Patterning Magnetic Recording Media by Deposition on Imprinted, Etched, Pillars

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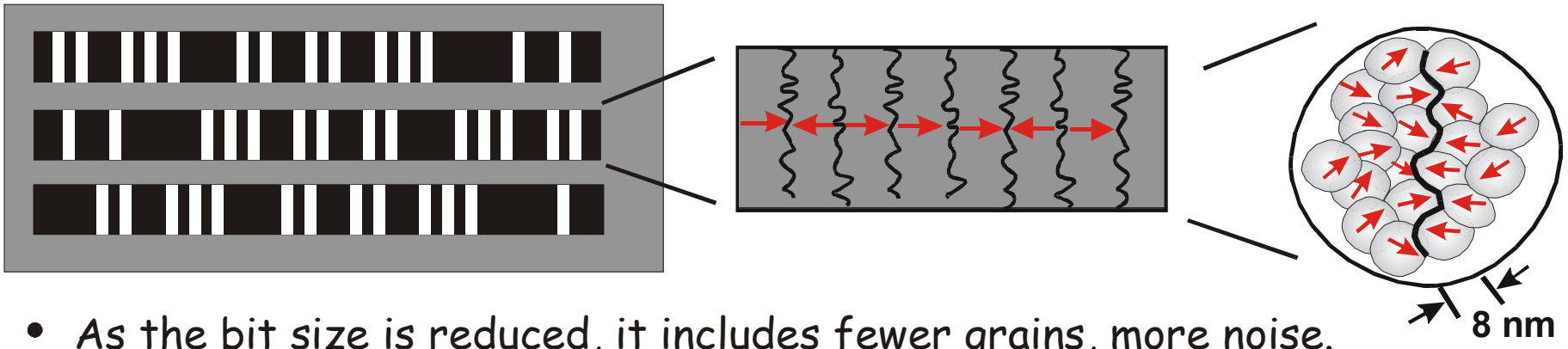
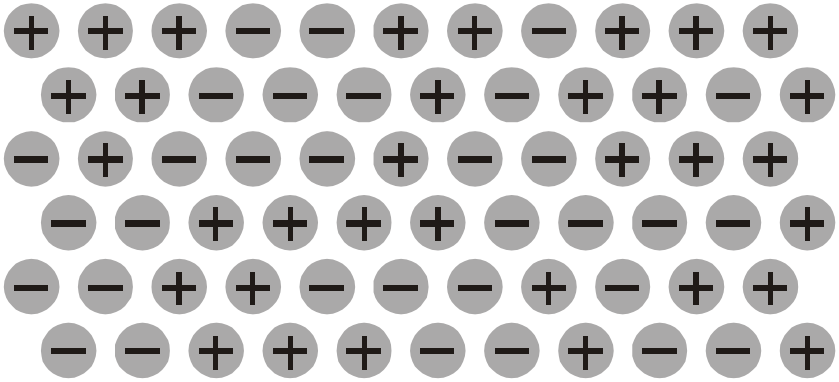
Conventional Granular Recording Media



- As the bit size is reduced, it includes fewer grains, more noise.
- If the grains are made smaller they come thermally unstable

Patterned Media

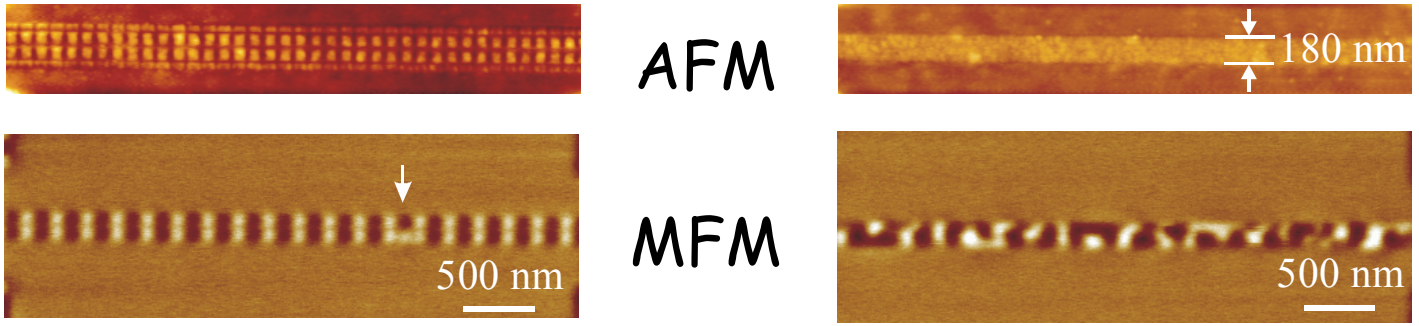


- Prepattern the location of magnetically isolated bits
- Isolated media smaller than about 100 nm forms single magnetic domains (exchange dominates magnetostatic interaction)
- Isolated bits down to <10 nm dia. can be stable

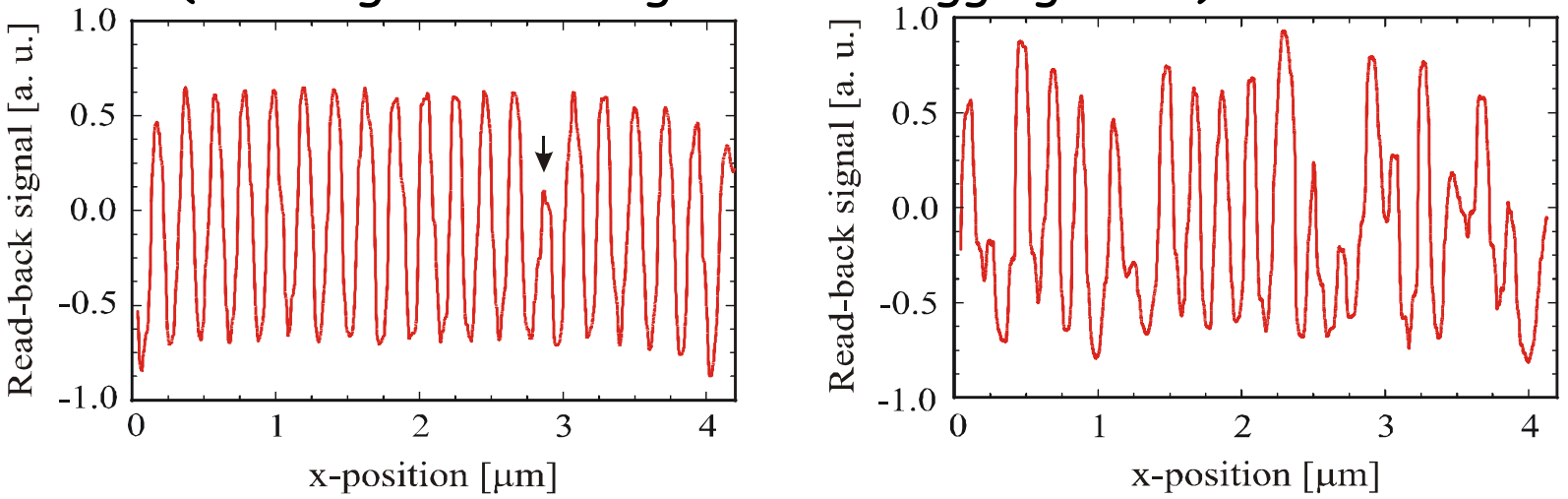
Patterned vs. Unpatterned Media

(Patterned with a focussed ion beam)

