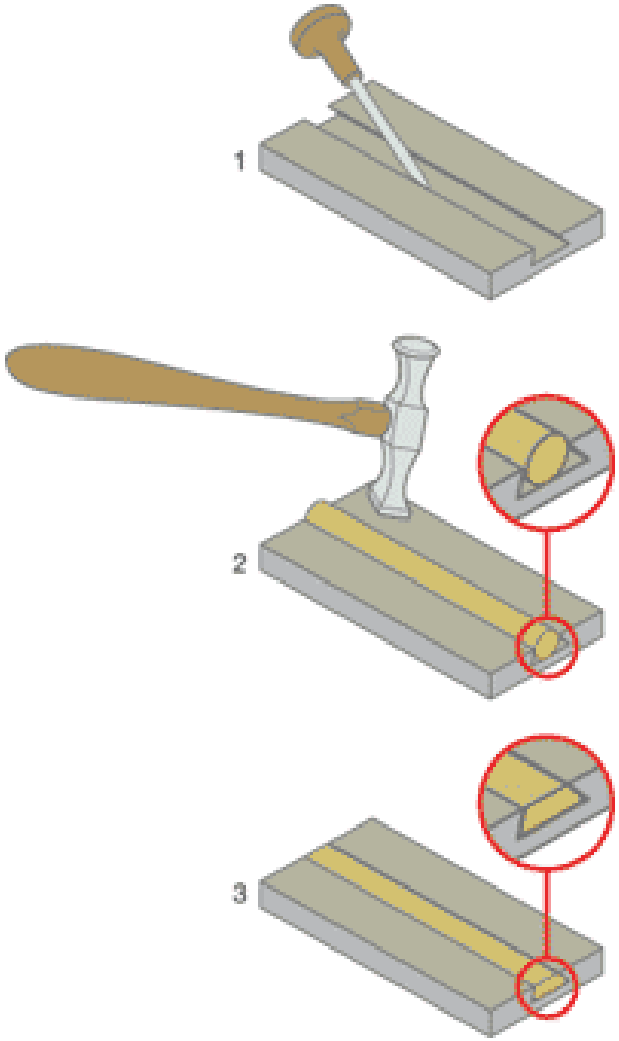
Lecture 12

Chemical Engineering for Micro/Nano Fabrication

Sword decorated by damascene

The Damascene Process



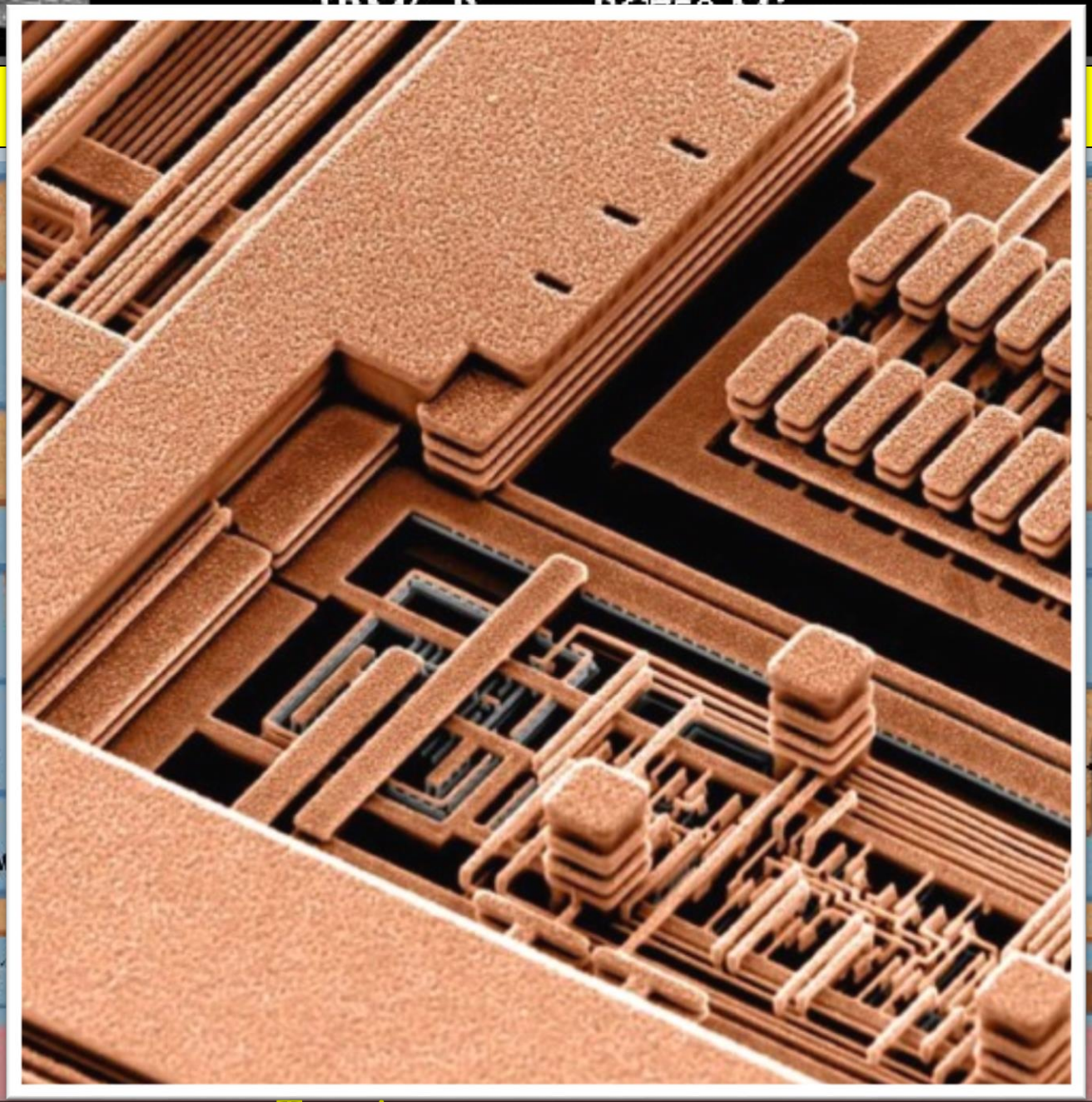
Carve/engrave a groove into a metal substrate

