Nanoimprint lithography at Hewlett-Packard

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MIT
Stanford
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Nanotechnology Forum

Outline

- Overview of hp's portfolio in nanotechnology
- The problems with photolithography
- Why hp is interested in nanoimprint lithography

Nanotechnology research @ hp

Quantum Science Research, Palo Alto

Director	Dr. R. Stanley Williams
Nanimprint:	Dr. William Tong
	Dr. Gun-Young Jung
	Dr. Wei Wu
Nanofabrication:	Dr. Saif Islam
	Ms. Xuema Li
Chemistry:	Mr. Douglas A. A. Ohlberg
	Dr. Zhiyong Li
Bottoms-up fab:	Dr. Ted Kamins
	Dr. Shashank Sharma
Electrical metrology:	Dr. Duncan Stewart
Comp architecture:	Mr. Phil Kuekes
	Mr. Greg Snider
	Mr. Warren Robinett
Theory	Dr. Alexander Bratkovski

Applied Molecular Sys., Corvallis

Managers:	Ms. Susan Richards
	Dr. Ken Abbot
	Dr. James Stasiak
Nanofabrication:	Mr. Jim Ellenson
	Mr. Tim Hostetler
	Dr. Ken Kramer
	Dr. Kevin Peters
	Dr. Jennifer Wu
	Dr. Qingqiao Wei
	Dr. Tim Meyer
Chemistry:	Dr. Garry Hinch
	Dr. Tom Etheridge
Electronic materials:	Dr. Sven Moeller
	Dr. Randy Rannow

Lawrence Berkeley National Lab

- Dr. Deirdre Olynick
- Dr. Alex Liddle

UCLA

- Prof. F. Stoddart – Dept. Chemistry & Biochem
- Prof. Yong Chen – Dept. Mech. Eng.

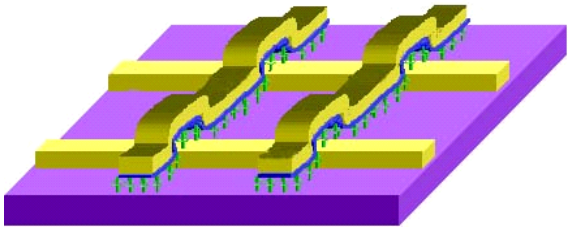
Caltech

- Prof. Jim Heath – Dept. Chemistry

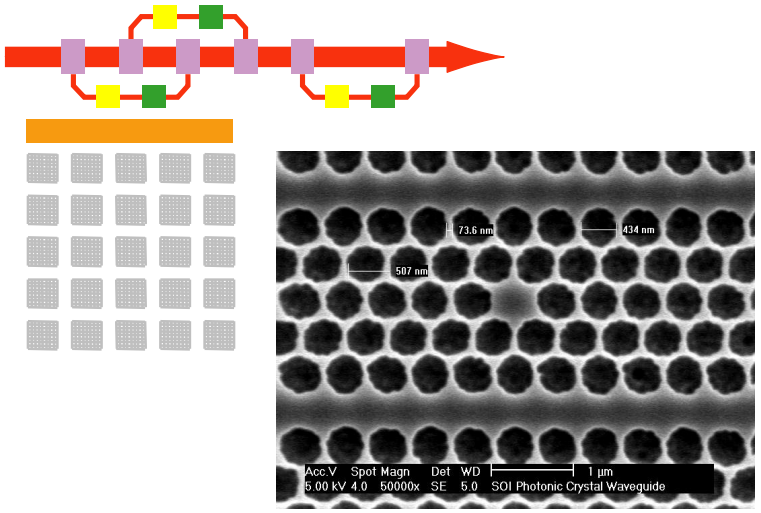
*Funding partly provided by DARPA

Areas of research for QSR

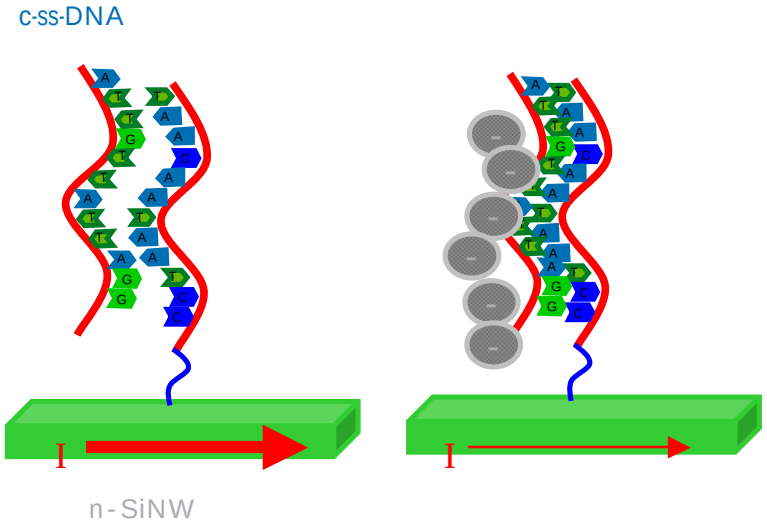
- Why go “nano”?
  - Because certain intrinsic properties of matter, e.g color, chemical reactivity, and electrical resistivity, depends strongly on the size and shape at the nanoscale.



