# Advances in the Ion Beam Thin Film Planarization Process for Mitigating EUVL Mask Defects

Paul B. Mirkarimi, E. Spiller, S.L. Baker,
D.G. Stearns, J. Robinson, S. Hau-Riege, and V. Sperry
Lawrence Livermore National Laboratory
Livermore, CA. 94550

J.A. Little, E.M. Gullikson, and P.P. Naulleau
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

T. Liang and A.R. Stivers
Intel Corporation
Santa Clara, CA. 95052

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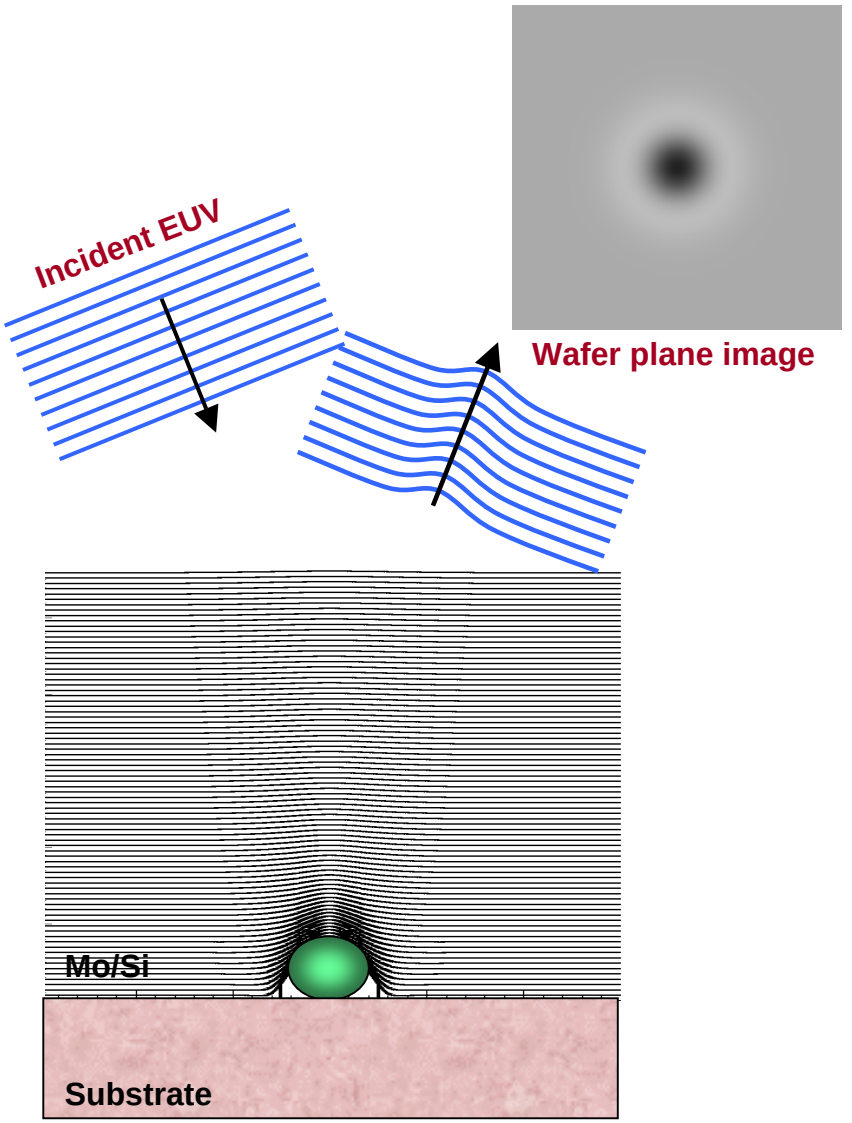
# Strategy for combating EUVL mask blank defects

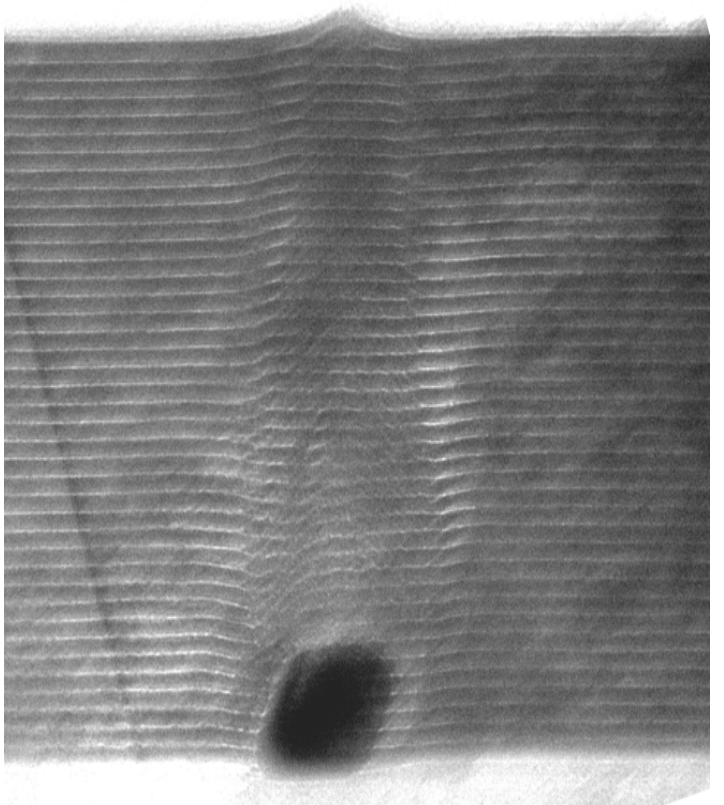
EUVL mask blank defects

- Defects nucleated at the substrate
  - **Smoothing**
  - Substrate cleaning
  - Phase defect repair (e-beam technique)
- Defects nucleated in the bottom layers
  - Low defect deposition
  - Phase defect repair (e-beam technique)
  - **Smoothing**
- Defects nucleated in the top layers
  - Low defect deposition
  - Amplitude defect repair (milling technique)