Lay gold wire into the groove and hammer until flat

Polish and smooth the surface

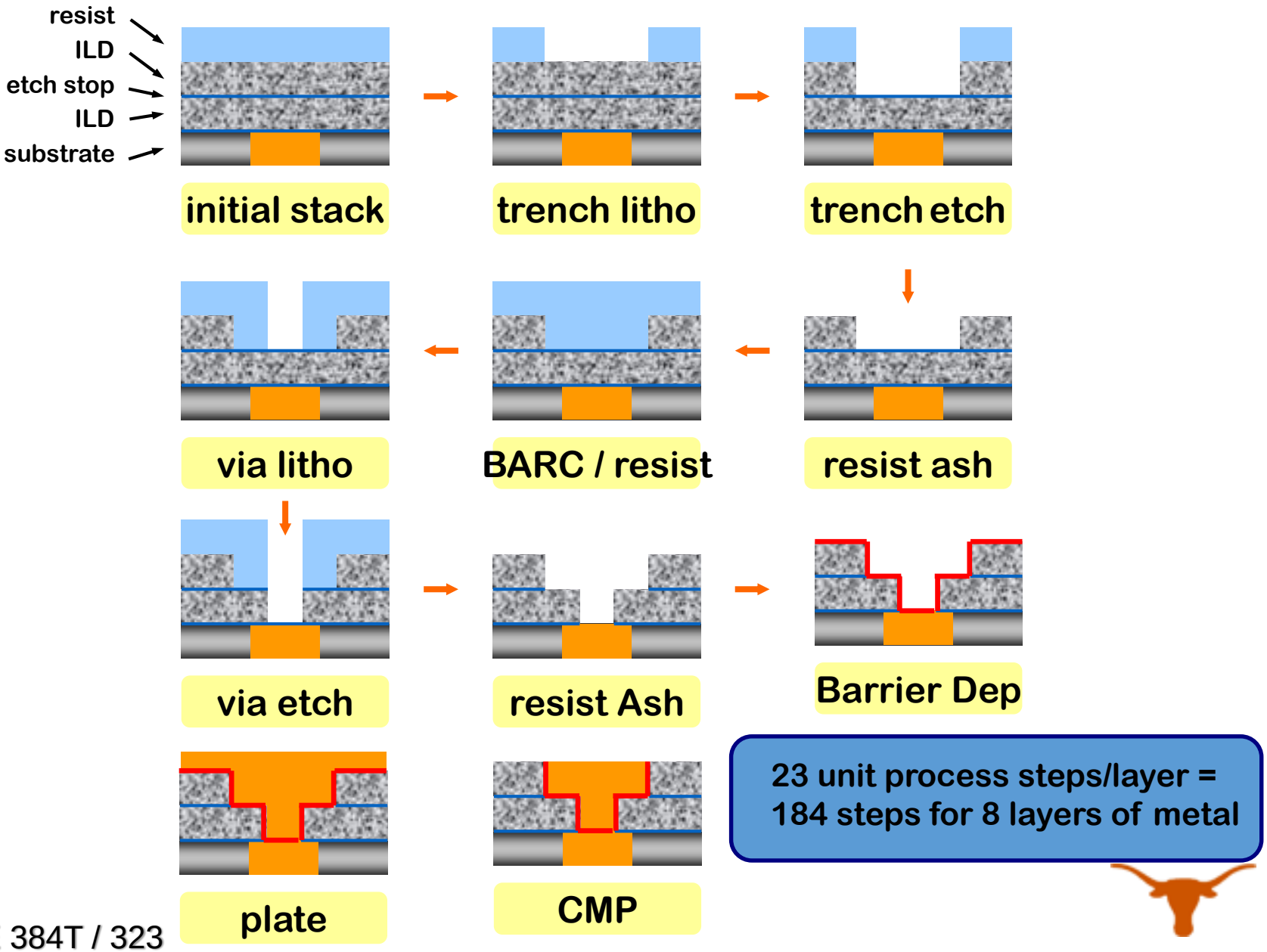
Damascene Art

Damascene Art



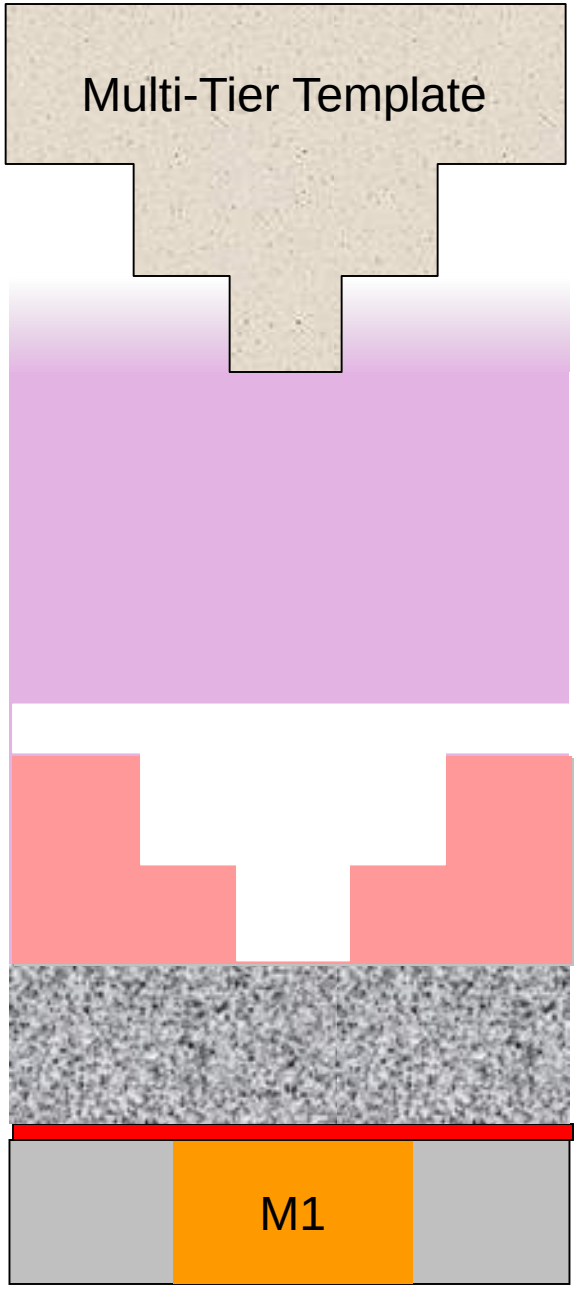
Transistor

ATDF Dual Damascene Process



23 unit process steps/layer =
184 steps for 8 layers of metal

NIL Damascene Process



# of process steps: 3

SFIL IMPRINT

Release

◀ Cured SIM

◀ CVD ILD

◀ Copper Barrier