Molecular electronics

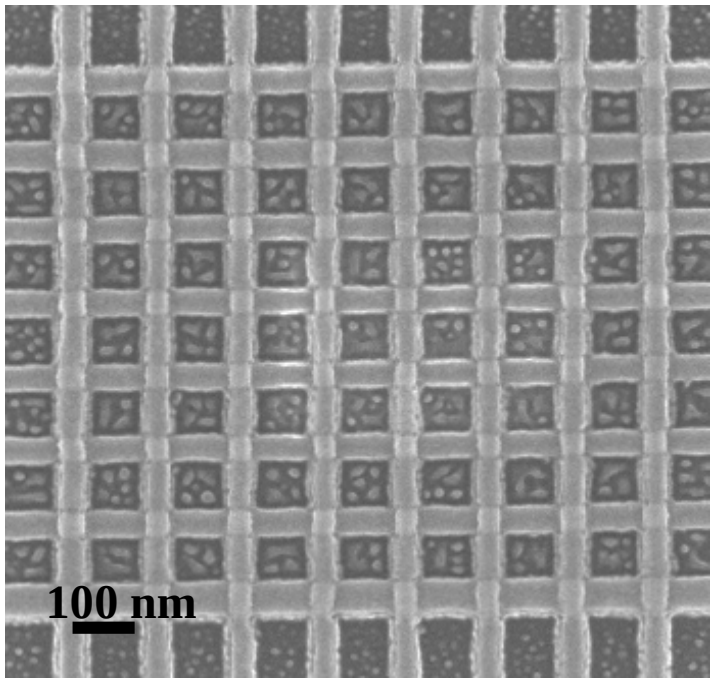


Photonics

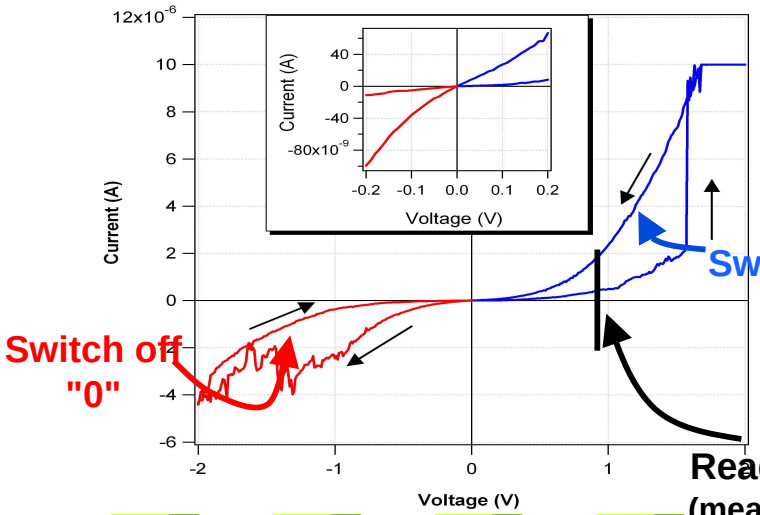


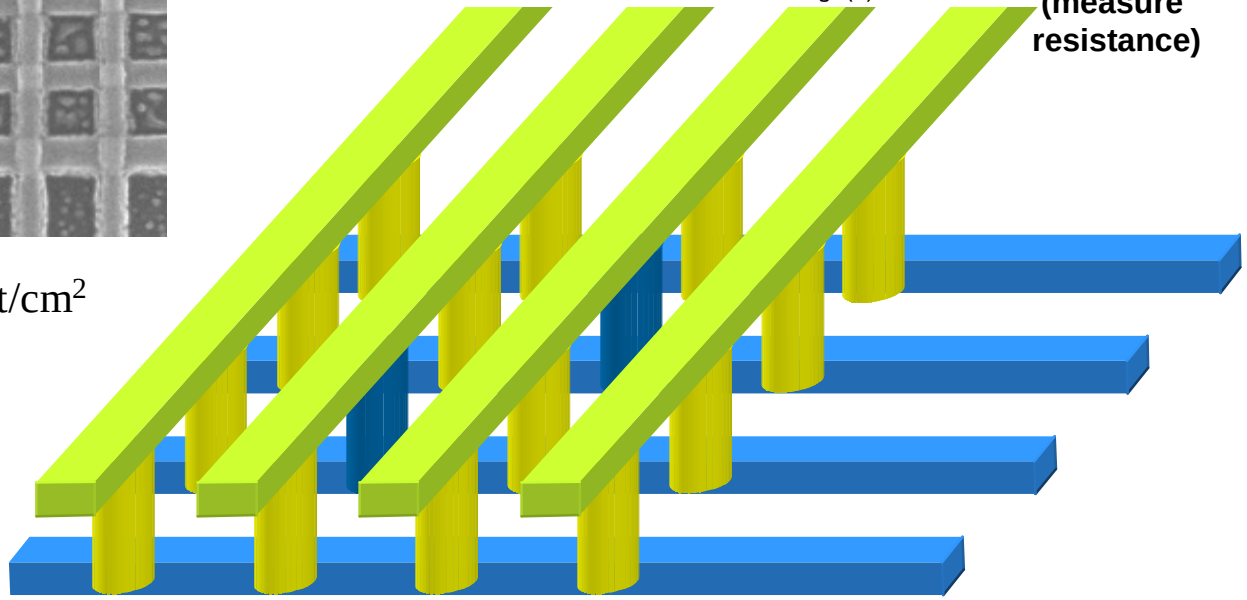
Sensors

Nanoimprinted crossbar molecular switch memory