# Example of printable phase defects in EUVL mask blanks




XTEM of a coated sphere



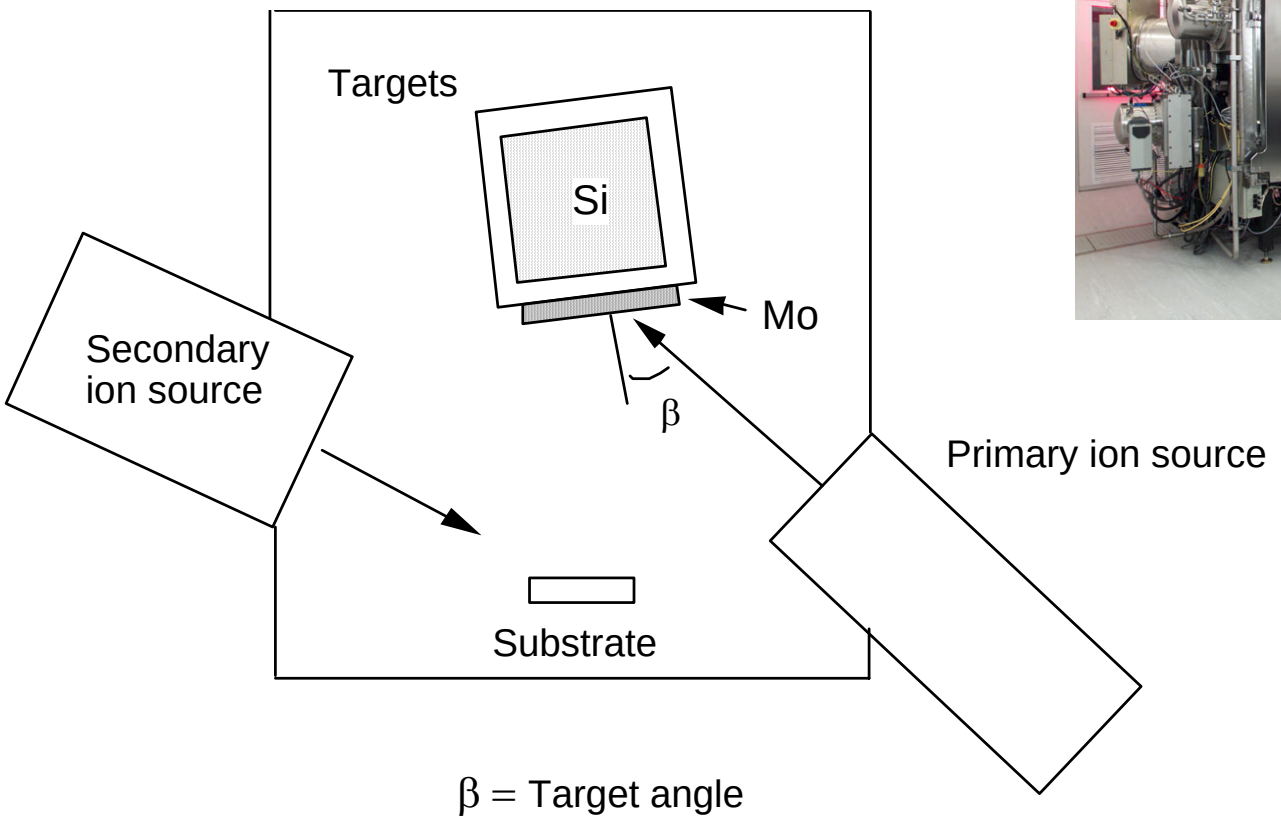
# 2003 Project Goals

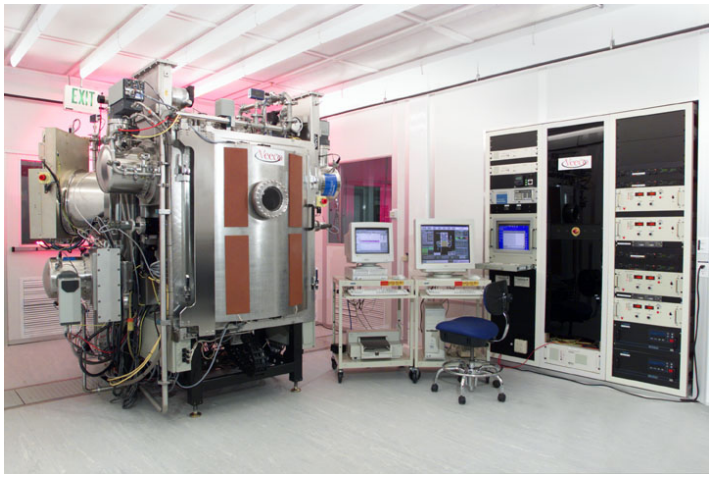
- Smooth 60 nm mask substrate particles to render nonprintable in an EUVL stepper
- Smooth 70 nm mask substrate particles to render nonprintable in an EUVL stepper
- Create controlled substrate pit defects and begin investigation of smoothing of substrate pit defects

*Note: the process to smooth 50 nm substrate particles is being cited this month by R&D magazine as one of the top 100 technological innovations of 2002 ("R&D 100 award").*

# Our ion beam sputter deposition tool has a secondary ion source for ion-assisted deposition

Our Ion Beam sputter Deposition (IBD) system

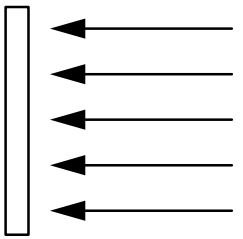


# The ion beam thin film planarization process utilizes a Mo/Si-based coating and etching technique to smooth substrate particles

- *Deposit extra Si when depositing the Si layers*

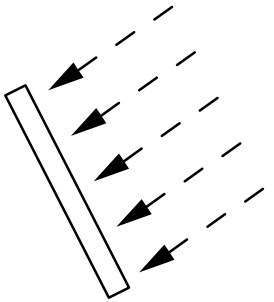
Deposit at near-normal incidence



**Deposit**

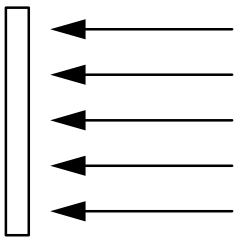
- *Etch the extra Si away*
- *Design process so that bilayer period thickness is approximately 7 nm*