NIL Damascene Process

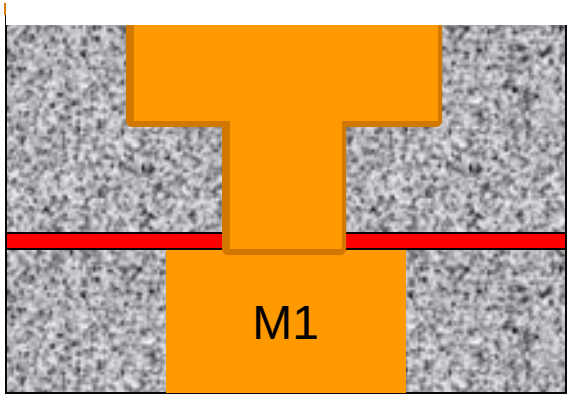
of process steps: 8

x 8

64

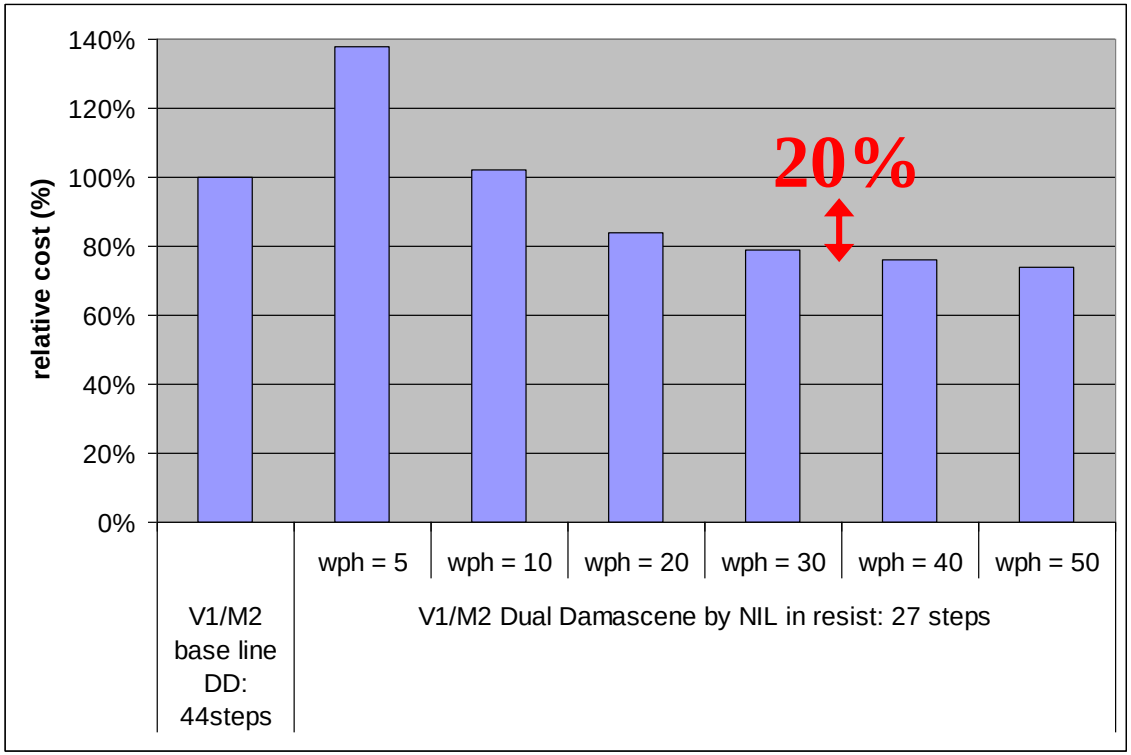
Savings of

184 – 64 = 120 steps



CMP e

BEOL Multilevel Imprint Cost Saving

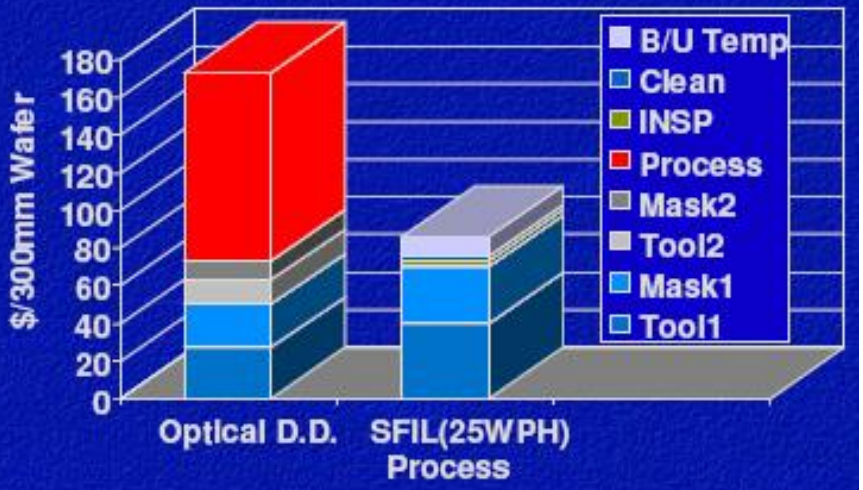


- 20% ***overall*** saving at 30 wph
- Cost analysis courtesy of Sergei V. Postnikov, Infineon Technologies; presented at Semicon Europa 2007, Stuttgart, Germany