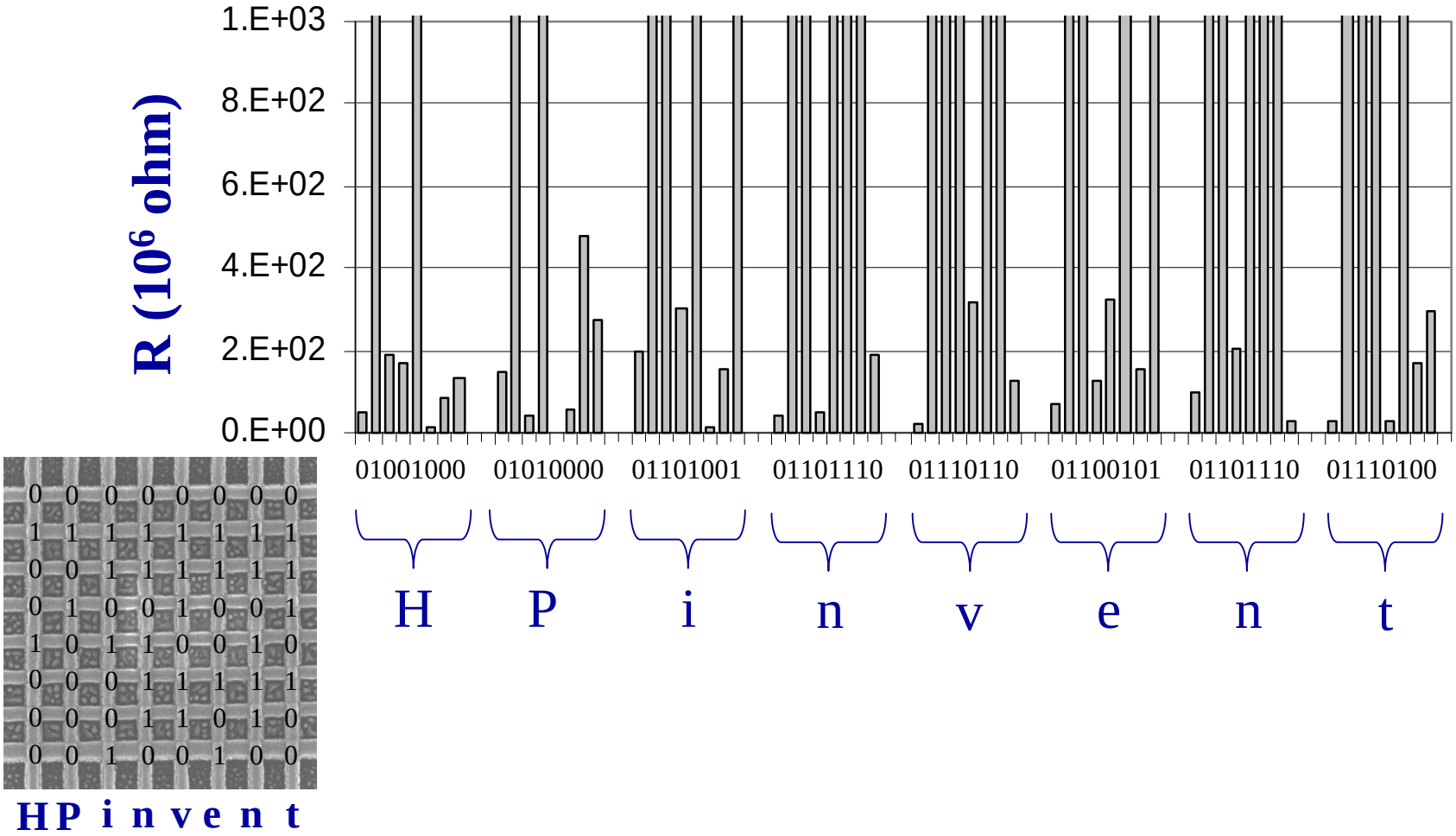
Cell density : 6.4 Gbit/cm^2





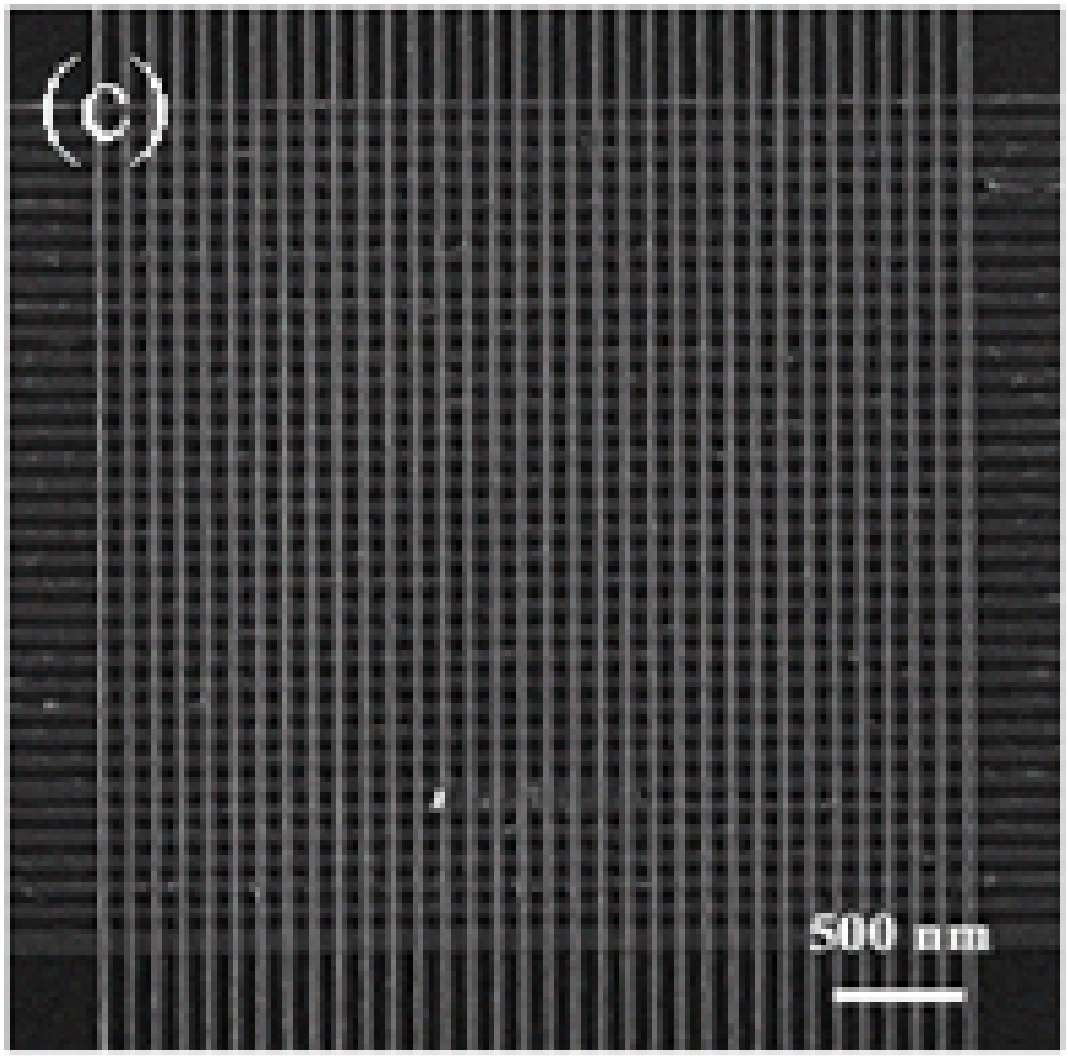
Y. Chen, G. Jung, et al. "Nanoscale molecular-switch crossbar circuits", Nanotechnology, 14, 462 (2003)

“HPinvent”