Rotate and etch at near-normal incidence



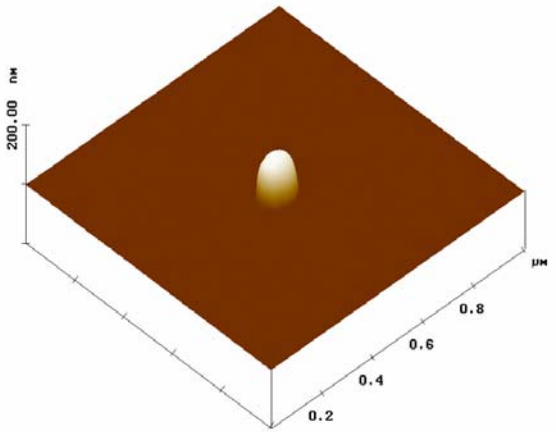
**Etch**

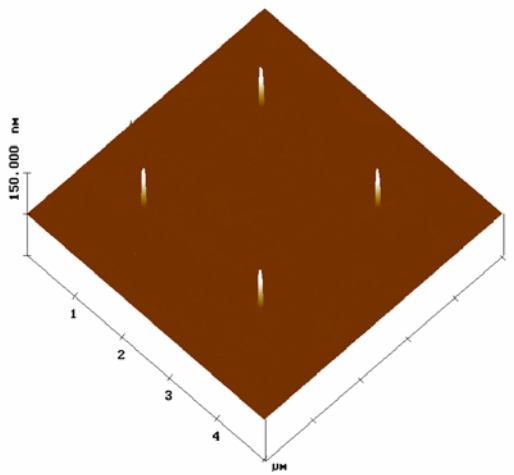
Rotate back and deposit



**Deposit**

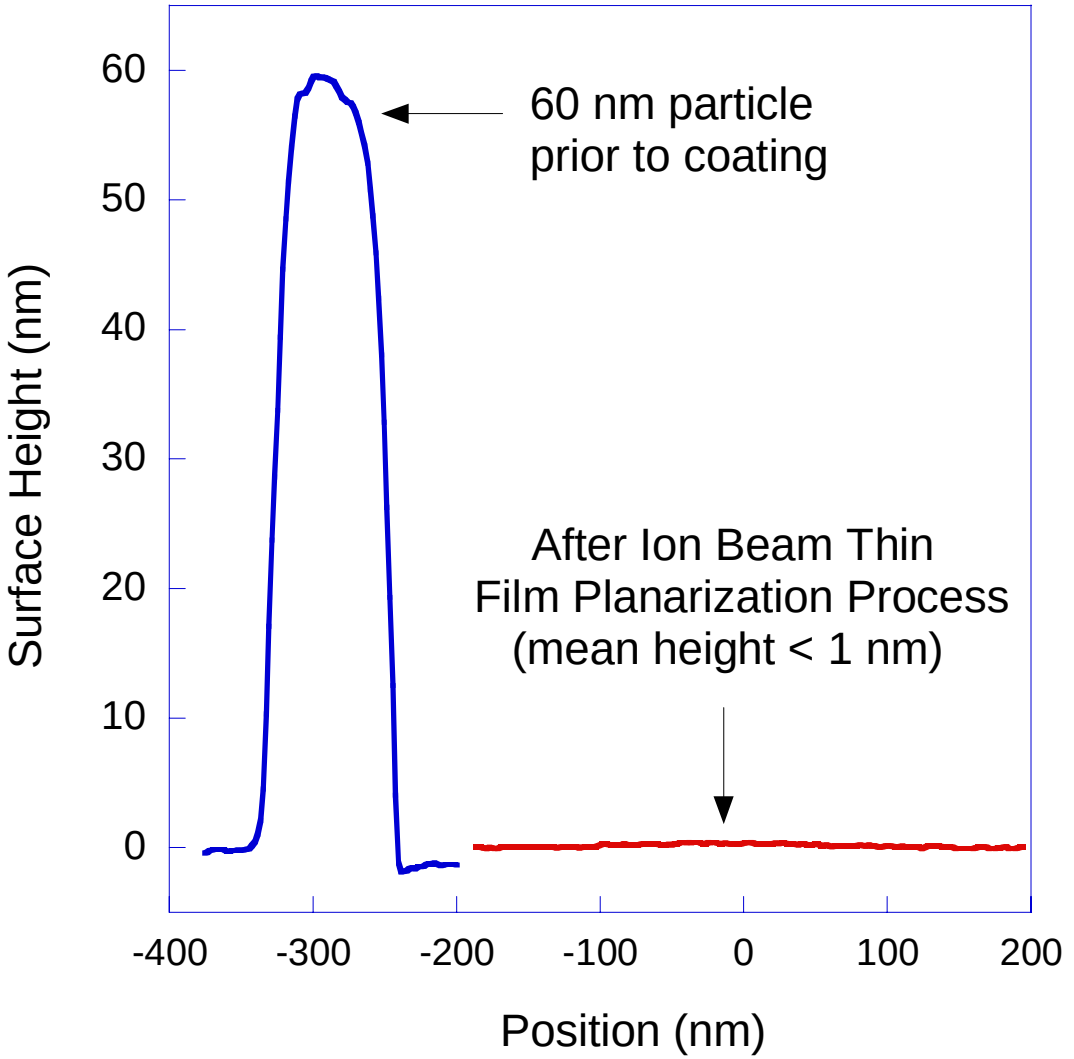
# We have moved to using programmed defects from gold nanoparticles for advancing the particle smoothing process



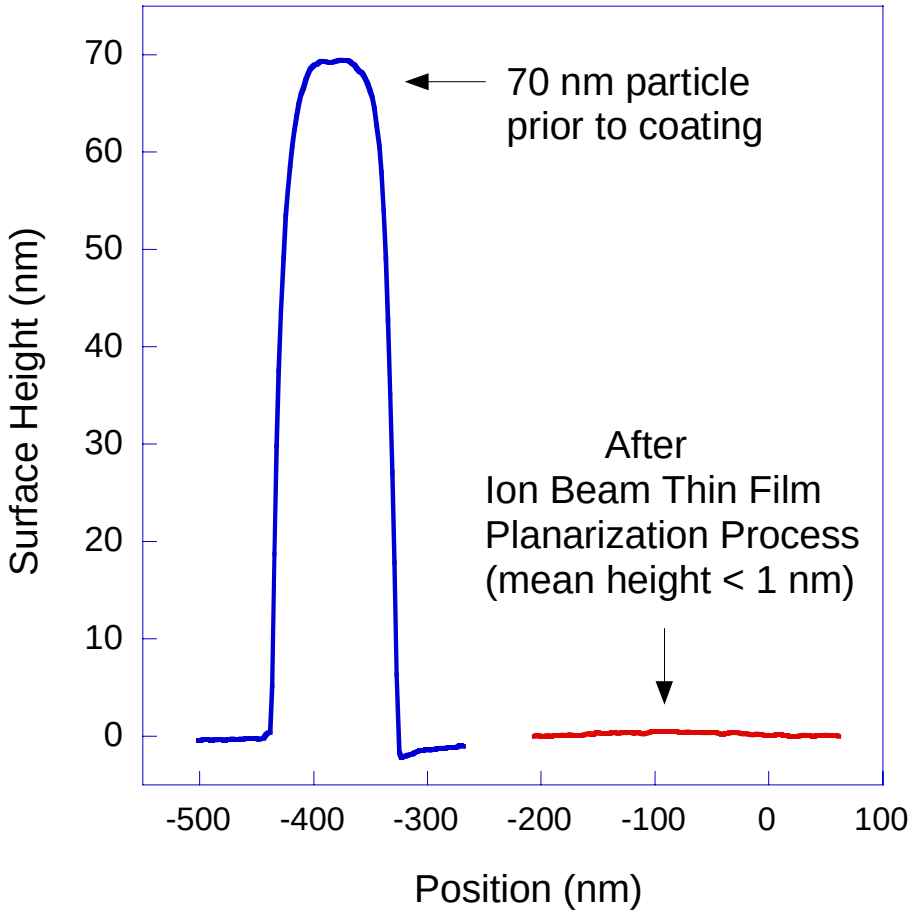



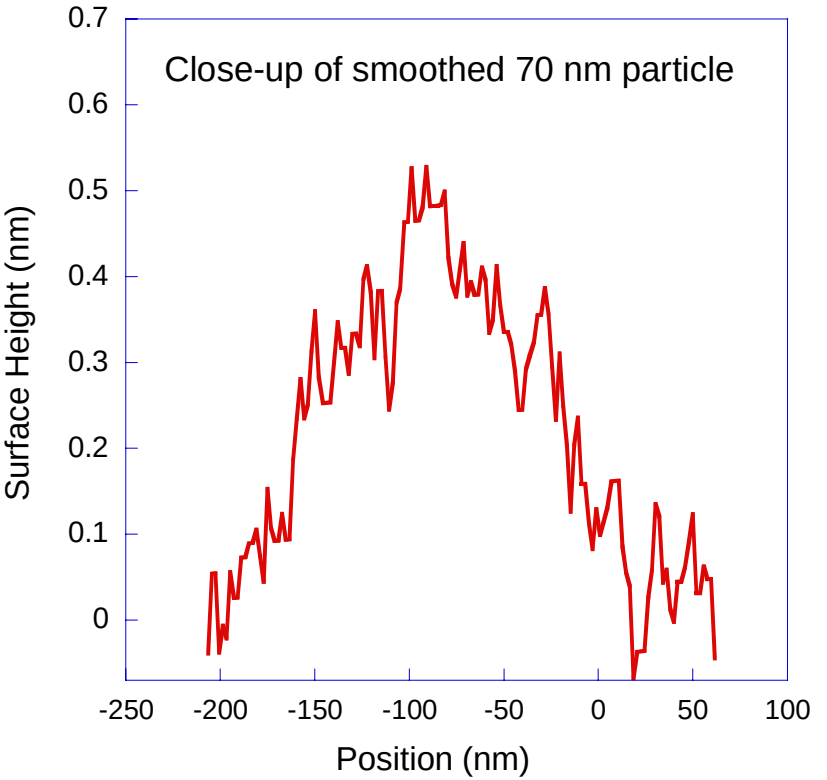

- Enough data to be comfortable relying on these substrate defects made from a glassy resist (at LBNL).
- Developed a process to generate > 10 useable programmed defect test samples from a single wafer; this makes it more cost-competitive with the Au nanoparticle samples).
- Metrology time is lowered due to predictability of defect locations
- Less variation in size distribution and size can be controlled better
- Potential to do printability experiments
- Potential to synthesize pit defects as well as bumps

