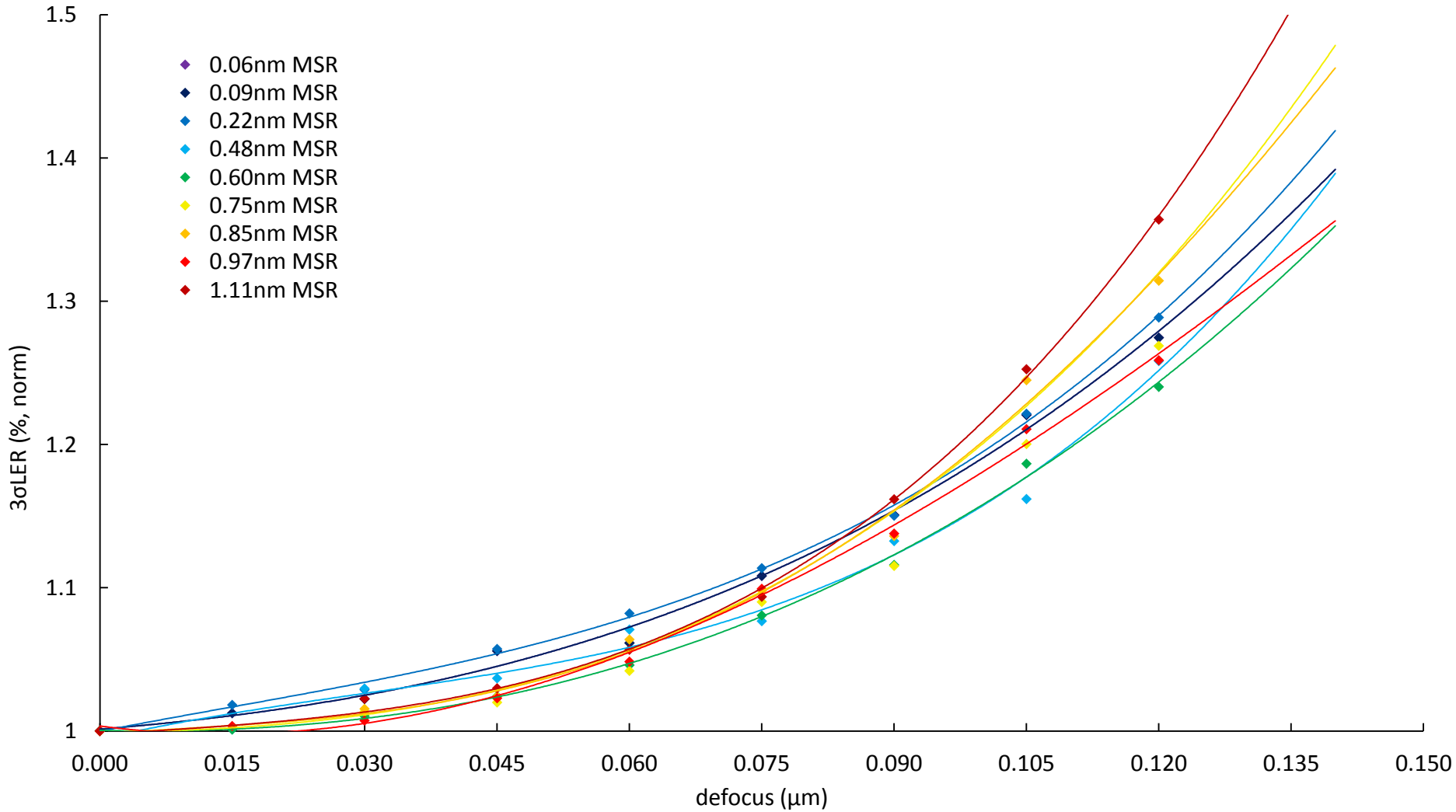
L/S RESULTS (2/4)