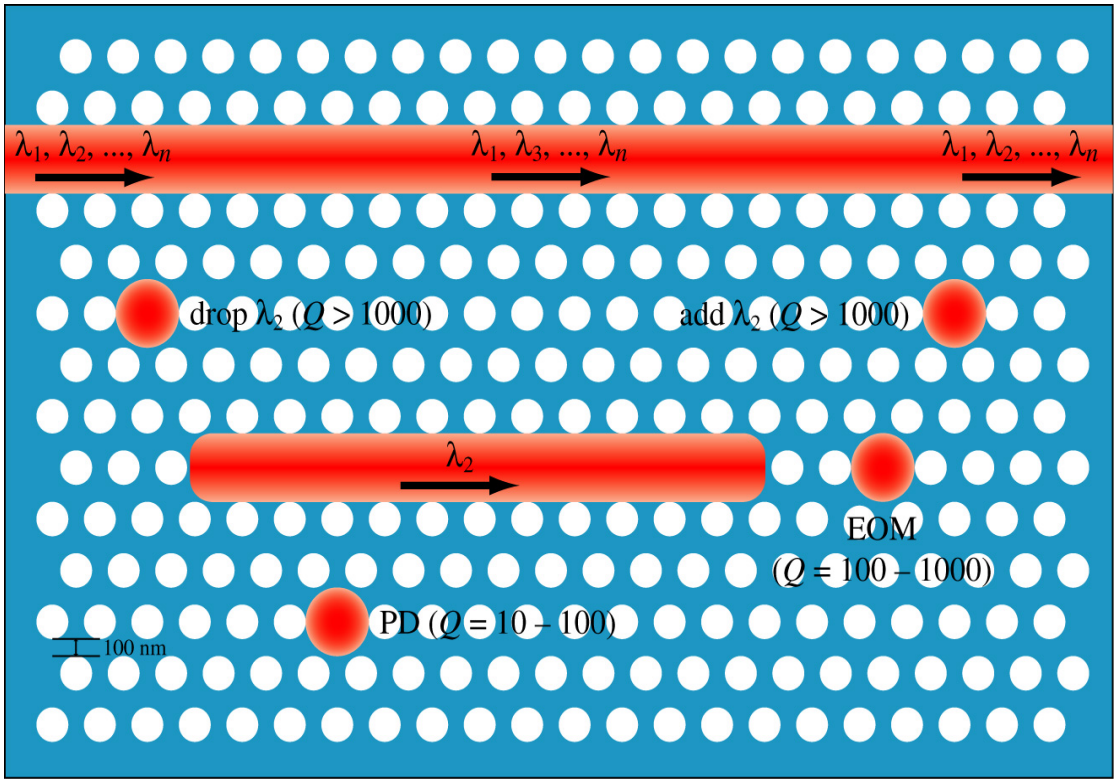
Y. Chen, G. Jung, et al. “Nanoscale molecular-switch crossbar circuits”, Nanotechnology, 14, 462 (2003)

Sub-50 nm hp resolution achieved



G. Y. Jung (HP Labs), to appear in Nano Letters

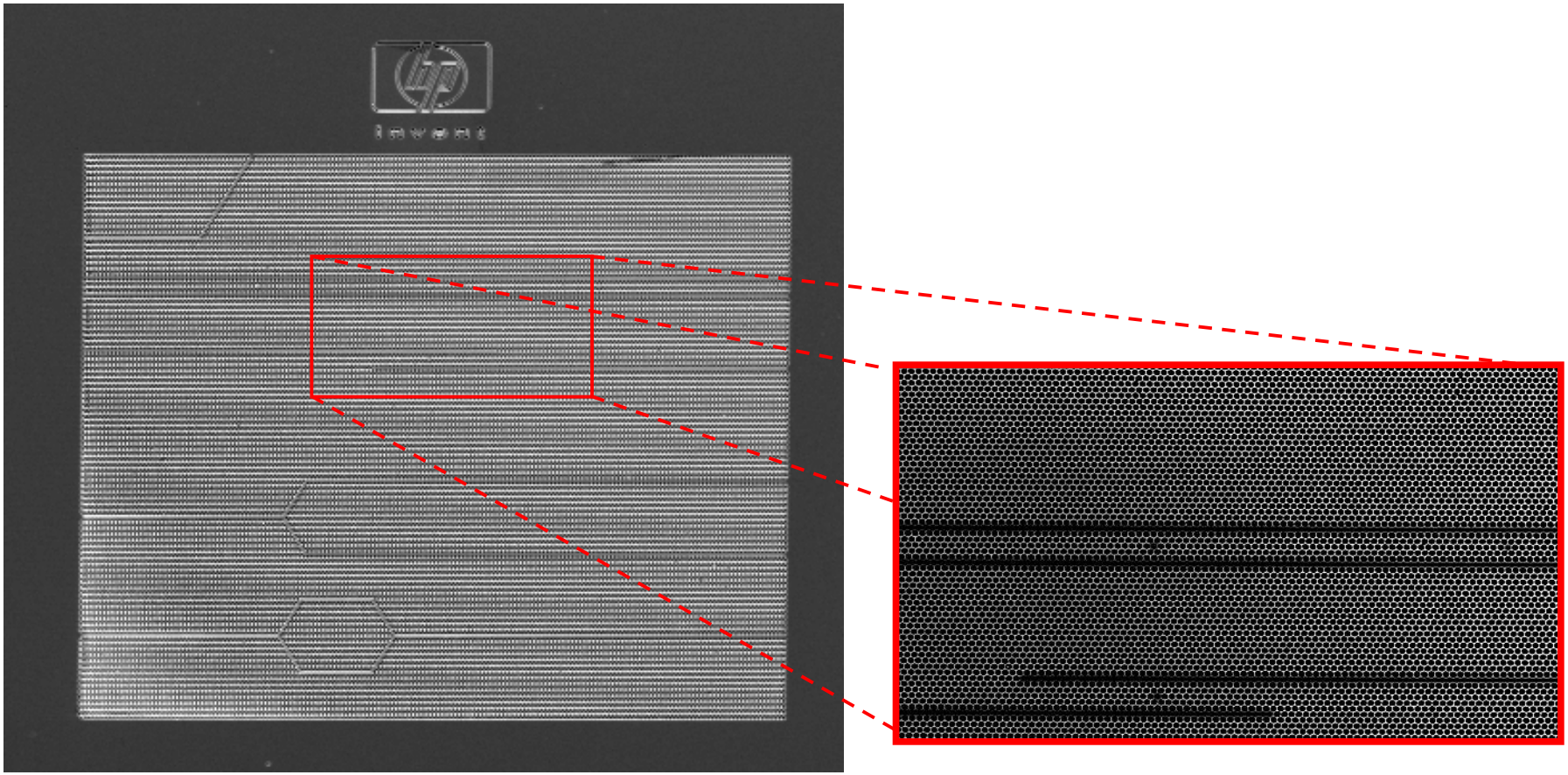
Vision: Nanophotonic crystal waveguide for on board communications



Advantages:

- ü High speed
- ü Low loss
- ü Cost effective

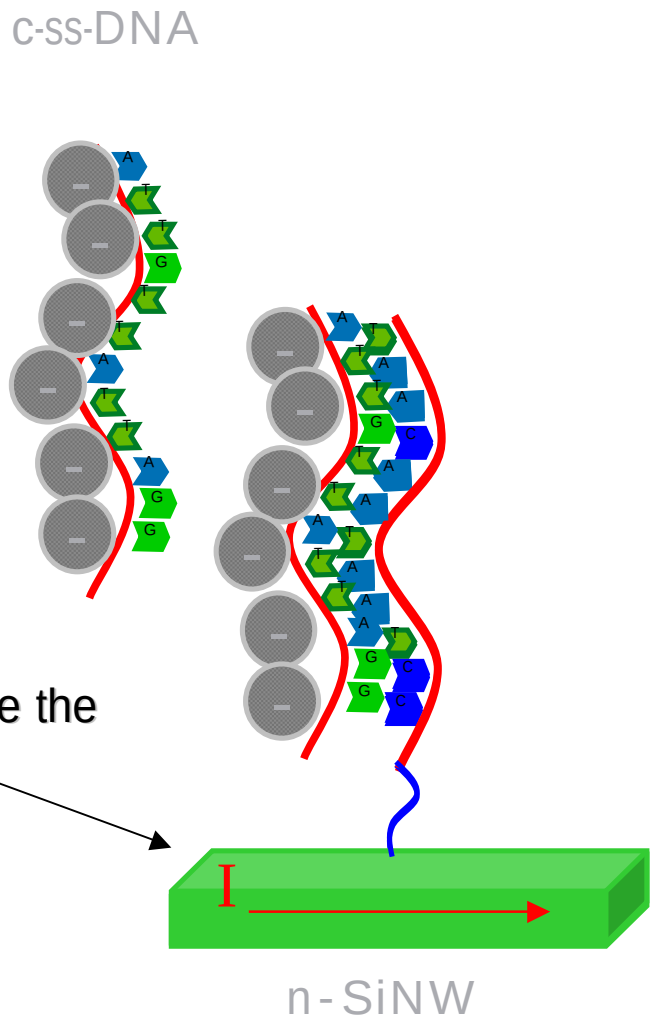
Photonic crystal waveguide successfully fabricated by nanoimprint lithography



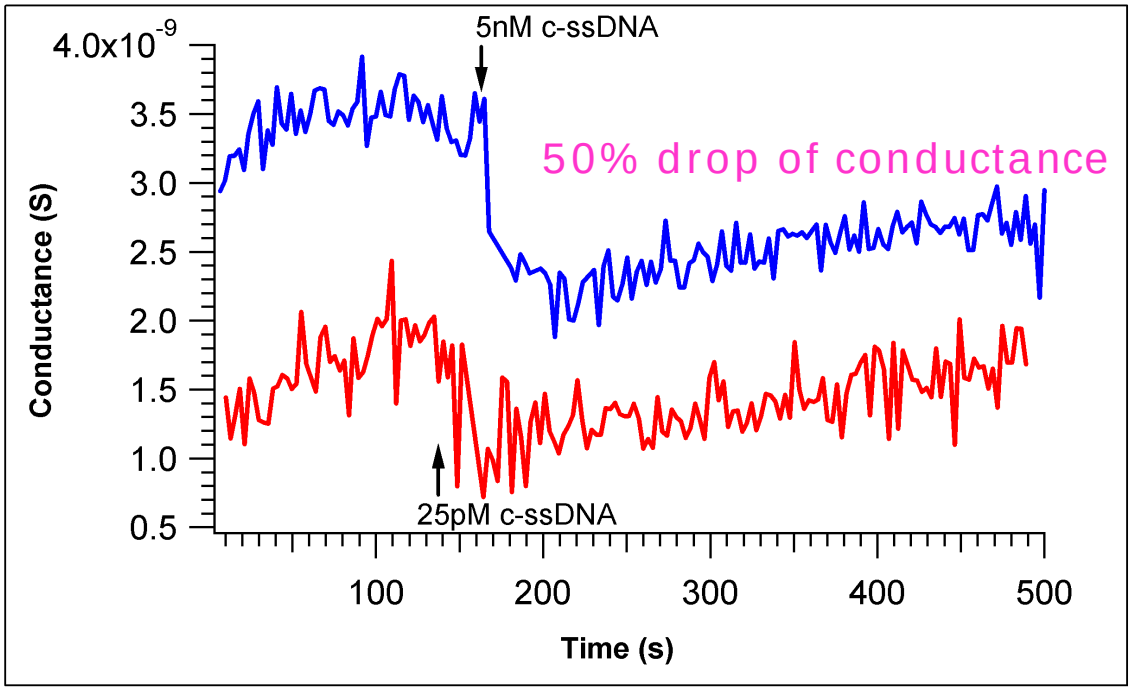
--Jim Ellenson, Tim Hostetler, Ray Beausoleil, Hewlett Packard

DNA identification sensor: toward single molecule detection

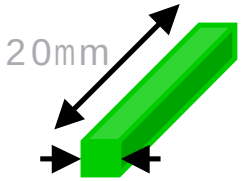
- Use complimentary DNA as a selective receptor.
- Captured DNA alters current through nanowire