# Our ion beam thin film planarization process has smoothed 60 nm diameter substrate particles to below 1 nm in height

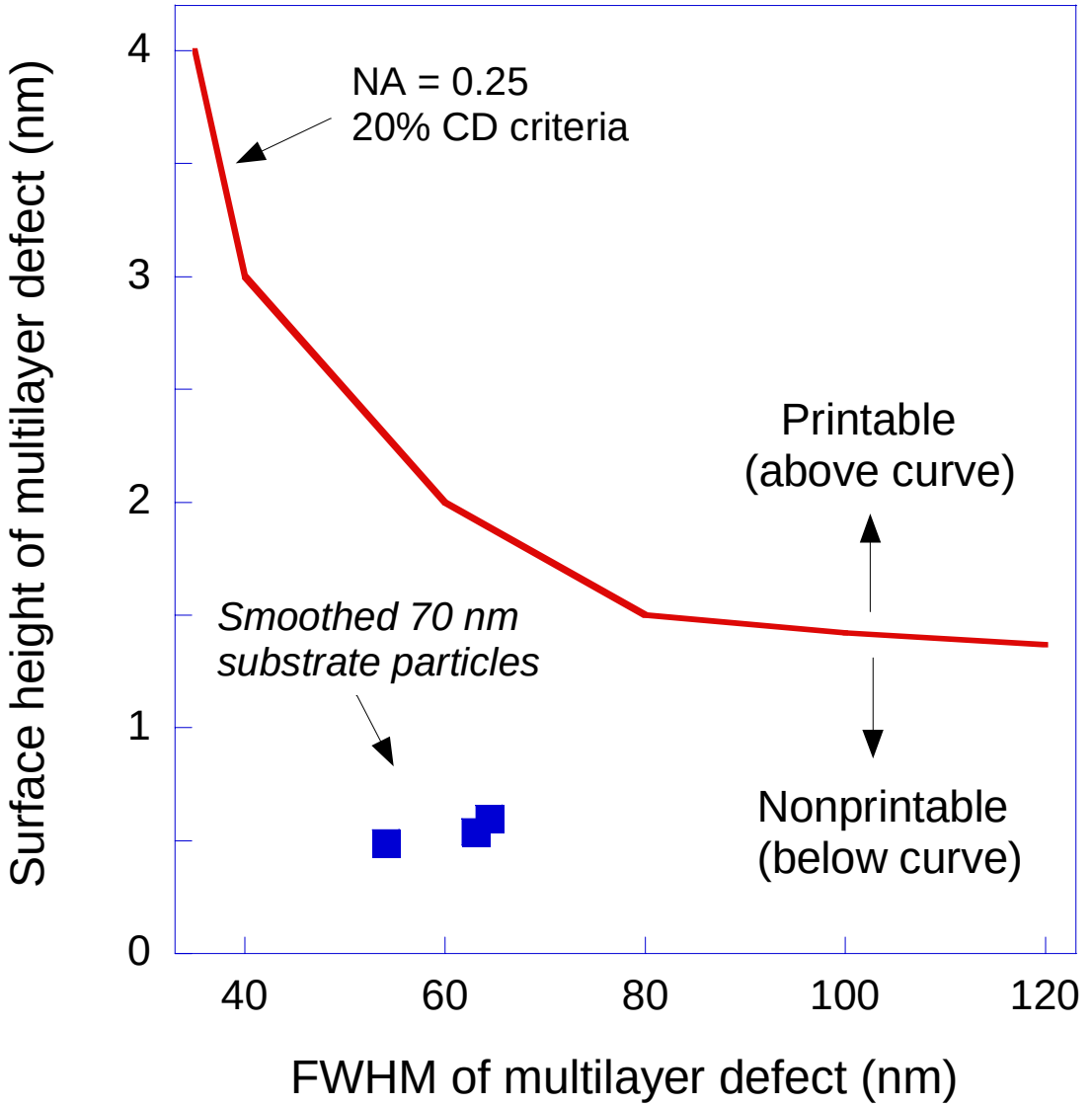


# Our ion beam thin film planarization process has smoothed 70 nm diameter substrate particles to below 1 nm in height



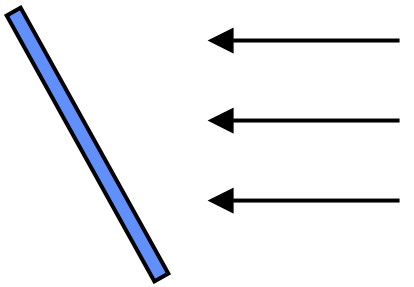
# 70 nm substrate particles have been smoothed below the EUVL printability threshold



# Coating uniformity is also important

- The smoothing process will need to be done under conditions yielding excellent thickness and reflectance uniformity for eventual EUVL mask blank production.

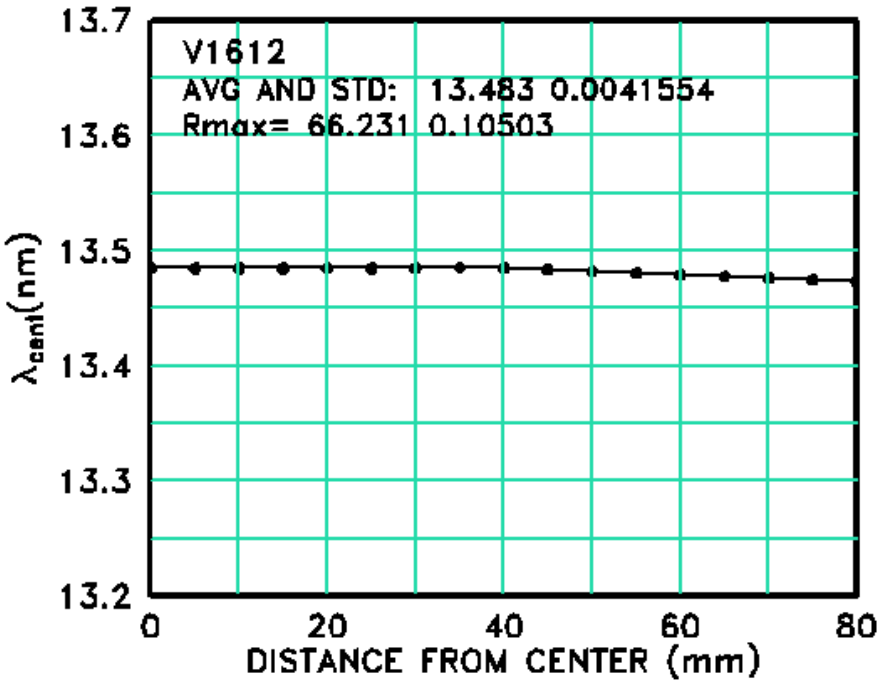
- This requires the deposition flux arriving at an off-normal angle, which is generally not conducive to particle smoothing.