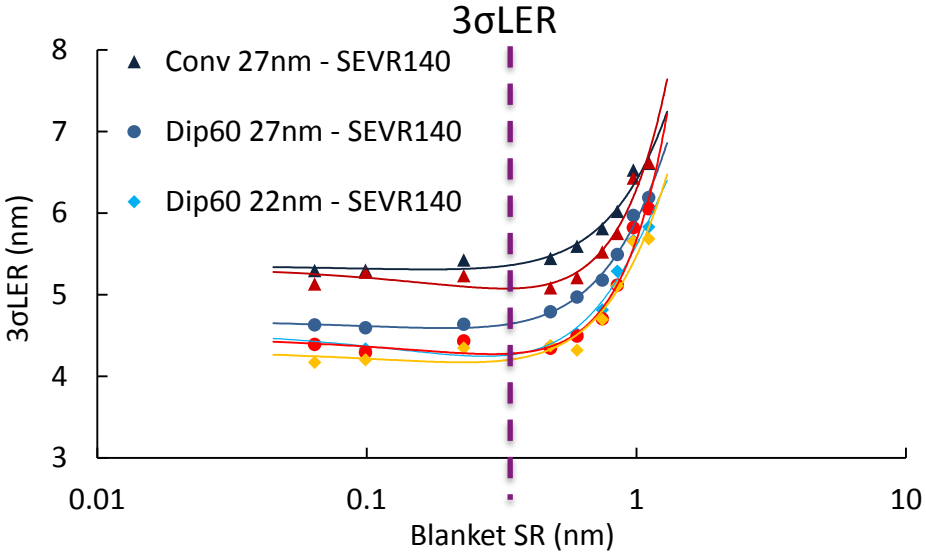
❖ The 3σLER worsening appears for frequencies f < optical system cut-off

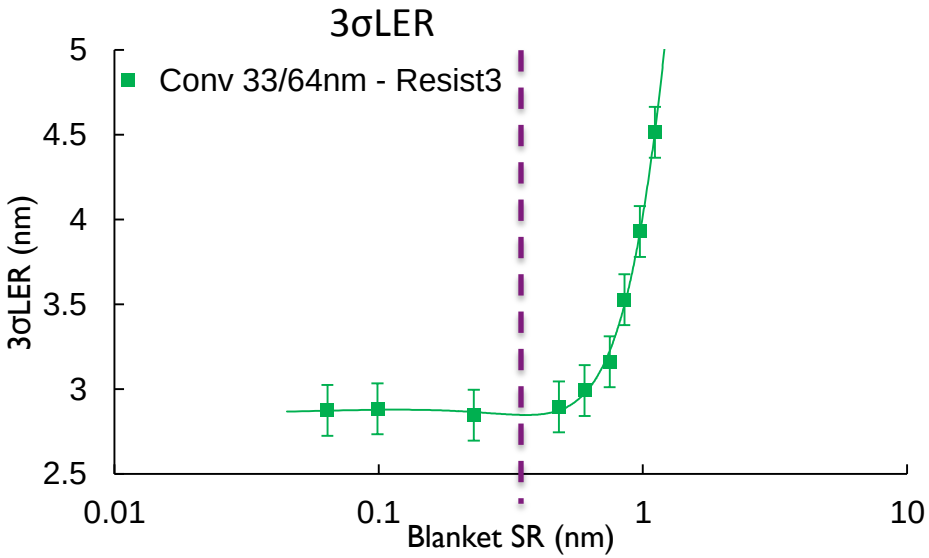
L/S RESULTS (3/4)