S-FIL C.o.O. Case Study – Low-k Process
Optimistic NIL Assumptions

C.o.O. = Tool$ + ΔProcess$ + Mask$

+ Add. Tool$ + MFG Factors & Yield Δ



$Optical_{2k}$ = $40 + $100 + $33 [$173]

+ Add. Tool$ + MFG Factors &

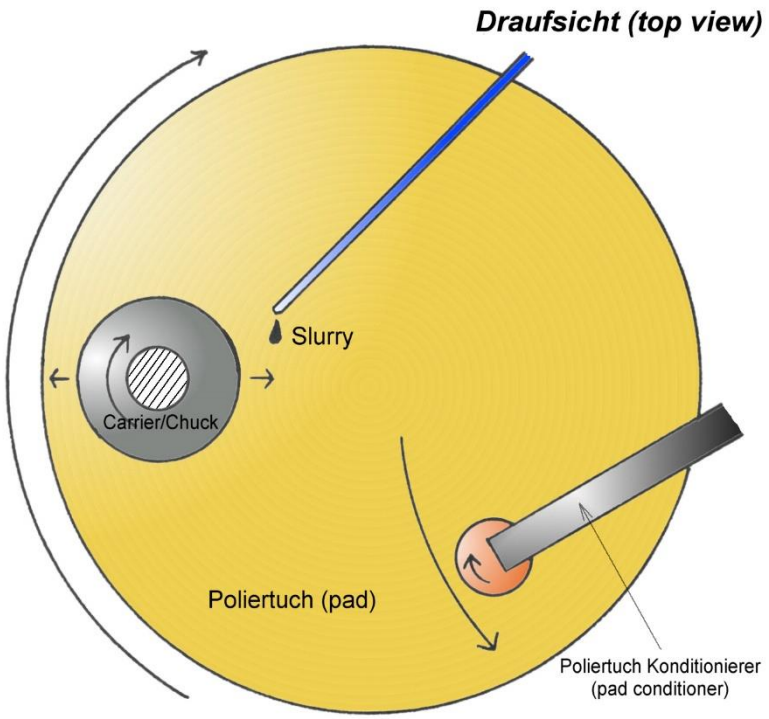
NIL_{2k} = $27 + ? + $30

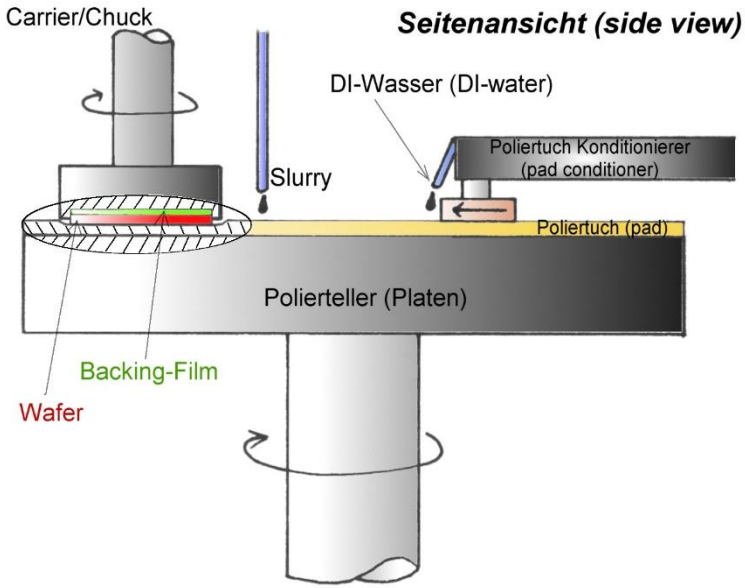
+ $6 + $30/3 & Yield Delta [$73]

ΔA$100
~58%

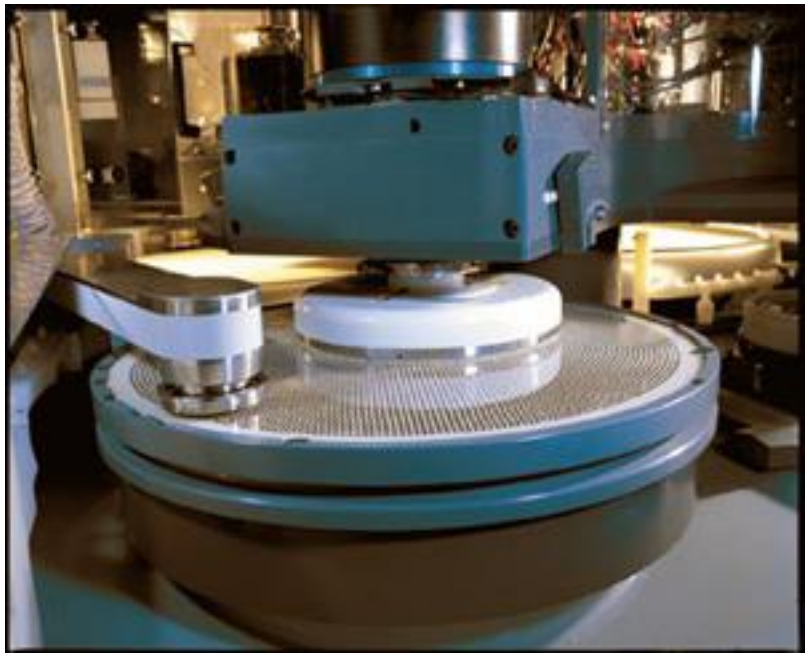
Lloyd Litt, et. al.