Successful sensing of DNA oligonucleotides on Si nanowire plateform



50nmn-Si Nanowire



Top surface

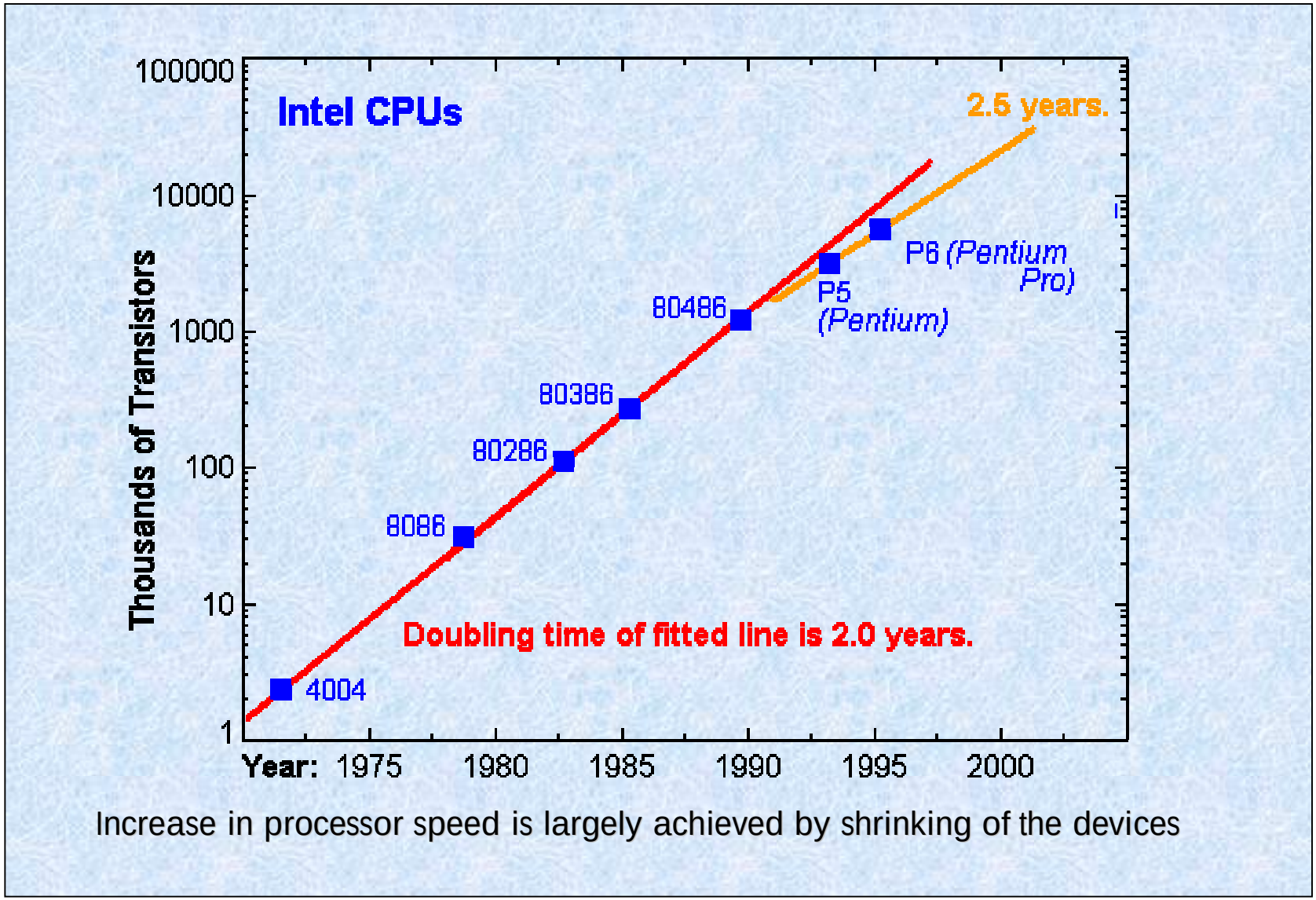
$1mm^2$

Zhiyong Li, HPL

Why hp is interested in nanoimprint lithography?

- New applications emerging from nanotechnology research require low-cost, high volume manufacturing of nanoscale device
- Currently, inkjet cartridges are made with trailing edge photolithography (I-line 365 nm)
- Hp is not interested in making nanoimprinter. Our goal is to help enable the technology

Moore's Law

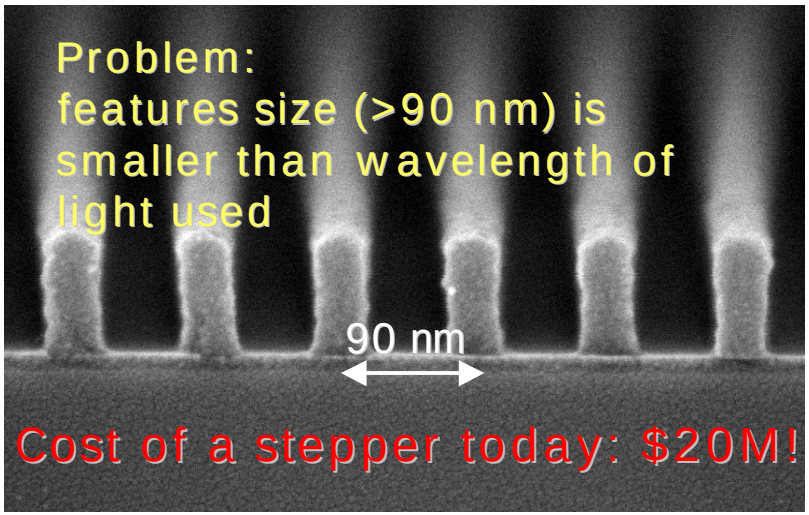


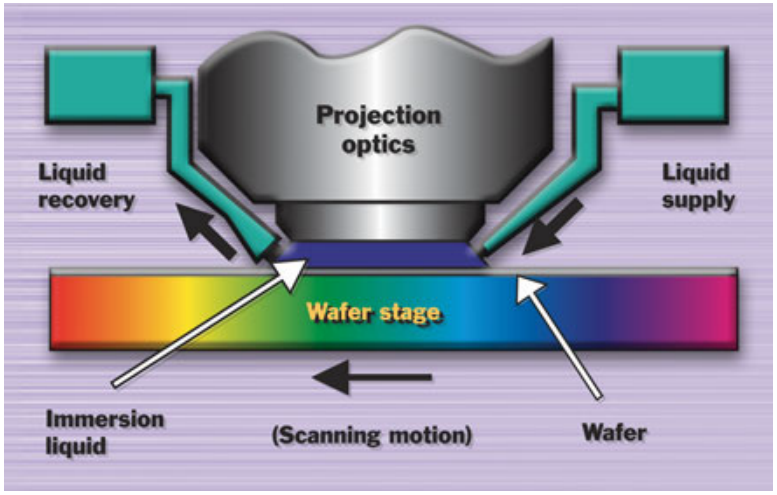
Increase in processor speed is largely achieved by shrinking of the devices

Moore's Second Law: Cost of a chip fab will double every two years

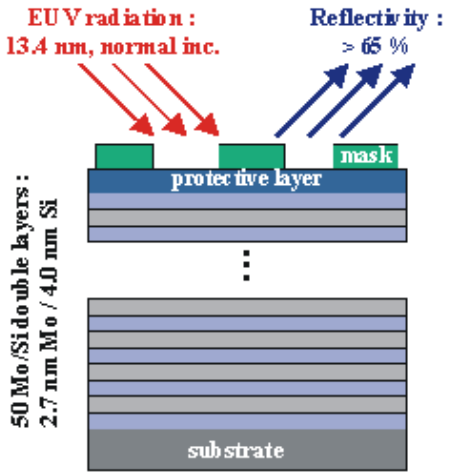
Consequence:
As device size shrink, only high cost devices in large volumes can be produced.
(Pentiums)

Photolithography is hitting a brick wall





Immersion lithography: $30M!!