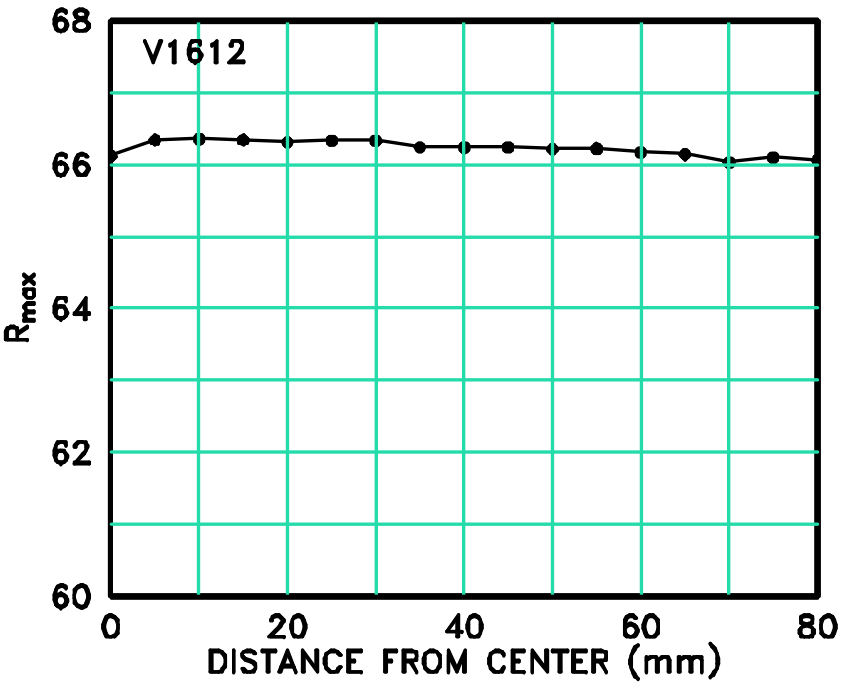
- With our process we can still smooth with an off-normal incidence angle in our deposition steps.

# We have coupled the 70 nm particle smoothing process with a process yielding excellent uniformity and good reflectivity

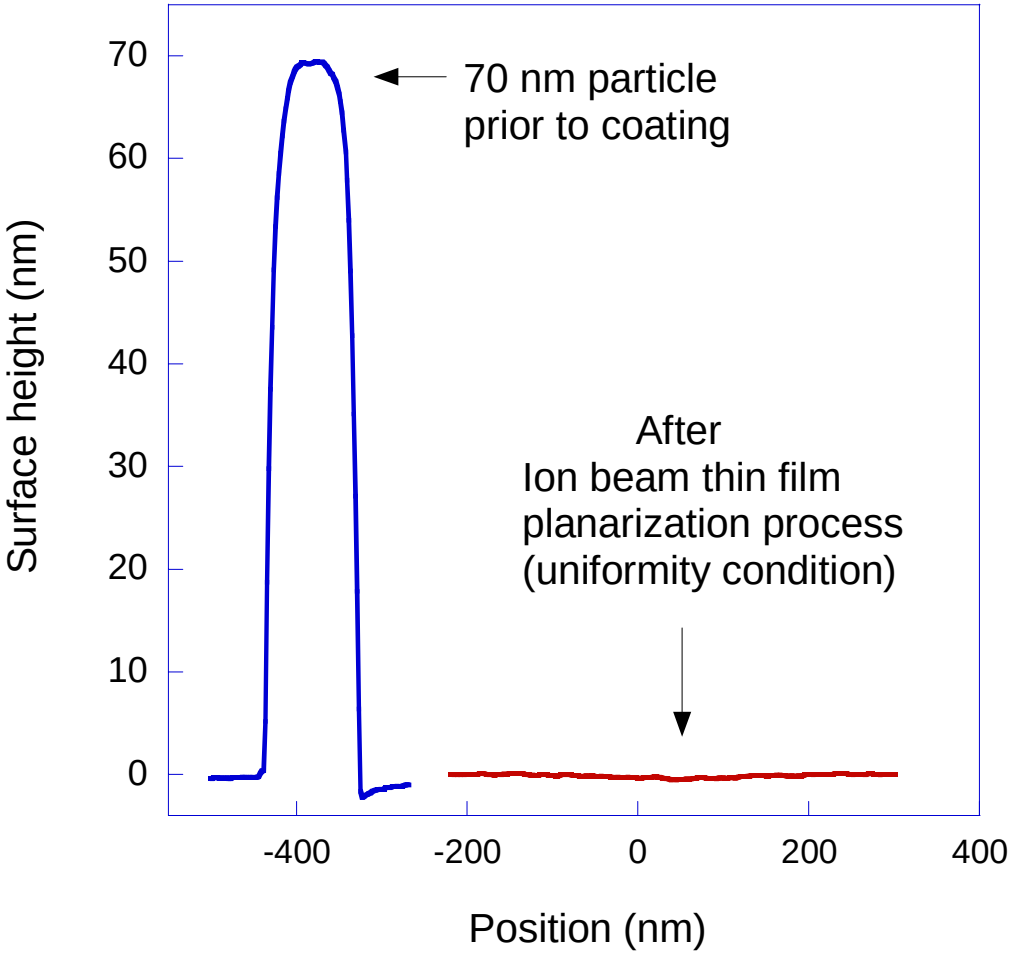
Centroid wavelength uniformity
Mean $\lambda$ = 13.483 nm
$\sigma$ = 0.00415 nm (0.03%)

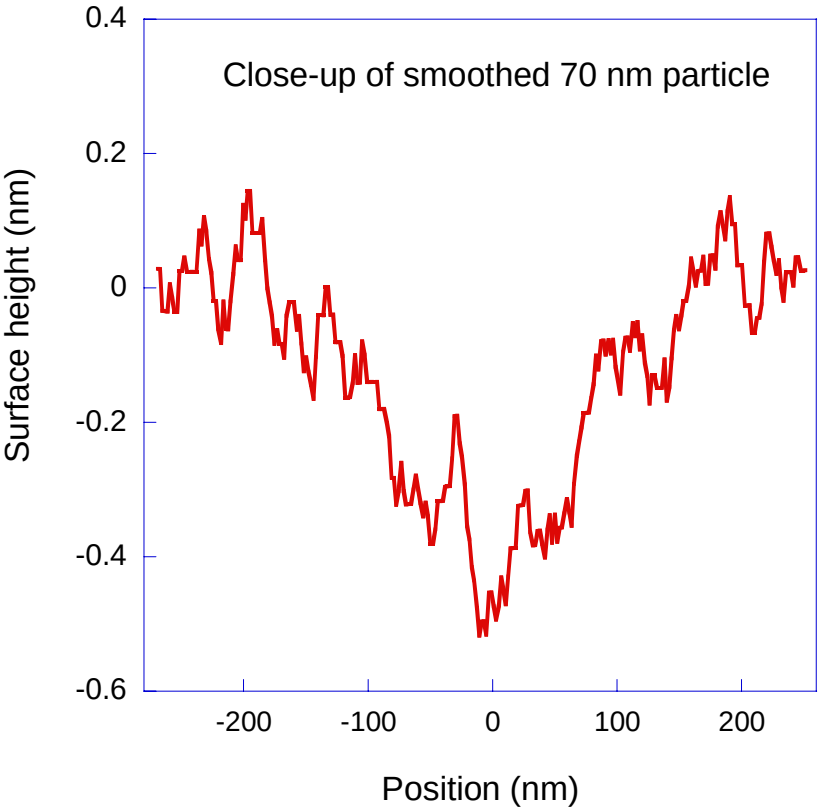



Reflectance uniformity
Mean R = 66.23%
$\sigma$ = 0.1050 nm (0.16%)