Chemical Mechanical Polishing

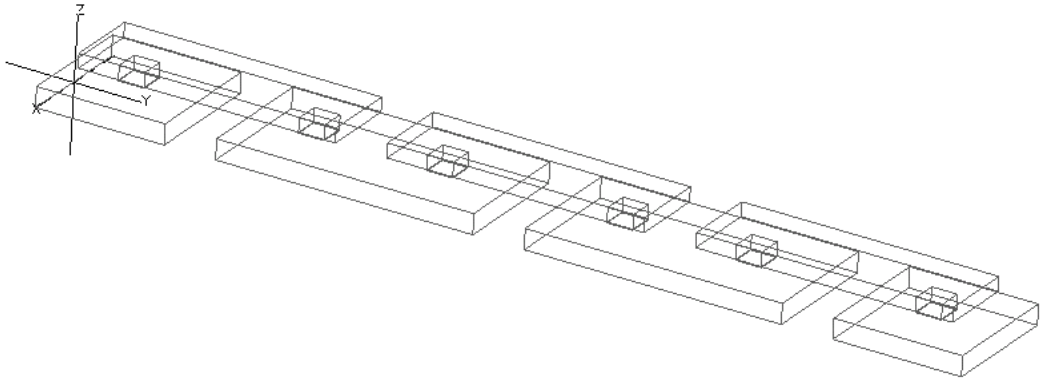


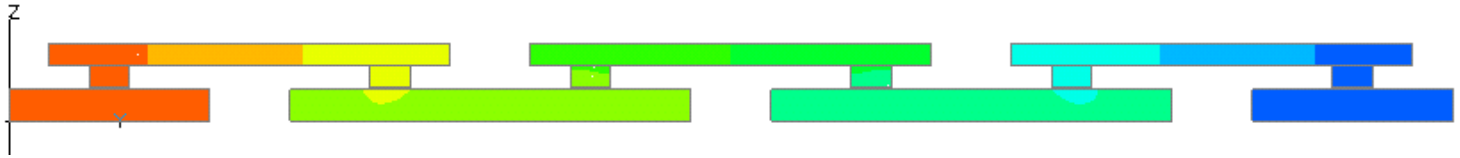


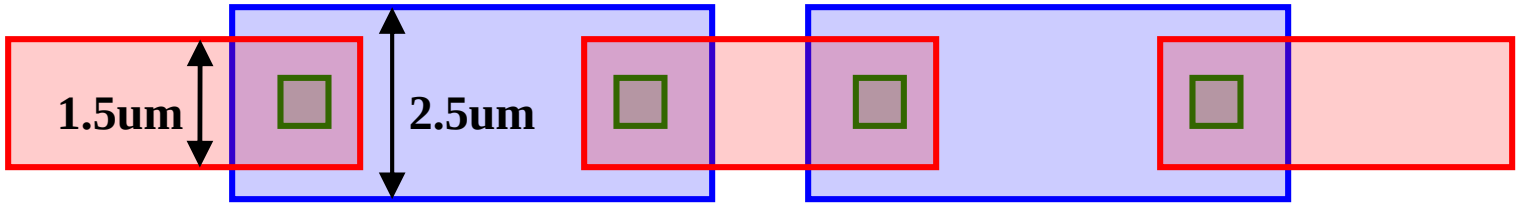
CMP Tools

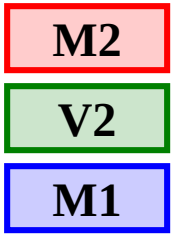


Via Chain Test Structure