Written at the same linear density (9700 fc/mm)



(Reading and writing with a dragging head)



Contact Lithography Methods

Printing

Paper (200 BC)

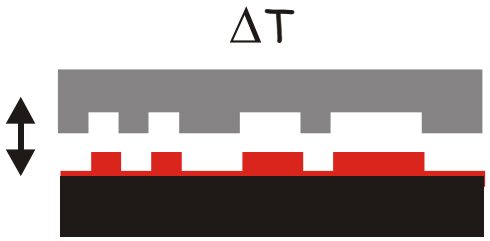
Microcontact Printing
(93) Whitesides

+chemistry
+fast
-low resolution
-poor etch resistance

Thermal Imprinting

Records (1900)

Nano-imprint lithography
(95) Chou

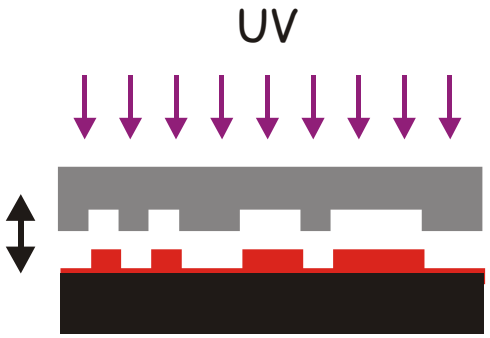


+simple
-somewhat slow
-thermal expansion
+Laser heating
+fast
+no expansion

Photocured Imprinting

Video disks (1980)

"Mold-assisted nanolithography:"
Haisma et al (96)
Willson



+fast
+low distortion

Imprint for microelectronic Lithography

+Intrinsic Resolution < 1nm

+No resist development process to degrade resolution

+3D patterning 

+Alignment is made easier by contact

(contact distortion not problem)

-A 1:1 technique

e-beam mastering unlikely below 20 nm

EUV to make stampers?

! Much needs to be done on defects and alignment

Imprinting for Patterning Magnetic Media

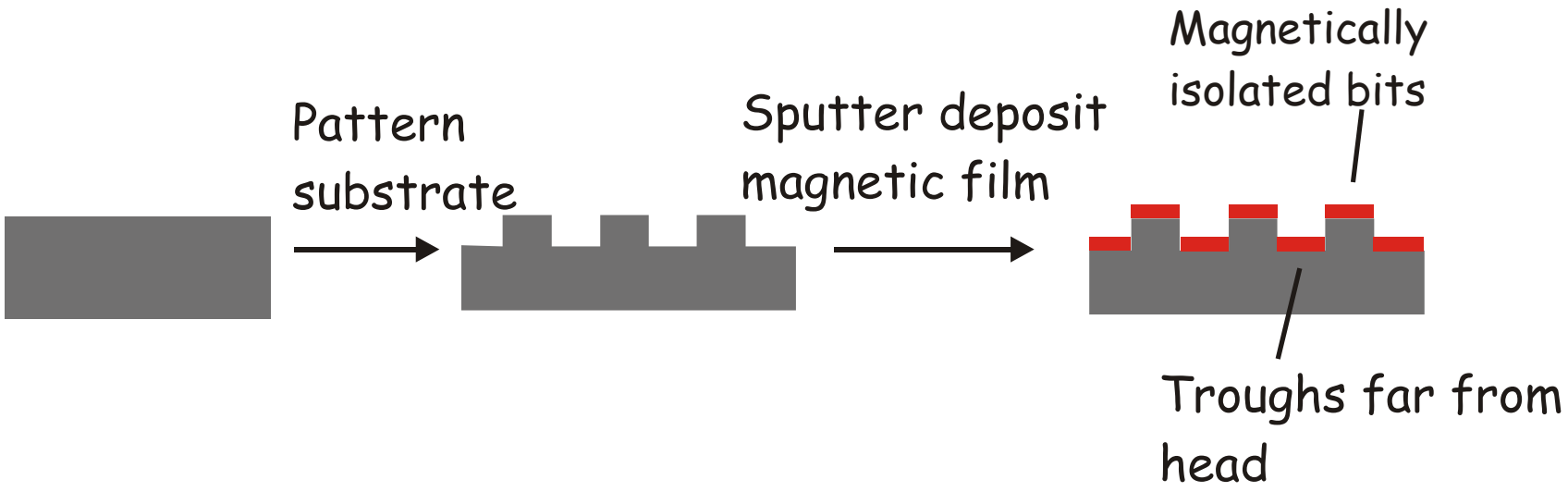
(Chou et al., 1998.)

- High Resolution Required: In 2006, 500 Gbit/in^2
  - 20 nm bits on 40 nm period, on circular tracks
  - extendable
- Low patterning cost: <= $1/disk
- But:
  - Only a single litho level required
  - Long range distortion > 1mm accommodated by head actuator
  - Defects (up to 10^{-3}) handled by error correction

Magnetic Patterning Methods

- Patterning the magnetic film
  - additive - lift off
  - subtractive - etching/milling
- Patterning the magnetics (by ions)
  - Poisoning by implantation
  - Disorder
- Patterning the substrate
  - Pattern holes and fill (Chou)
  - Pattern pillars (imprinting)

Substrate Patterning for Magnetic Isolation



- Because lithography is completed before film deposition, no process compatibility issues

  Implemented using thermal imprinting by
  Moritz, Landis, Nozières, Lebib, Chen, Diény, J. Appl. Phys., 91, 2002

- Also directly imprinted plastic substrates (no resist)
  imprinting provides surface finish