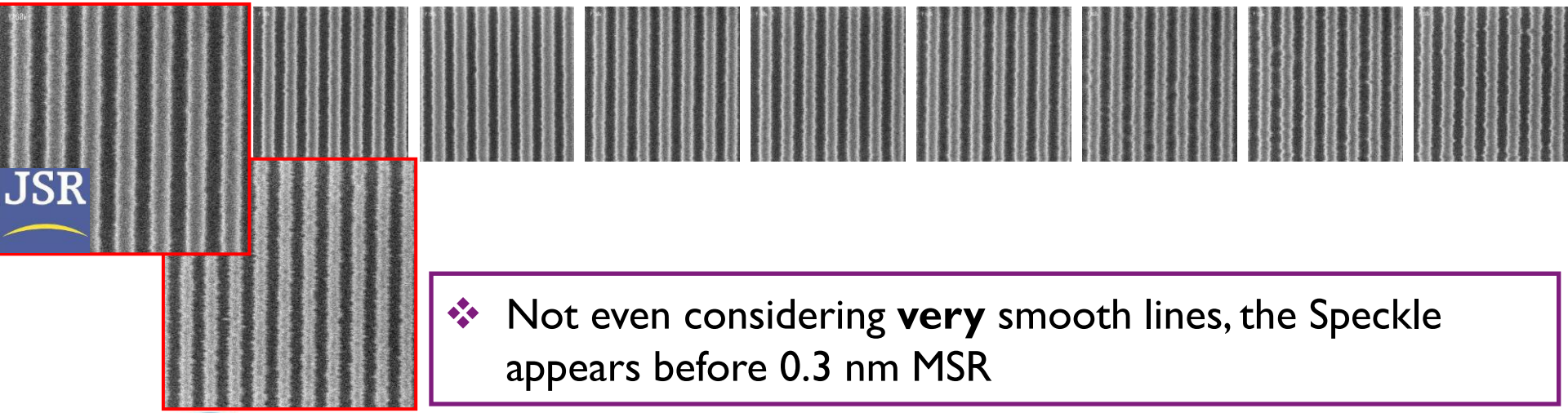


- The through focus behavior of the speckle is barely detectable only for high MSR

L/S RESULTS (4/4)