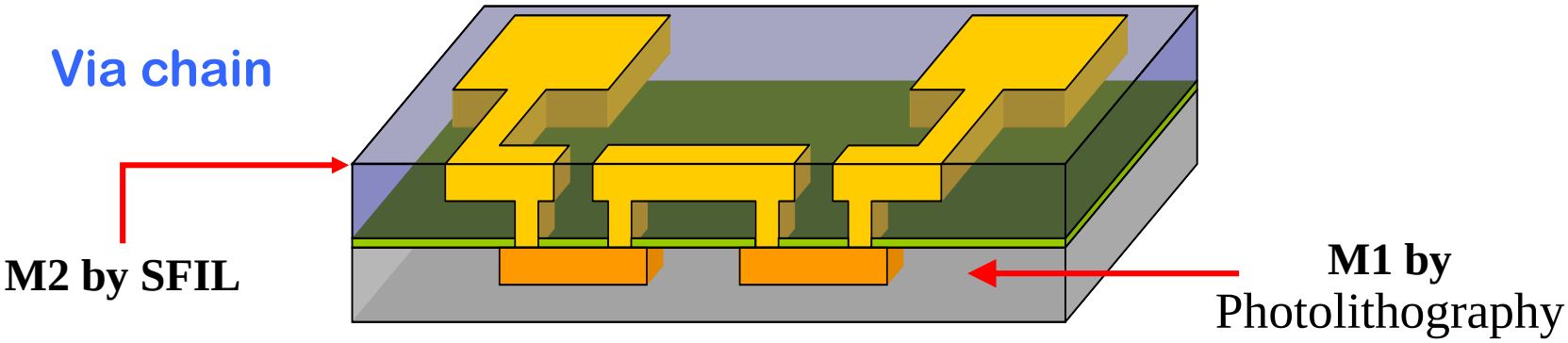


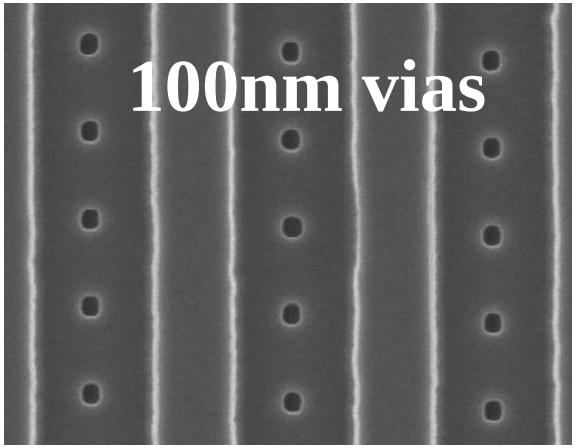


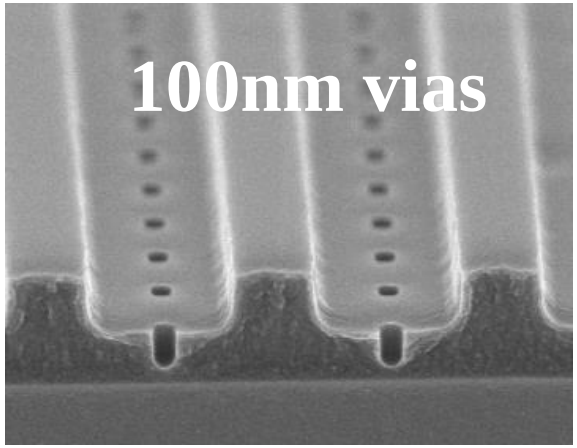


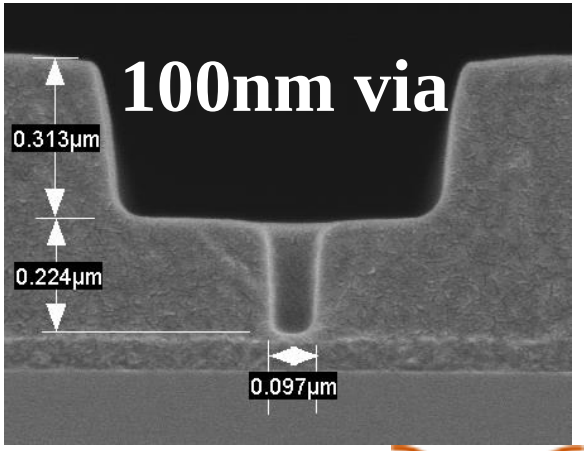


Via Chain Structures



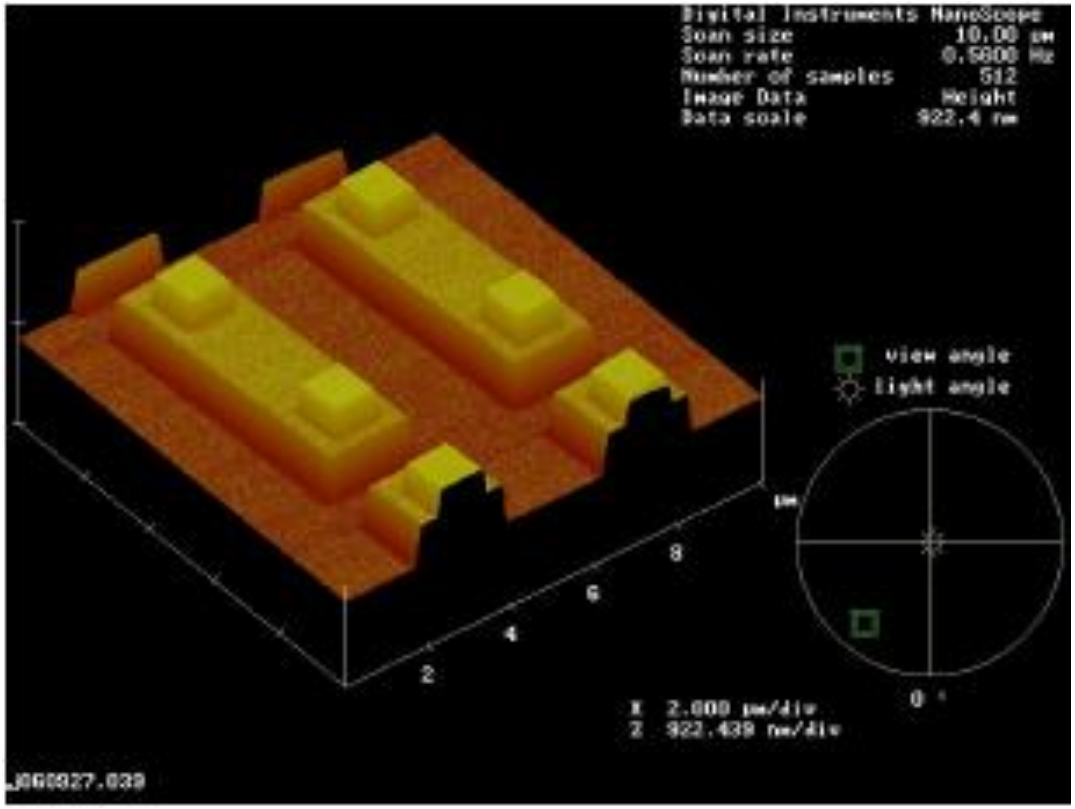