An Imprinting Process for Magnetic Patterning

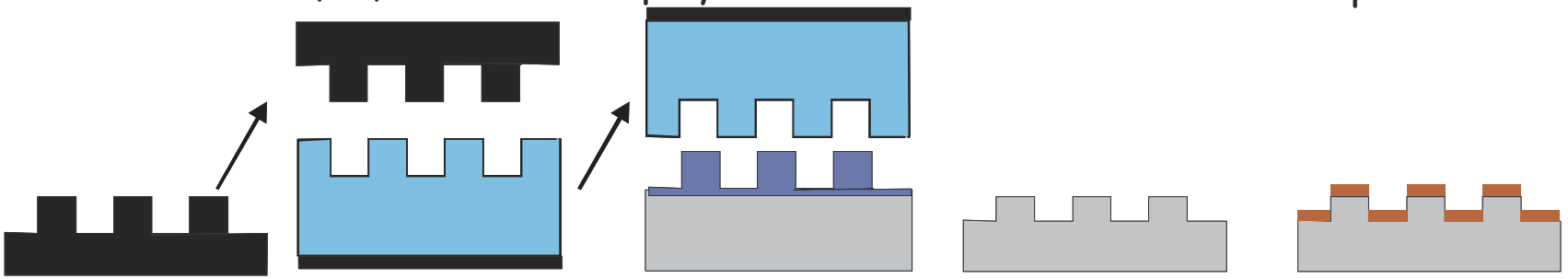
Make master by e- beam lithography

Form stamp by photo-polymerization

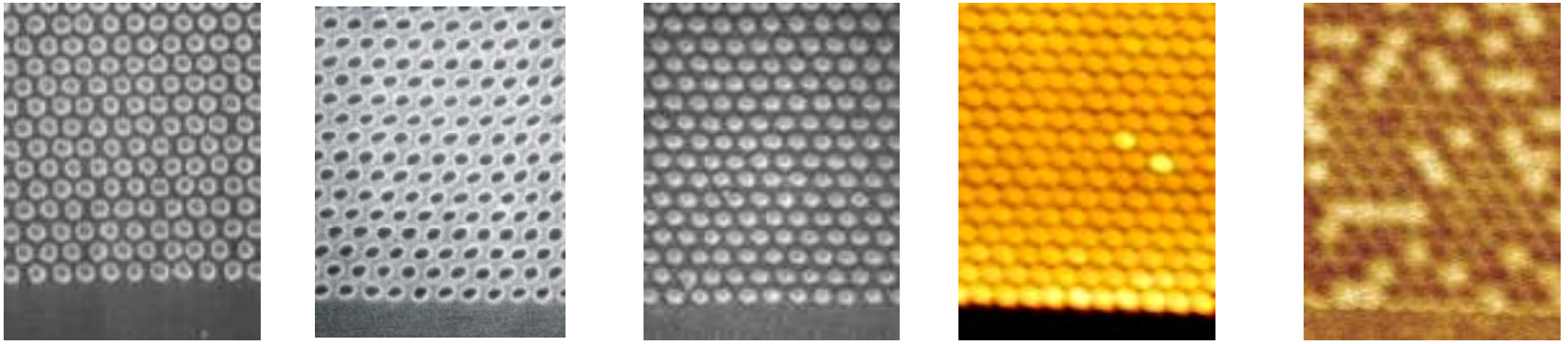
Form replica by photo-polymerization

Transfer Pattern by RIE

Deposit CoPt Multilayer by Evaporation

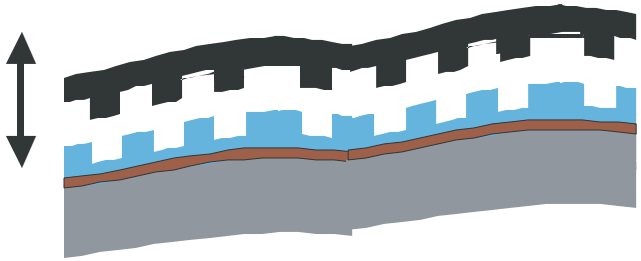


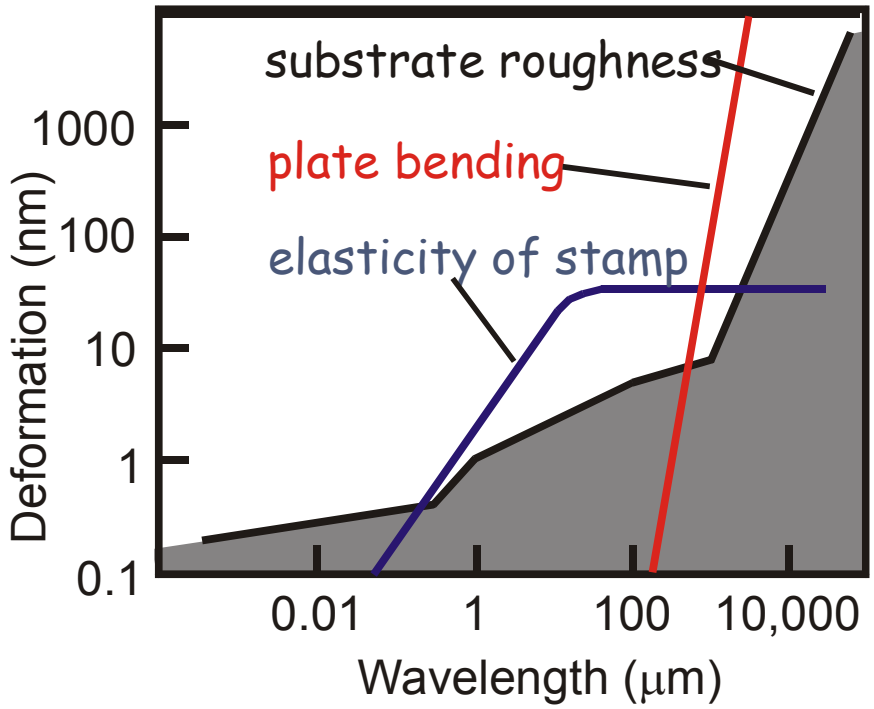
1 μm

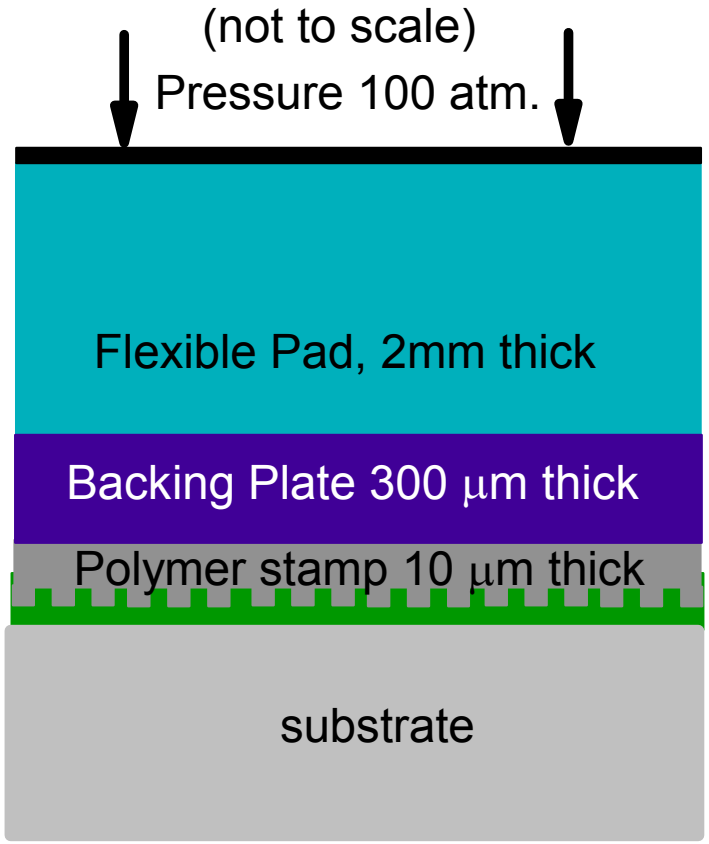


A stamp to Conform to Surface Roughness

- Maintain Bit Shape
- Long range order: 2nm over 1mm
- Conform to disk roughness and curvature