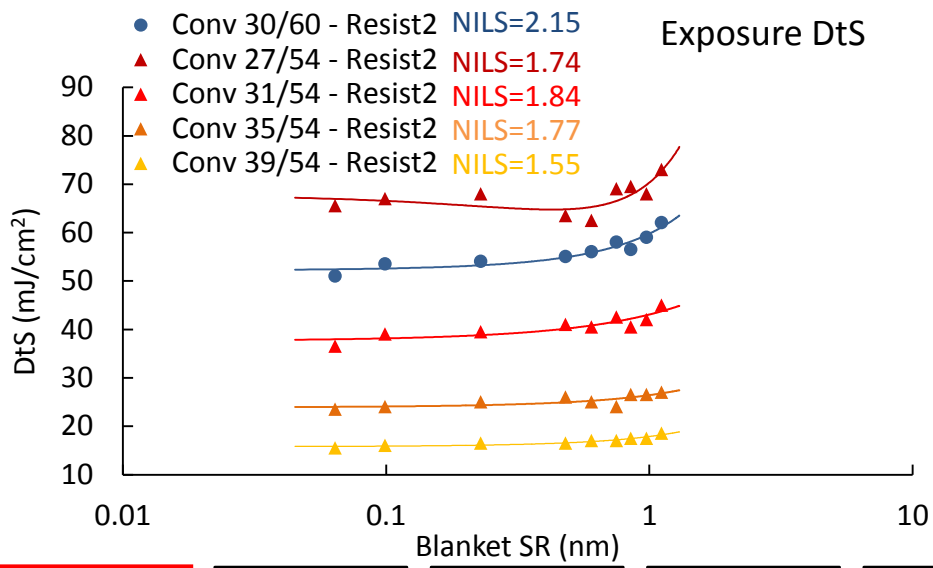


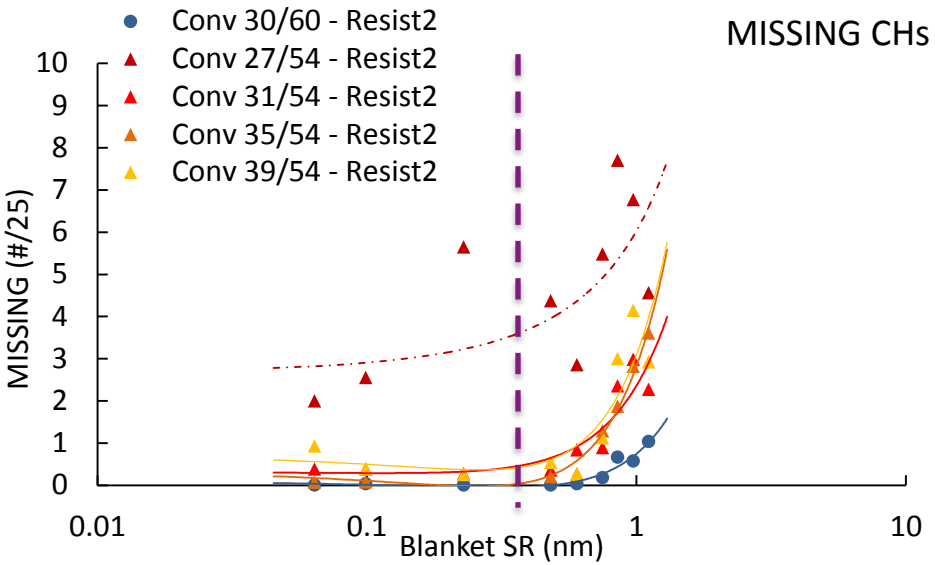


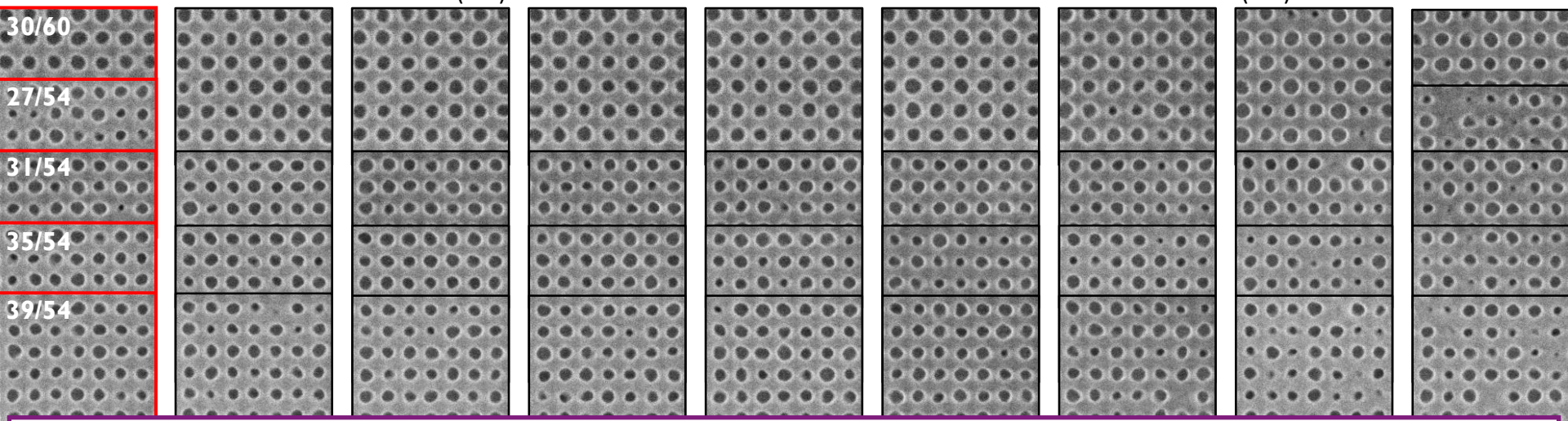


- Not even considering **very** smooth lines, the Speckle appears before 0.3 nm MSR

CH RESULTS (1/2)