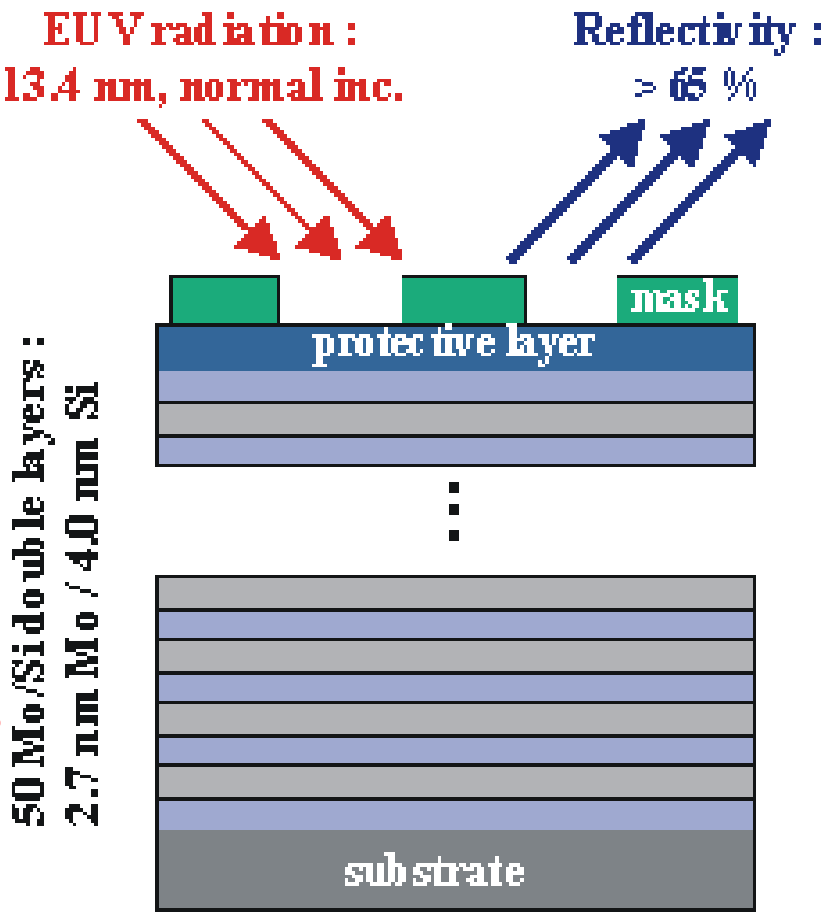


EUV Lithography: >$50M!!!

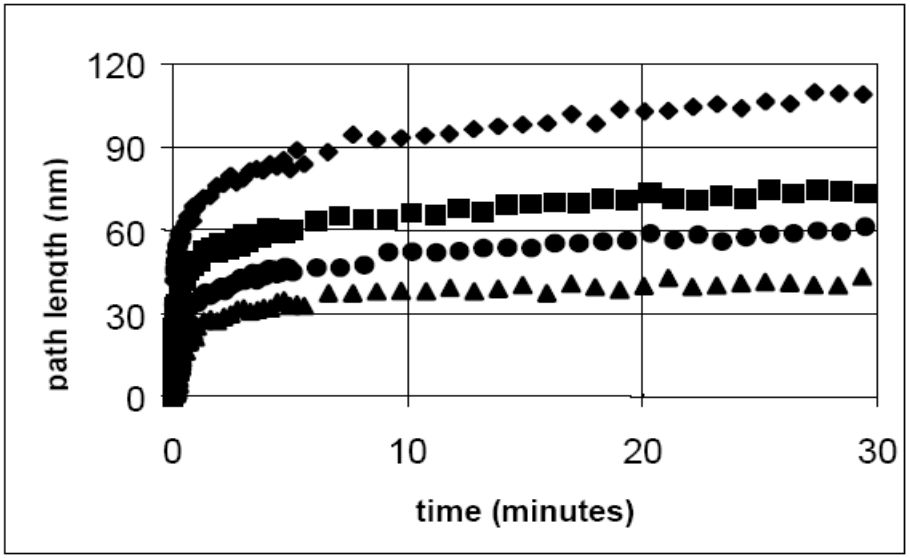
Problem with EUVL: throughput

- Targetted for 32 nm node (Y2013)
- Uses 13 nm photons.
- Requires multilayer mask

- Issues
  - Defects on mask easy to print
  - A high power EUVL photon source is yet to be found.
  - Photons have high energy, therefore low counts à Line edge roughness.
  - Chemically-Amplified Resists are needed (CAR)



Acid diffusion limits linewidth to ~35 nm



Temperature dependence of acid path length in t-BOC. PAG #3 (10wt%) in reservoir layer. 75°C (▲), 90°C (●), 100°C (■), 110°C (◆)

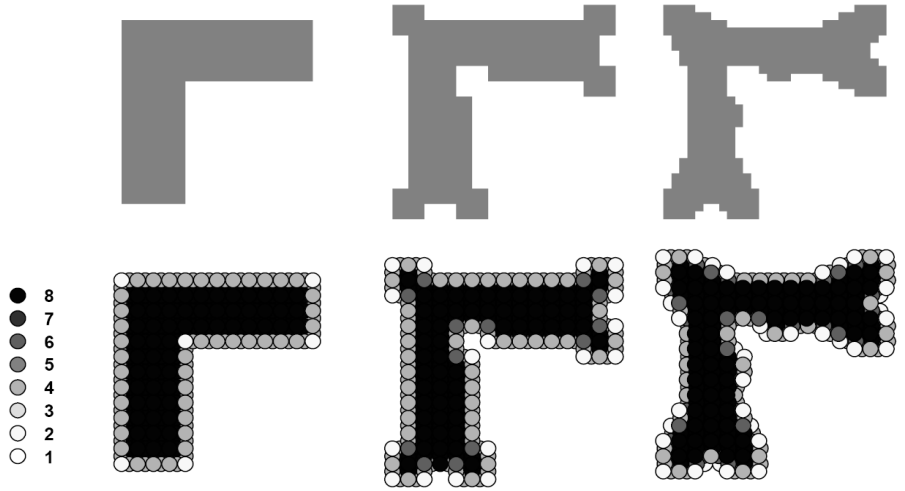
Source: Postnikov, S. V. et al., " A study of rosolution limits due to intrinsic bias in chemically amplified photoresists," to appear in JVST B. (Grant Willson, UT Austin)

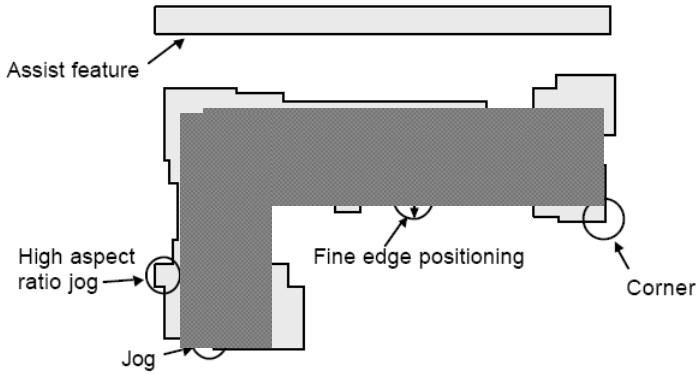
Key challenges in nanoimprint lithography