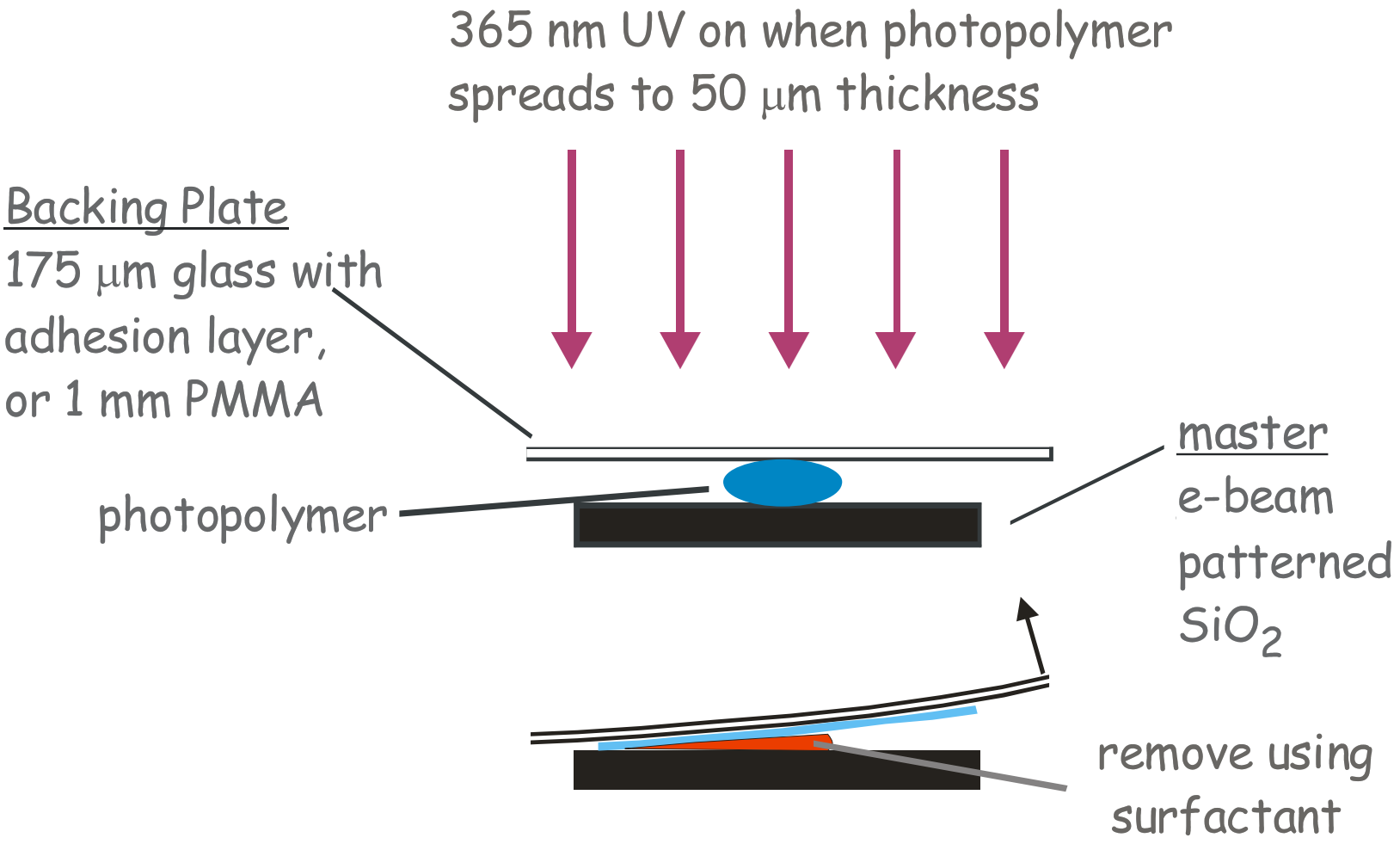




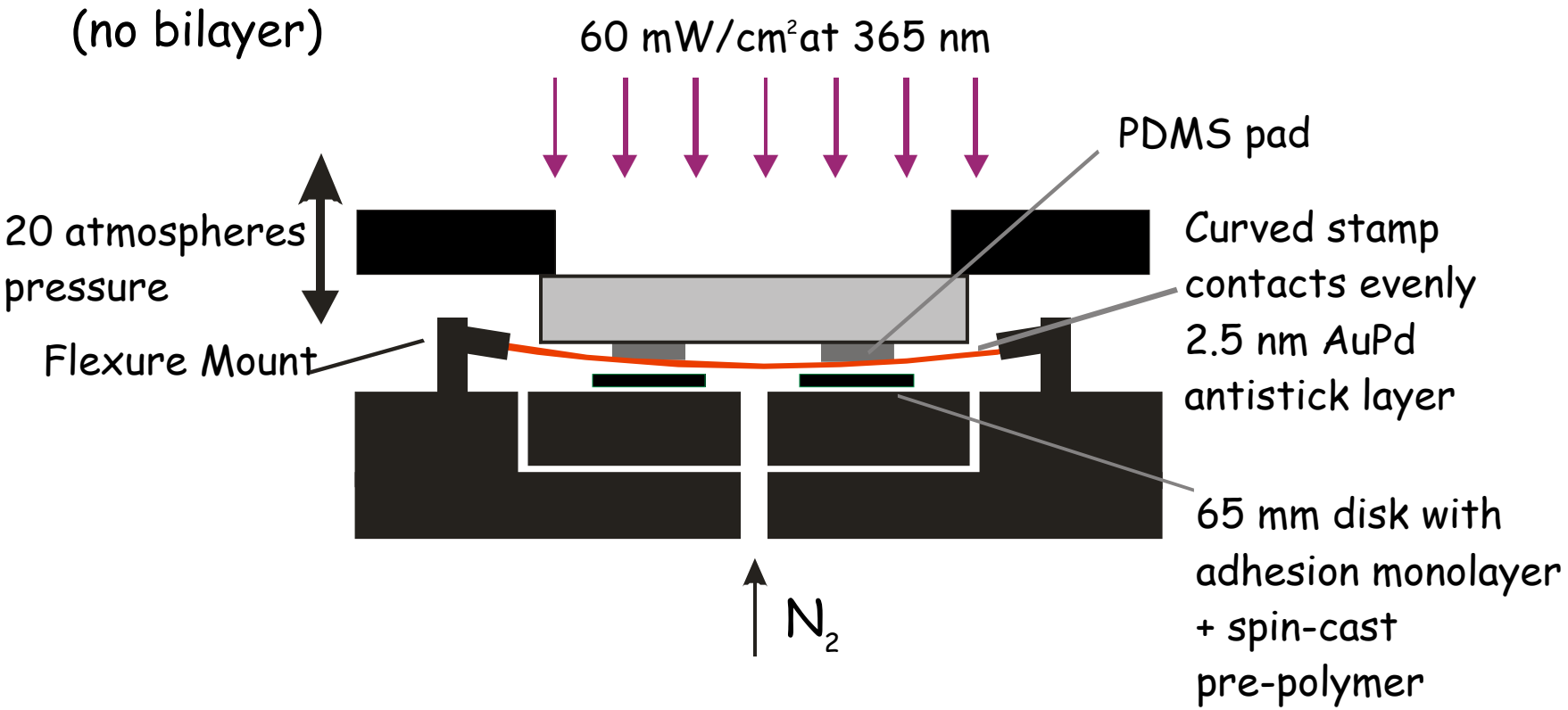


Flow of (spun) resist

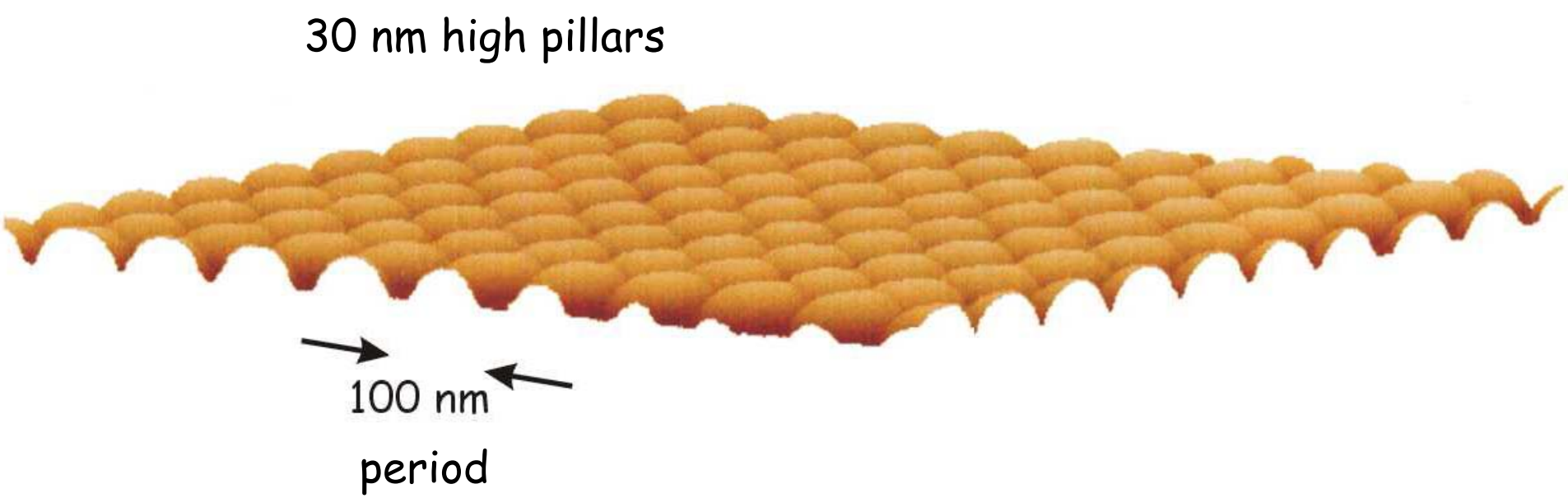
Making a Stamp from a Master



Imprinting a Replica



Imprinted Replica