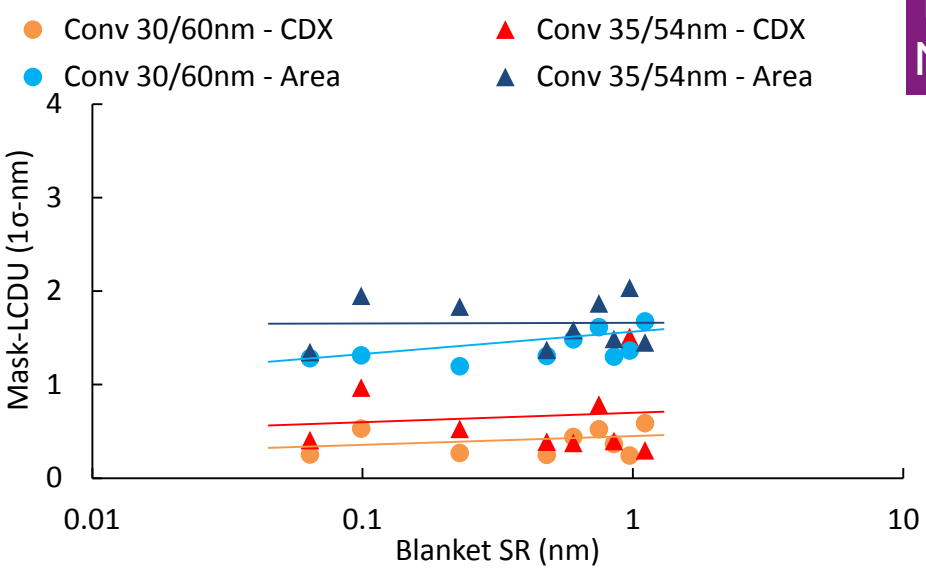


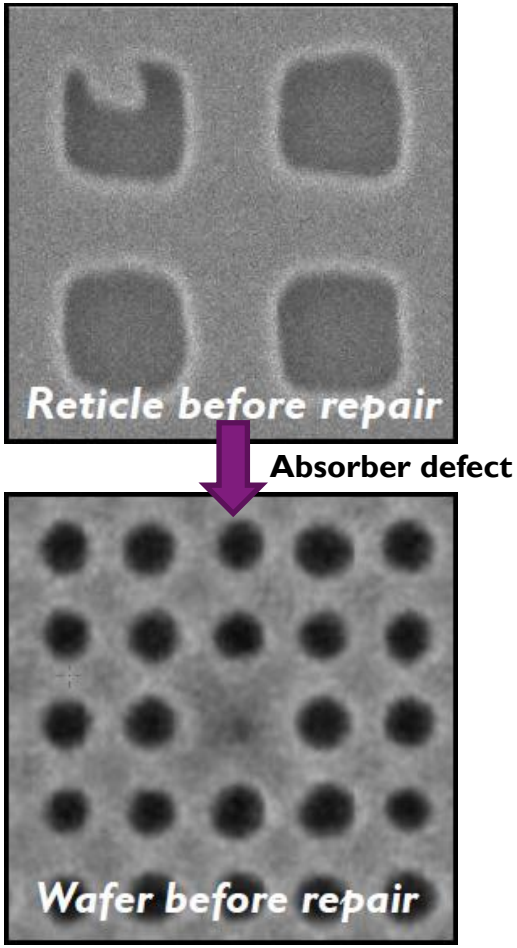


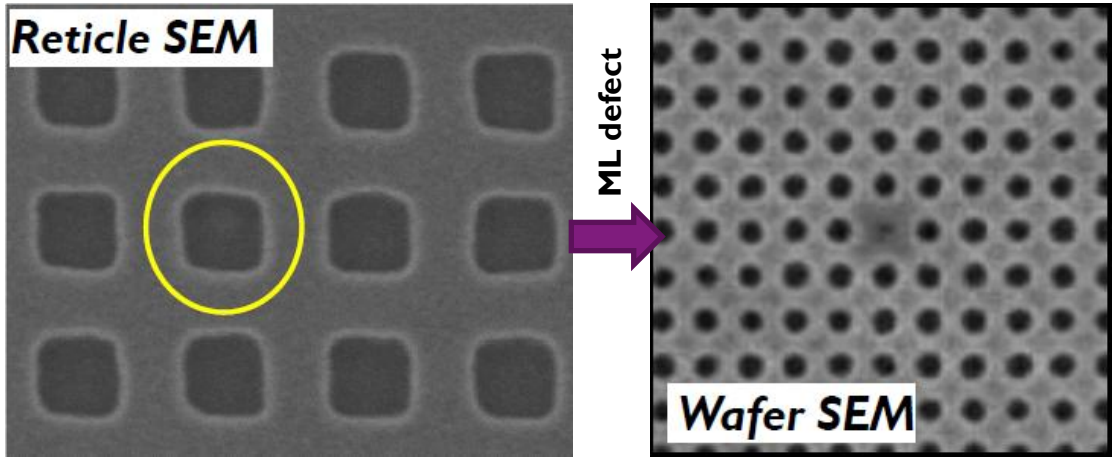
❖ As for L/S, CH variability increases for MSR > 0.3nm

CH RESULTS (2/2)

Tuesday 9:50-10:10, *D.Van den Heuvel:* Study of Multilayer Defects on sub-32nm hp EUV Reticles