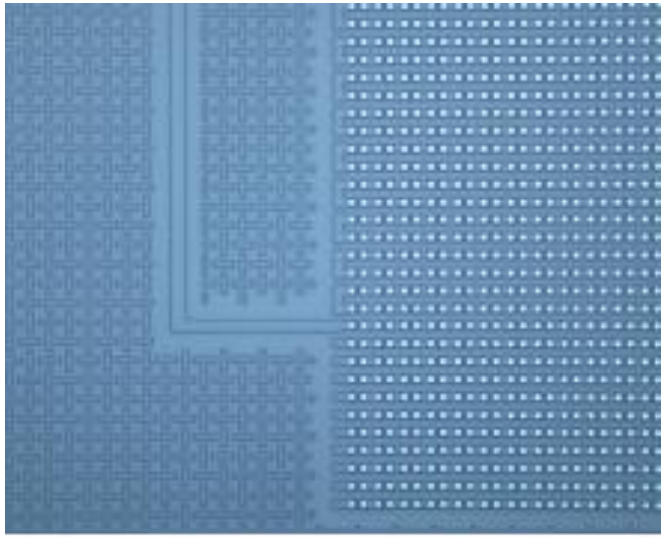


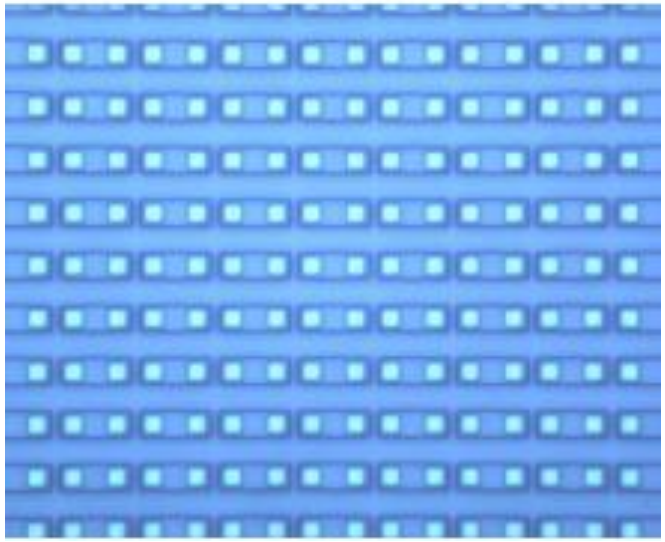


Template

TOPPAN

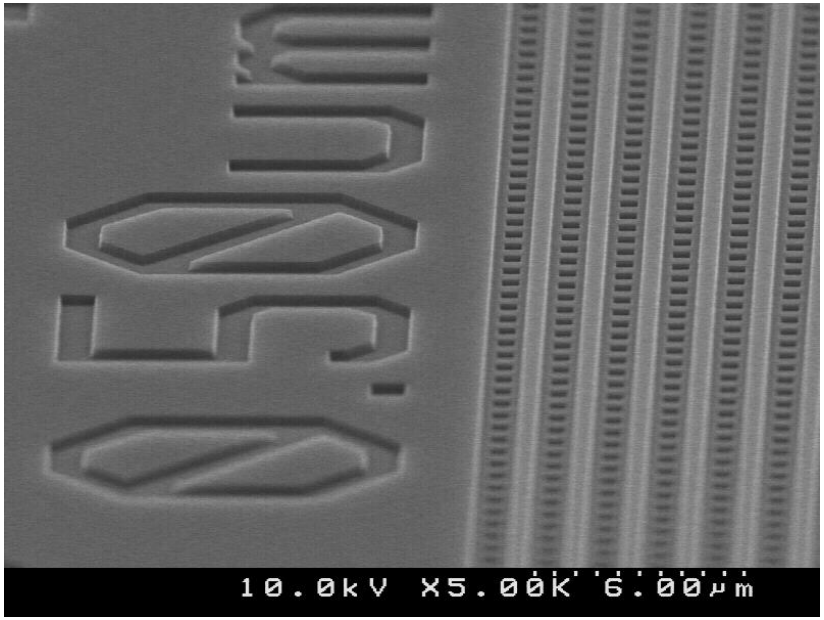


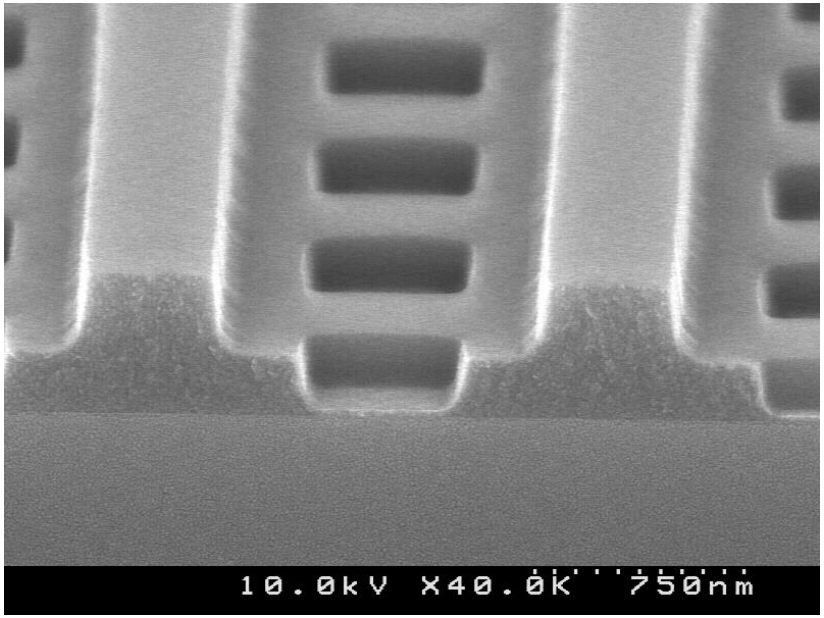


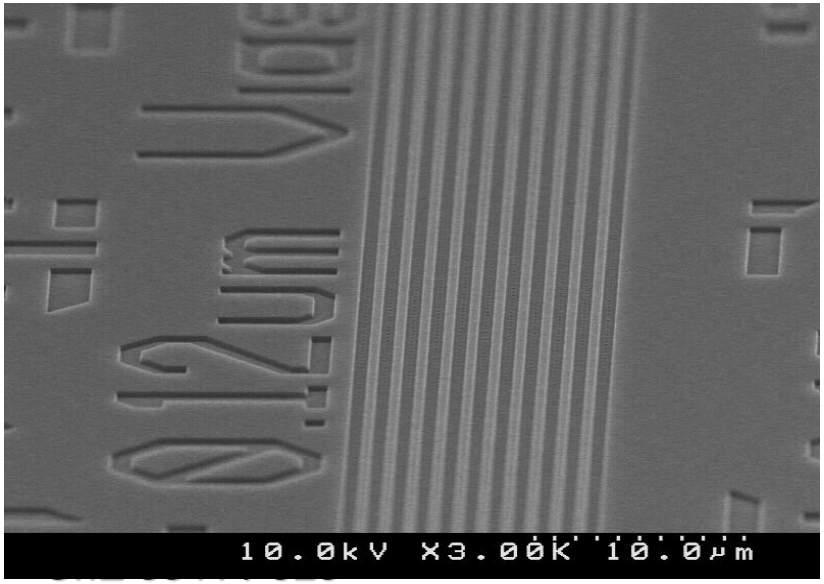