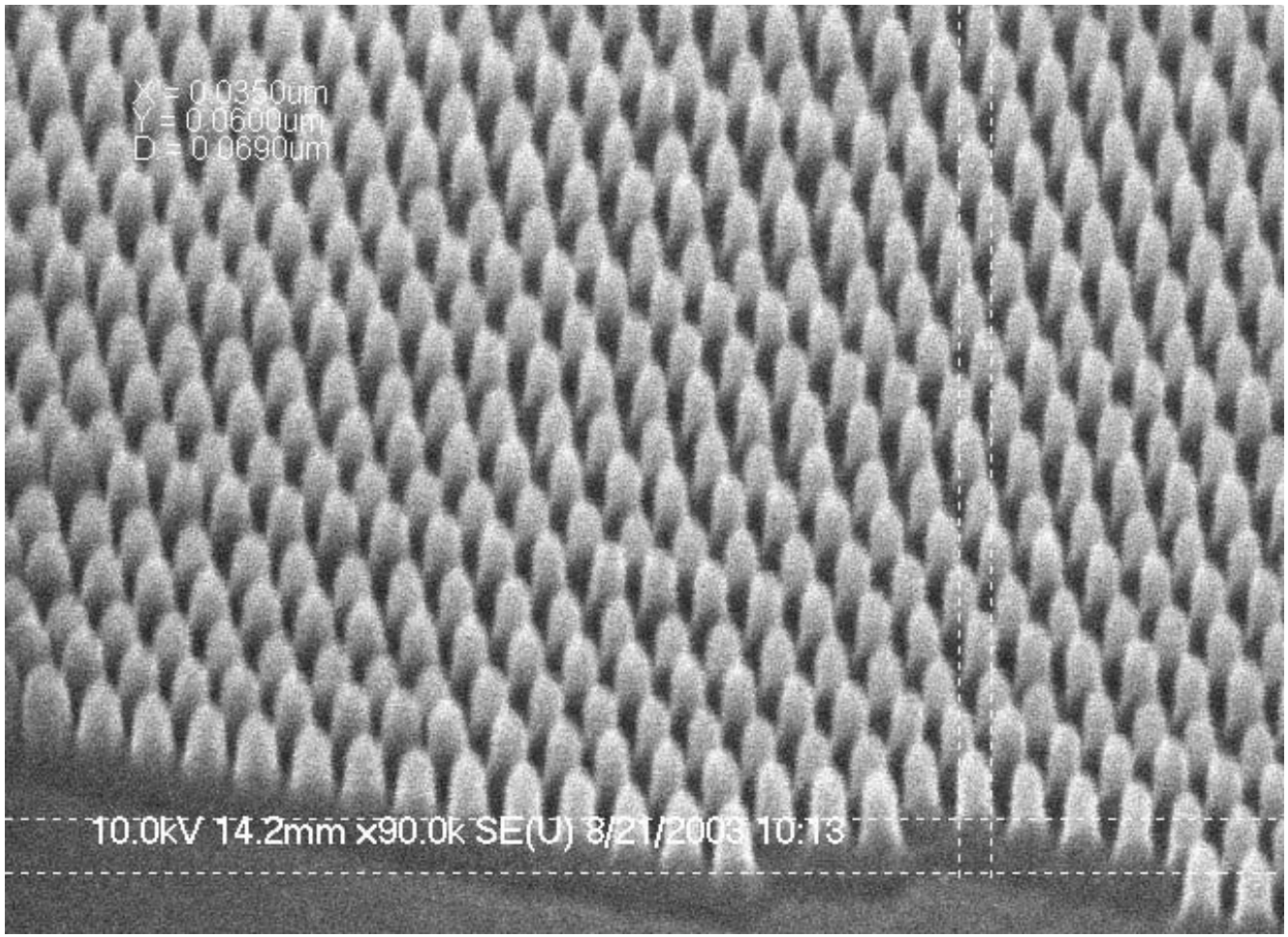


Resist Pillars

Diameter: 30 nm

Period: 50 nm

Height: 50 nm over 20 nm base



Serpentine Test Pattern Imprint

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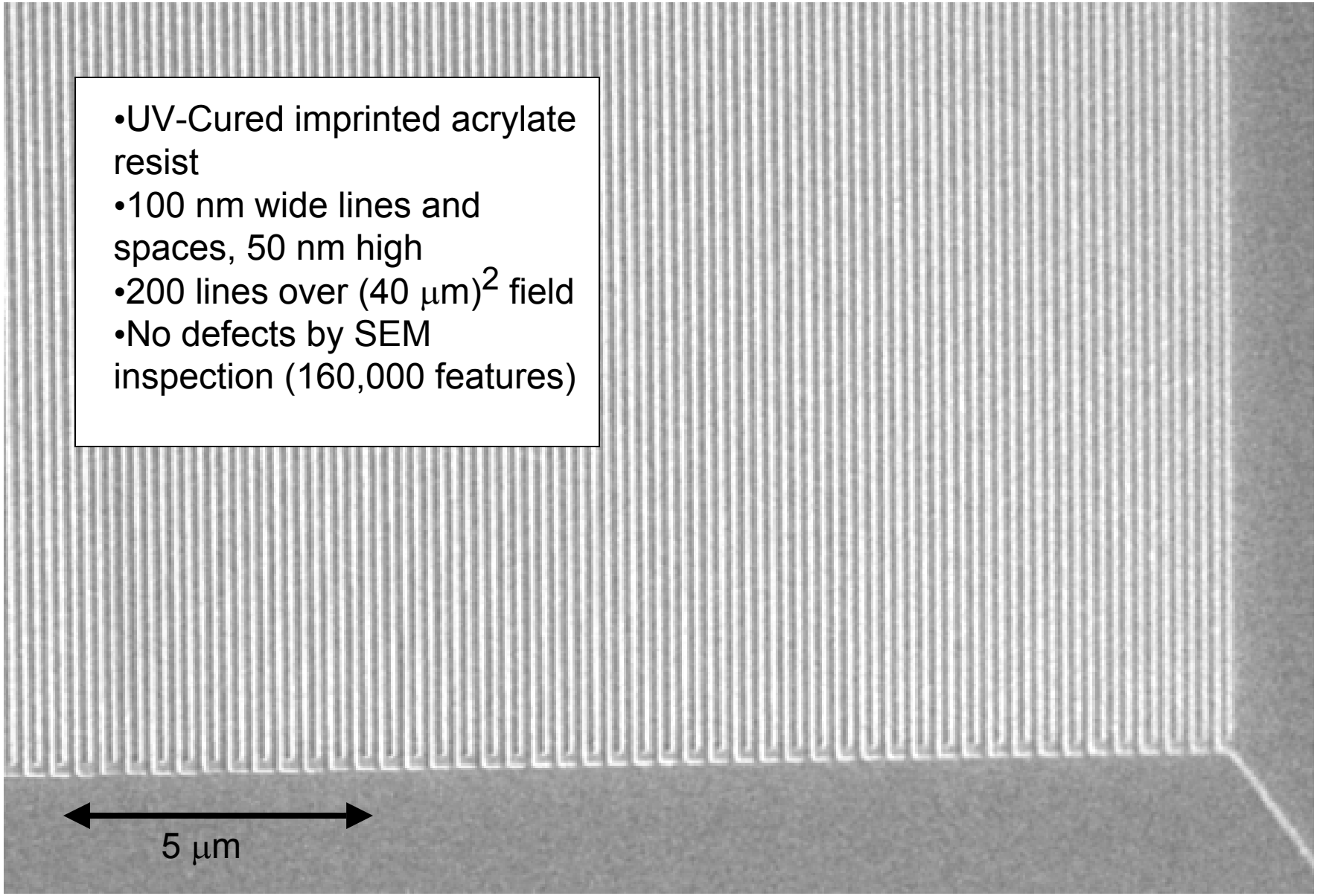