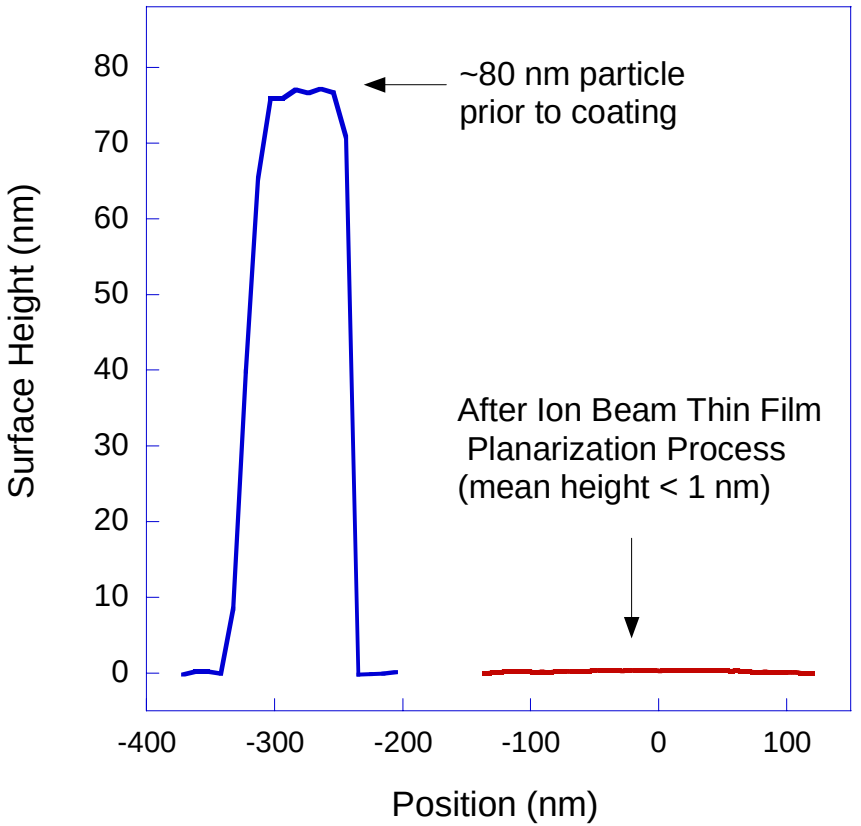


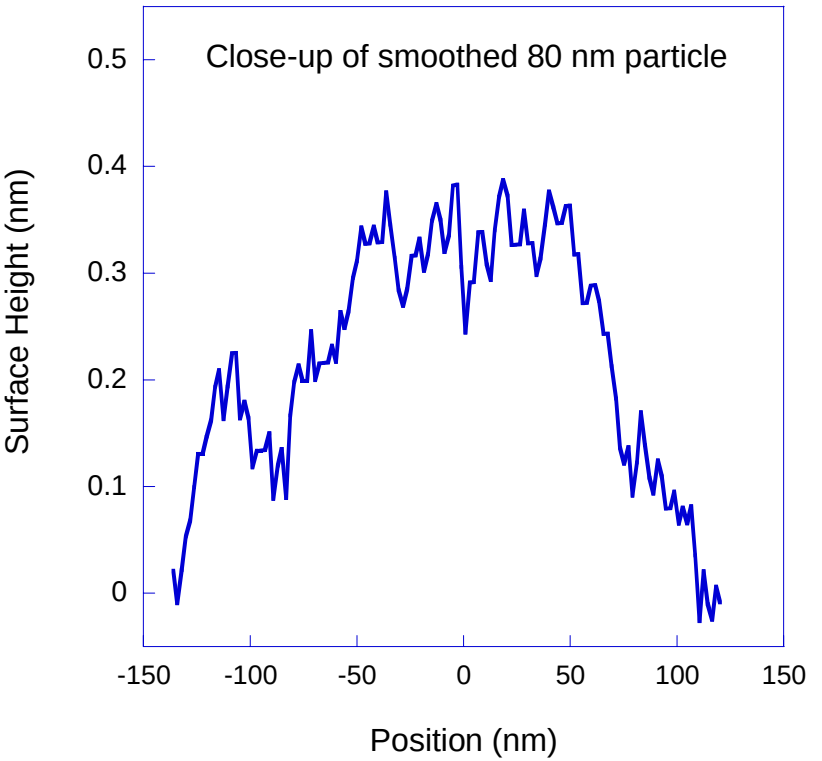
# Smoothing still renders particle defects nonprintable under conditions yielding excellent coating uniformity