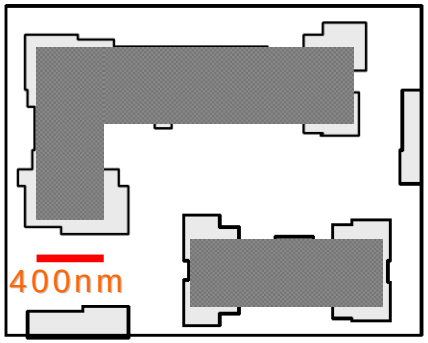
- Alignment
  - No expensive optics to take advantage of.
  - Solution in development: Moire pattern
  - Sub-pixel detection: 1/40 pixel (1 pixel ~ 100nm) feasible by commercial software e.g. Cognex
- Mold patterning
  - Mold is 1x instead of 4x as in current photomask

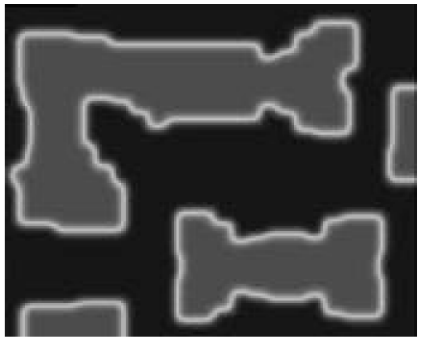
Patterning OPC features requires unprecedented accuracy on maskmaking

- Sub-wavelength printing puts a great burden on the mask patterning.
- OPC, Assist features, phase shift mask push cost
  - Current mask (90nm generation) cost >$1M per set



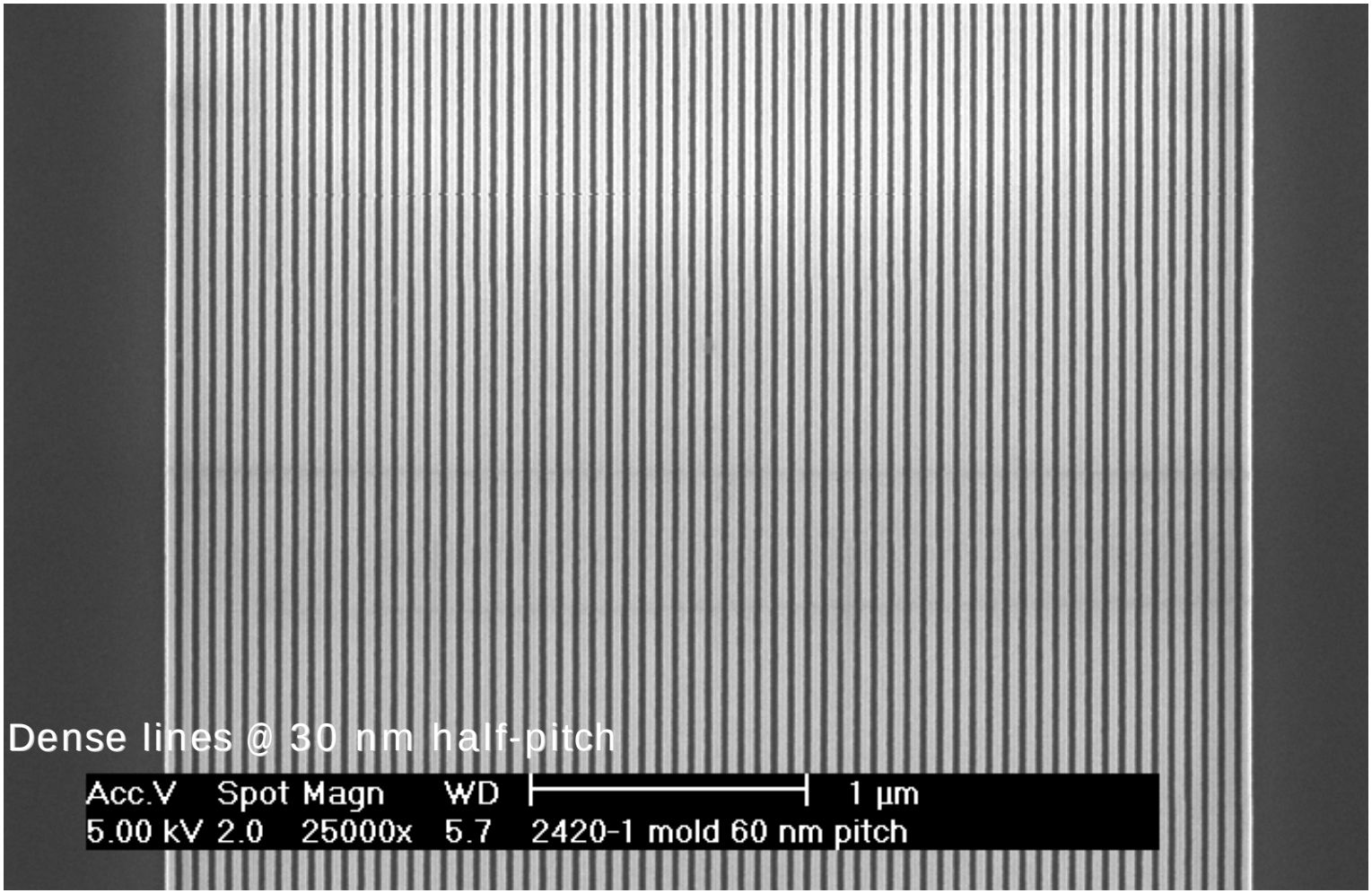






Source: T. Newman et al., “Evaluation of OPC mask printing with a raster scan pattern generation” (2002)

E-beam patterning can already achieve 30 nm hp



Nanoimprint mold patterned by
Deirdre Olynick, Alex Liddle, Lawrence Berkeley National Laboratory

Nanoimprint lithography can achieve the same resolution as photolithography, but is much more cost-effective

Commerical nanoimprinter: $0.5-1.6M

Nanoimprint lithography is on the ITRS roadmap 2003 as an official NGL

HP is interested in nanoimprint lithography because it enables low-cost, high-volume manufacturing, potentially allowing us to leapfrog over our competitors who employ photolithography

Summary

- Overview of hp's portfolio in nanotechnology
  - Molecular electronics, photonics, sensors
  - All require low-cost nanoscale fabrication
- The problems with photolithography
  - Cause: Features to be patterned are smaller than the wavelength of light used.
  - Potential solutions will only get more expensive: only high cost devices can be fabricated. (Intel Pentiums)
- Why hp is interested in nanoimprint lithography
  - A disruption technology that can provide low-cost, high tech solution to fabricate our nanoscale devices.

invent

Thank you!