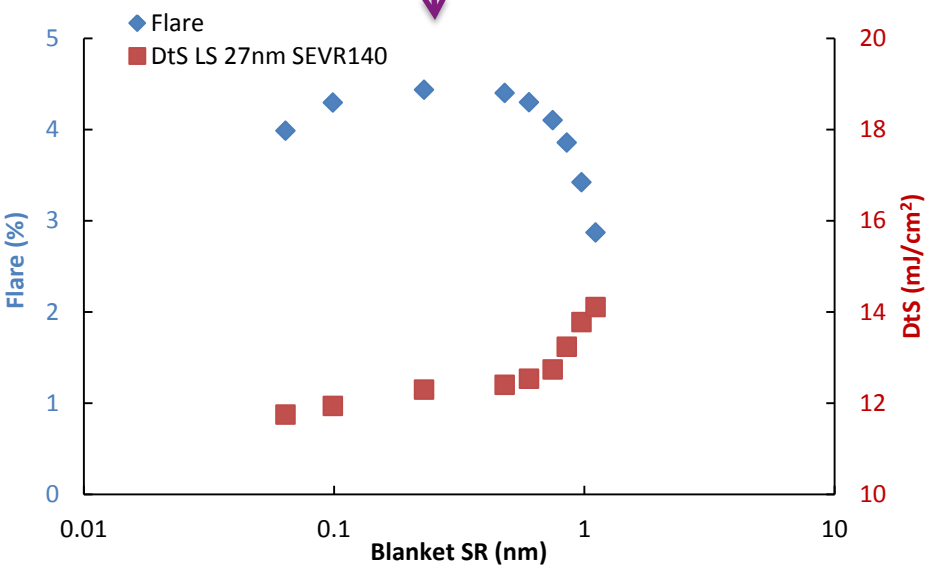


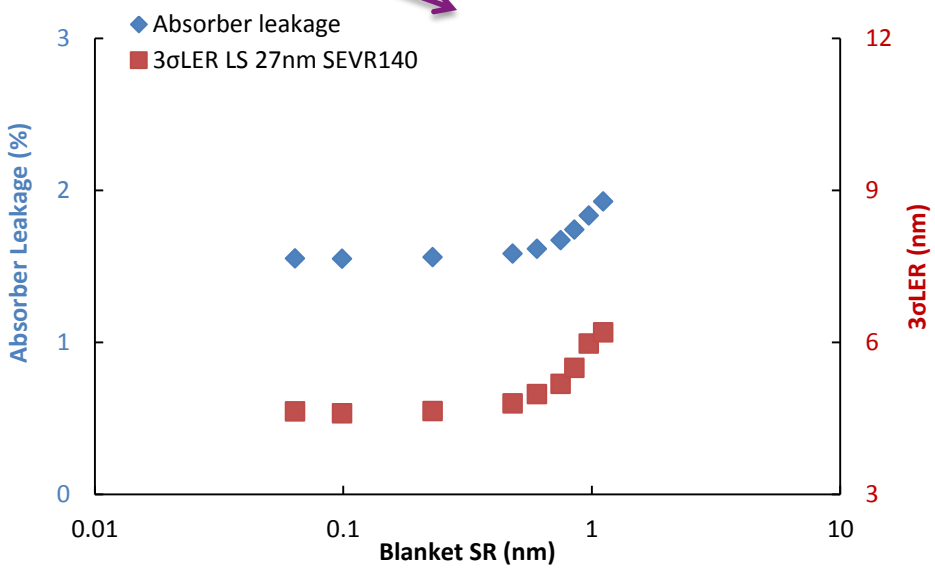
- CH CDX/Y & MEEF is not the only cause of LCDU/missing contacts

FLARE VS. SPECKLE (2/2)

$$Flare(\%) = \left(\frac{DtS}{E_{clear}}\right) x100 - R \qquad R = \frac{R_{Abs}}{R_{ML}}$$

G. Lorusso et al.: J. Micro/Nanolith. MEMS MOEMS 8(4), (2009)
G. Lorusso et al.: JVSTB 29(06F505), (2011)





- DtS increase correlates with Flare
- 3σLER increase correlates with absorber leakage

CONCLUSIONS

- Mask Absorber variability:
  - ≤ 10% impact at wafer level expected

- Speckle effect (mask surface roughness): primarily important to
  - keep the mask reflectivity as high as possible.
  - allow defect inspection

  Significant effects on pattern variability only for Blanket MSR > 0.3nm (rms)

QUESTIONS

Perseverance is the hard work you do after you get tired of doing the hard work you already did.

Newt Gingrich

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