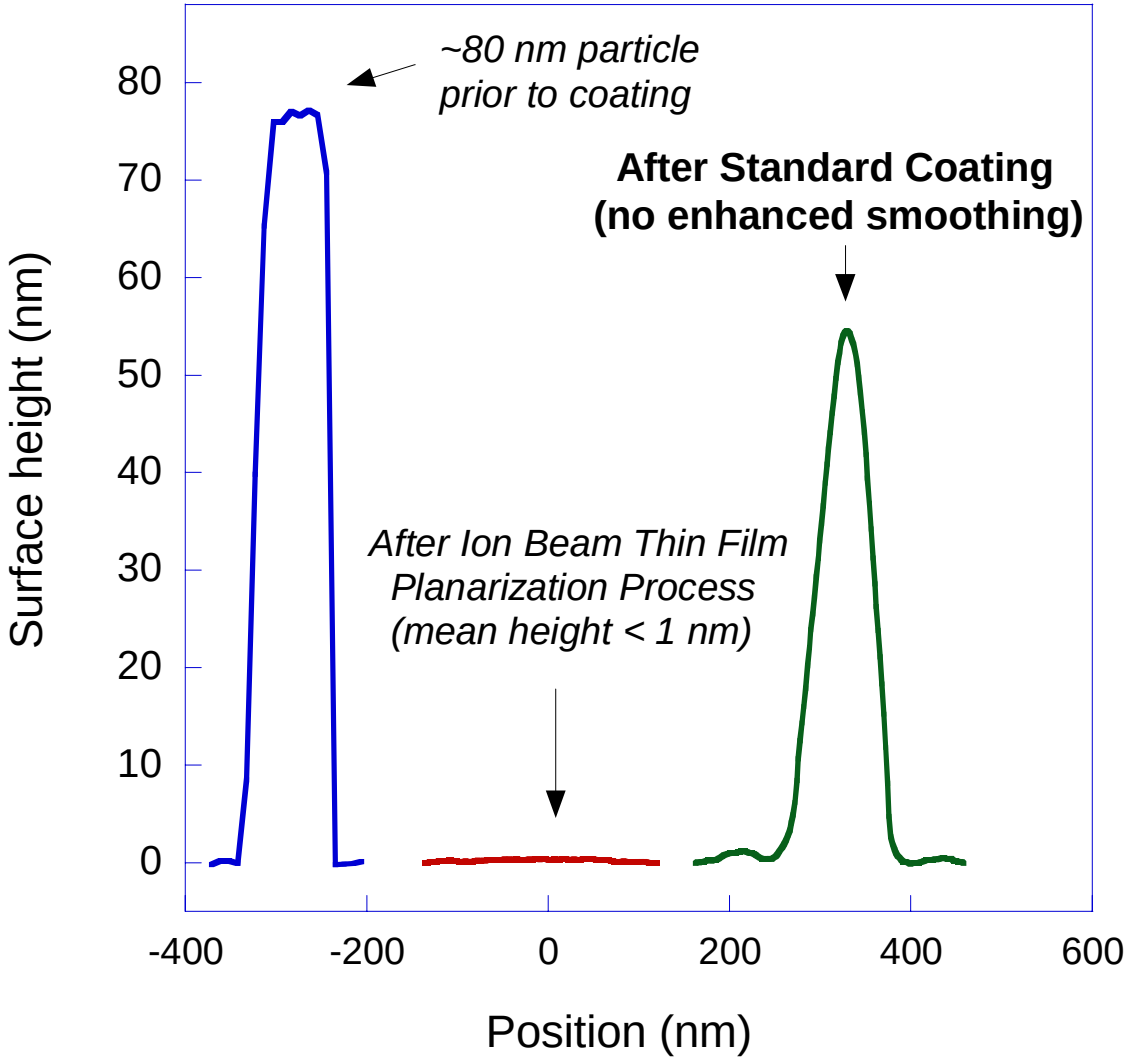



# The ion beam thin film planarization process has just been advanced to smooth 80 nm diameter substrate particles to below 1 nm in height



# The ion beam thin film planarization process has much greater particle smoothing properties compared to a standard Mo/Si deposition process



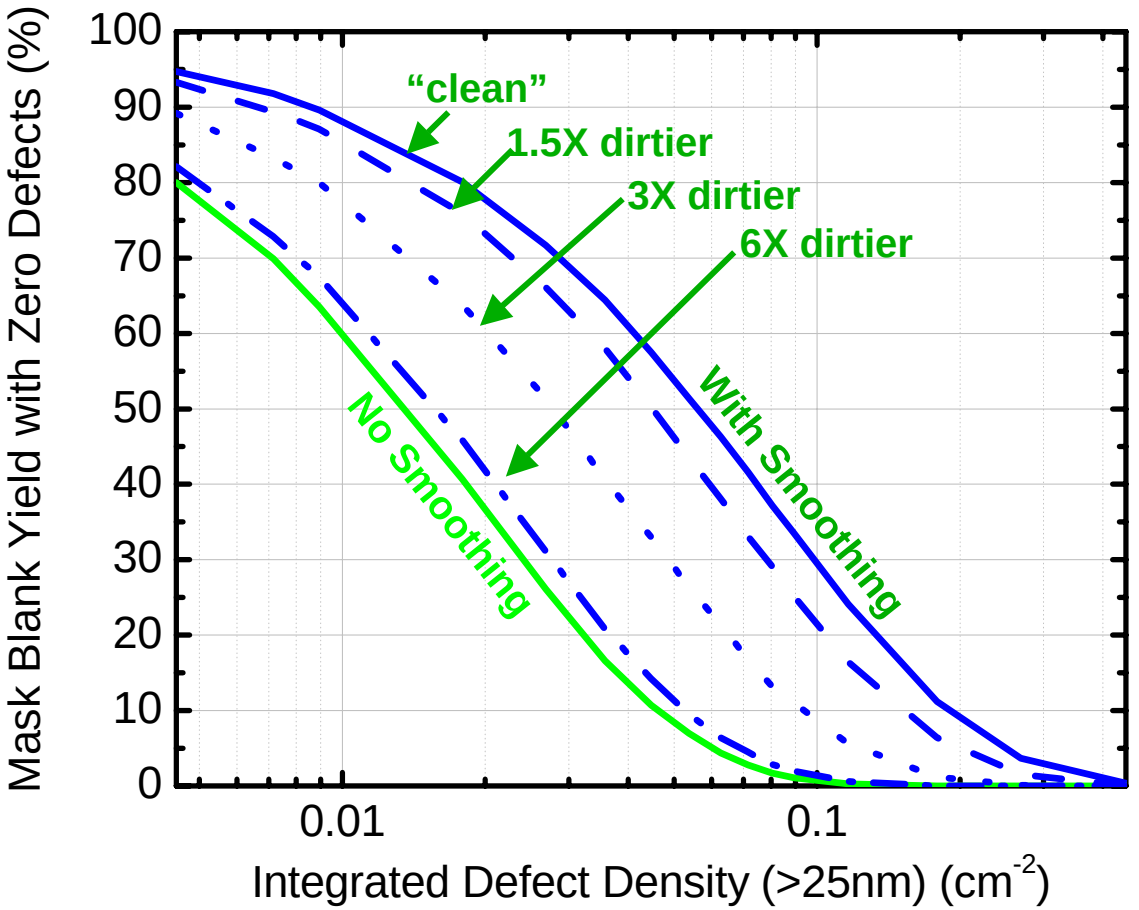
# There are two other important directions for the ion beam thin film planarization process (in addition to particle smoothing)

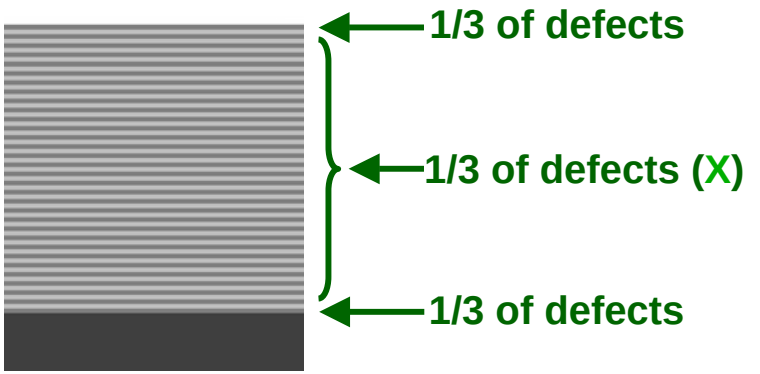
- Assess and improve cleanliness of smoothing process
- Smooth substrate pits and possibly scratches (note: there is no repair technique envisioned for multilayer pit defects, so smoothing would be particularly valuable)