Multiple Imprint Defect Rates

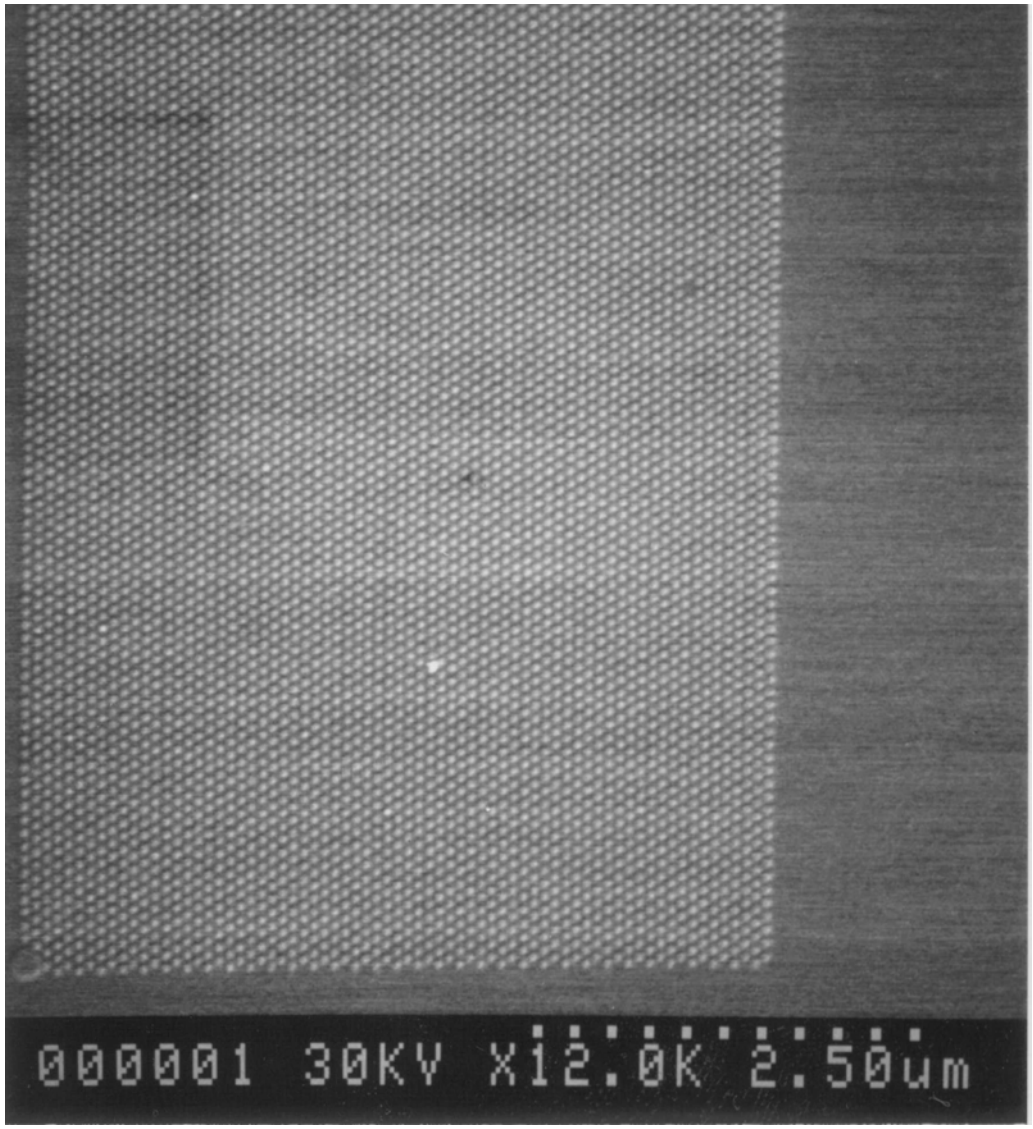
11th imprint from a single polymer stamp