We *will briefly discuss these topics in the following viewgraphs*

# Simulations indicate that the ion beam thin film planarization process must be relatively clean

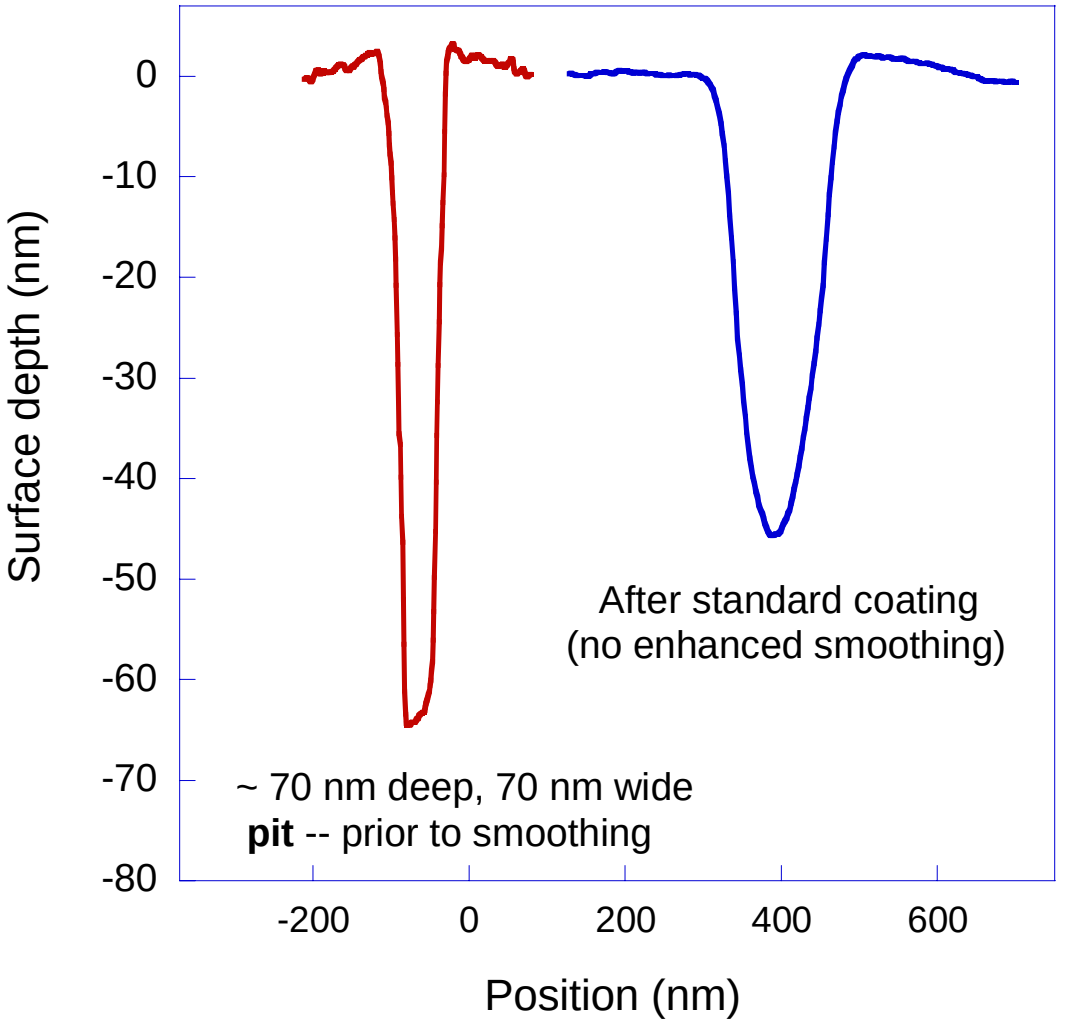
**(including defect repair)**



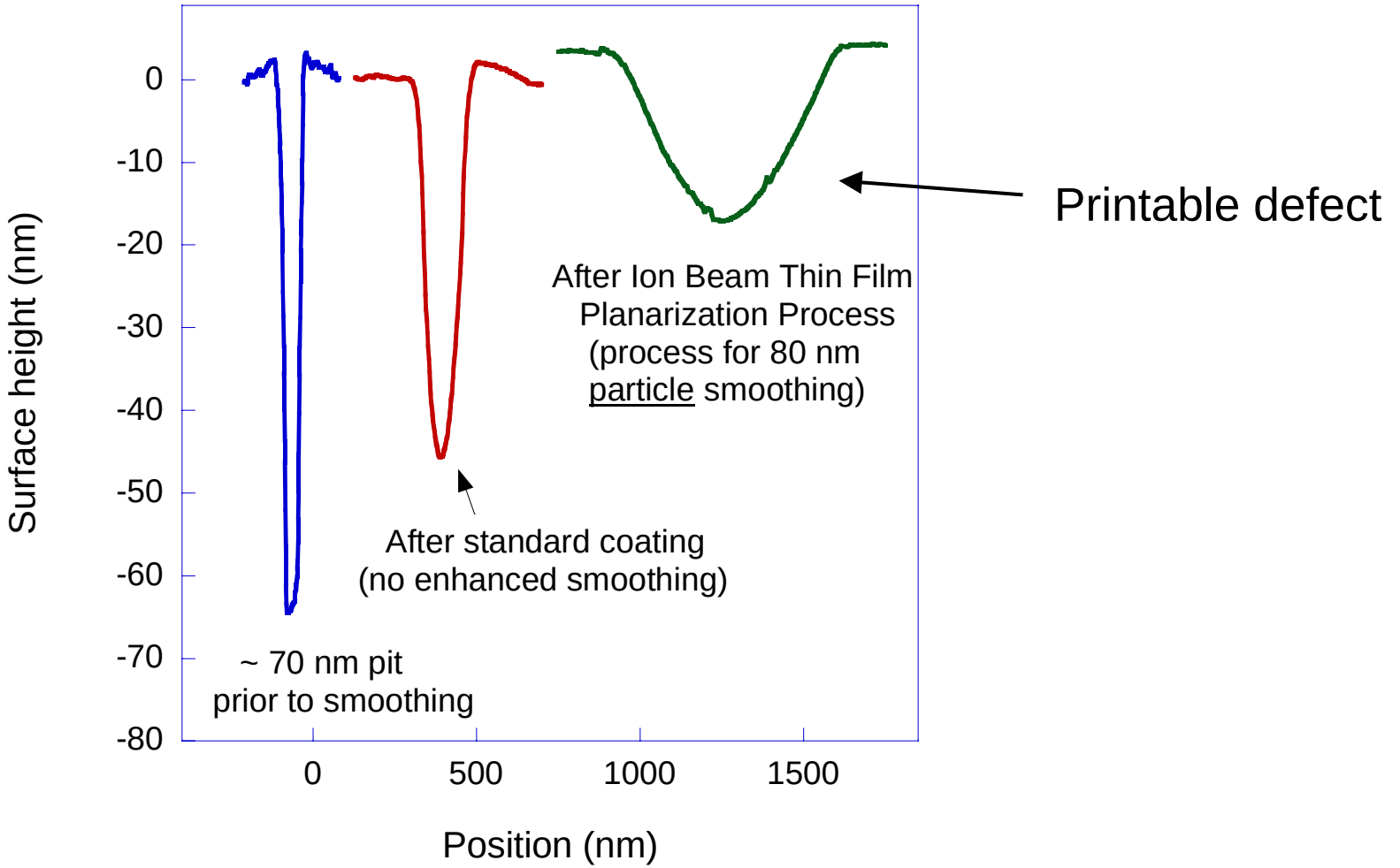




*Note: A project on this topic is anticipated in 2004 at ISMT-N, where Veeco Instruments and the VNL would play critical roles.*

# Have developed a process to produce substrates with programmed **pit** defects and have begun to evaluate smoothing of the pits



# More process development work is needed to smooth ~70 nm pit defects




This is definitely a challenge but we believe that we can make good progress in this (new) area by next year's symposium

# Summary

- The ion beam thin film planarization process has been advanced to smooth 60, 70, and 80 nm diameter particles to render them nonprintable.
- The 70 nm smoothing process has been coupled with a process yielding excellent uniformity and good reflectivity.
- Simulations indicate that the smoothing process must be made relatively clean.
- The first substrate pit defect samples have been produced, enabling us to evaluate smoothing of pits.
- Pit smoothing was observed but more process development is needed to render (~70 nm deep by 70 nm wide) substrate pits nonprintable upon coating.