60 nm pillars on 100 nm hexagonal array

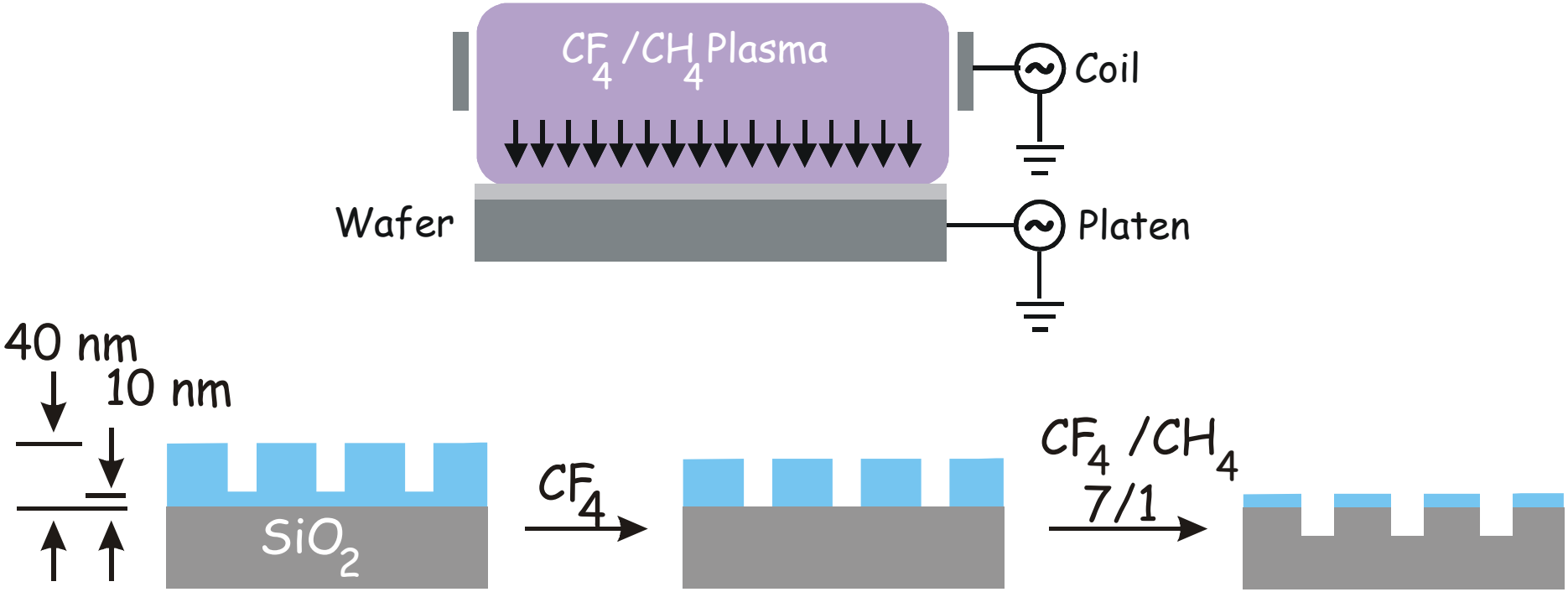
about 7000 pillars shown

pillar-size defect rate 1-2/10,000

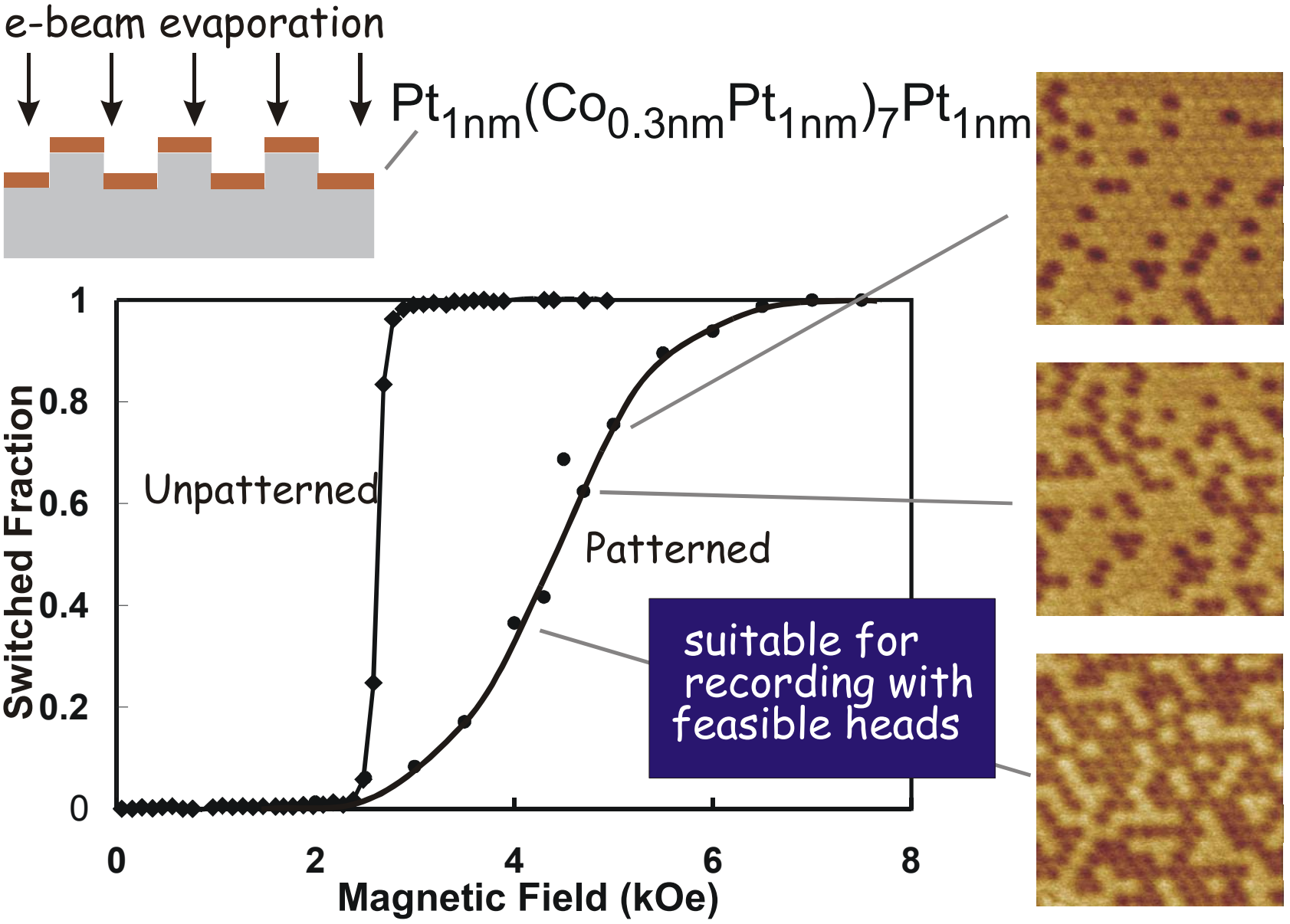
self-cleaning



Transferring Stamped Pattern



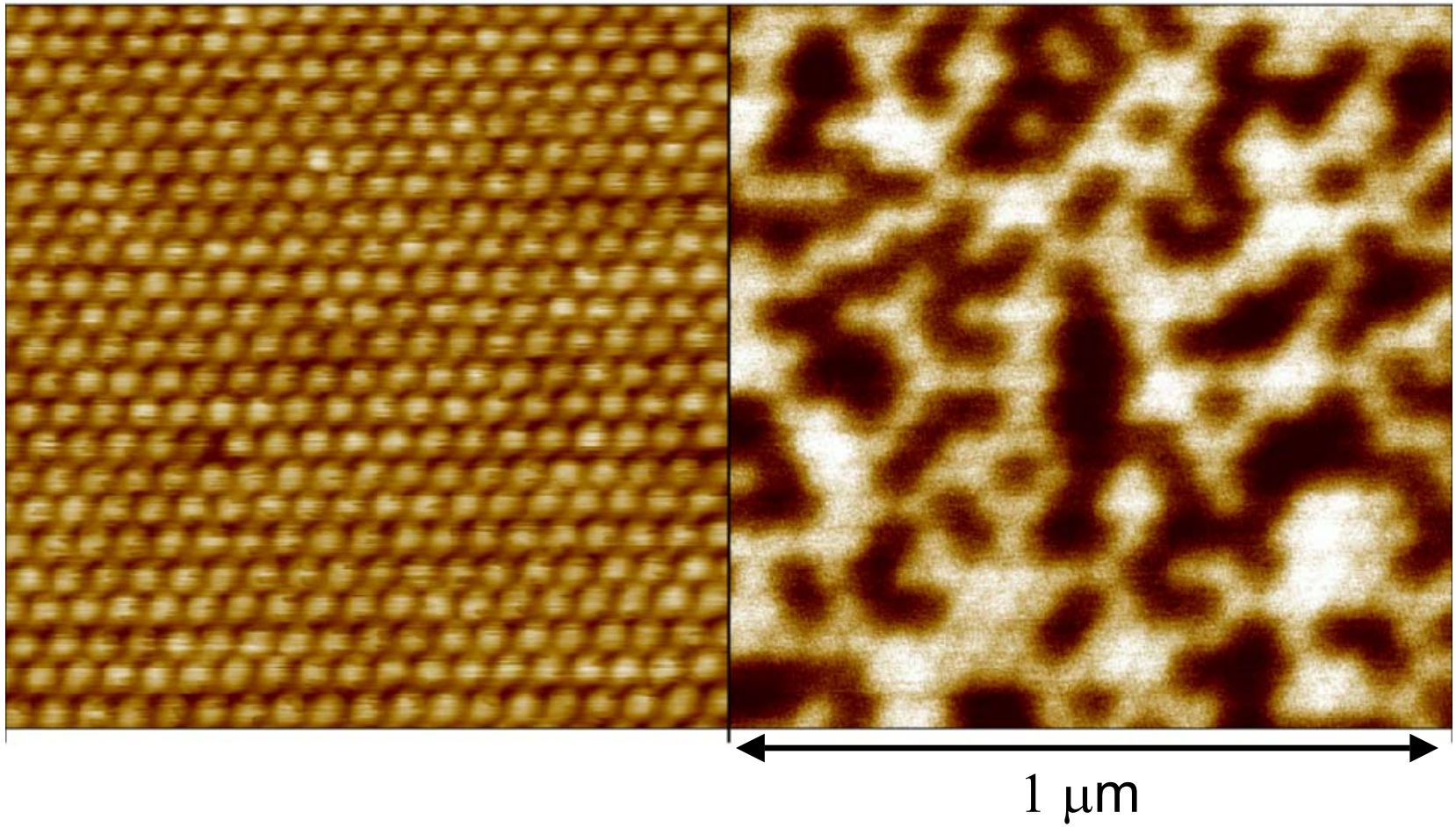
Magnetic Film Deposition and Characterization



300 Gb/in^2 Co/Pd Multilayers

Sputtered films on e-beam patterned pillars (S. Anders)

AFM MFM



Summary

- Patterning magnetic media can achieve high recording densities with low noise and high thermal stability

- This application is well-matched to the capabilities and limitations of imprinting.

- From an e-beam master, an almost unlimited number of flexible stamps can be formed.

- The flexible stamp accommodates surface roughness and curvature over the disk.

- Patterning pillars in the substrate provides magnetic patterning, eliminating processing after magnetic film deposition.