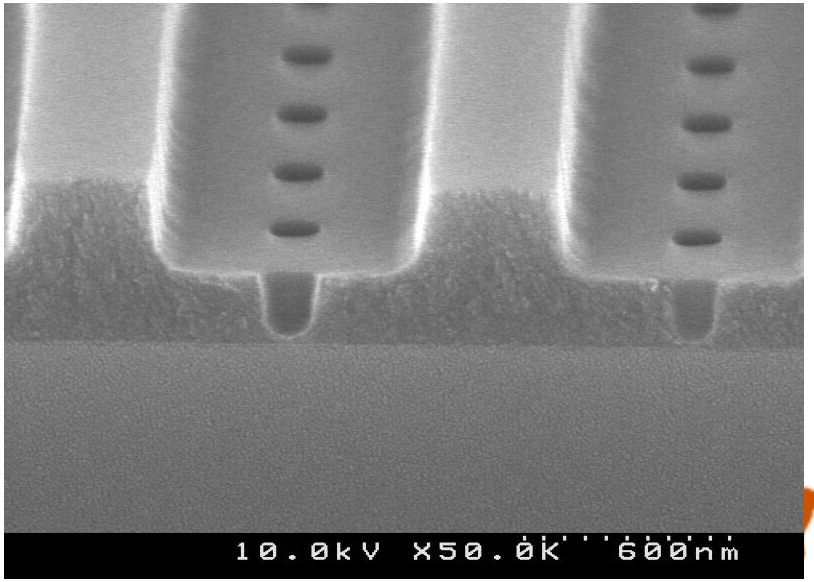
Via chain test site

Imprinting


0.60um
10.0kV X5.00K 6.00µm


10.0kV X40.0K 750nm

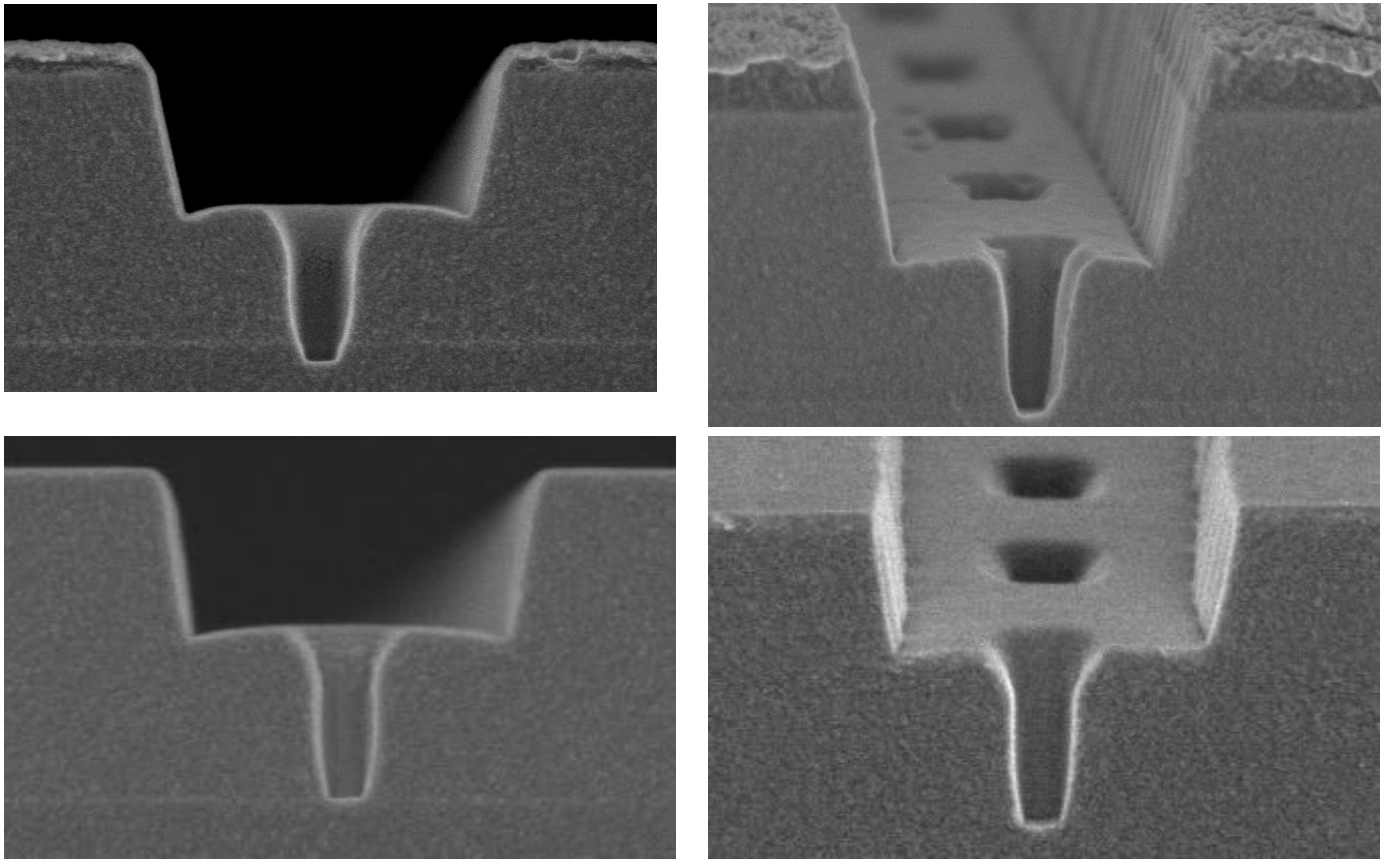

0.12um Vdd
10.0kV X3.00K 10.0µm


10.0kV X50.0K 600nm

Pattern Transfer Demonstration

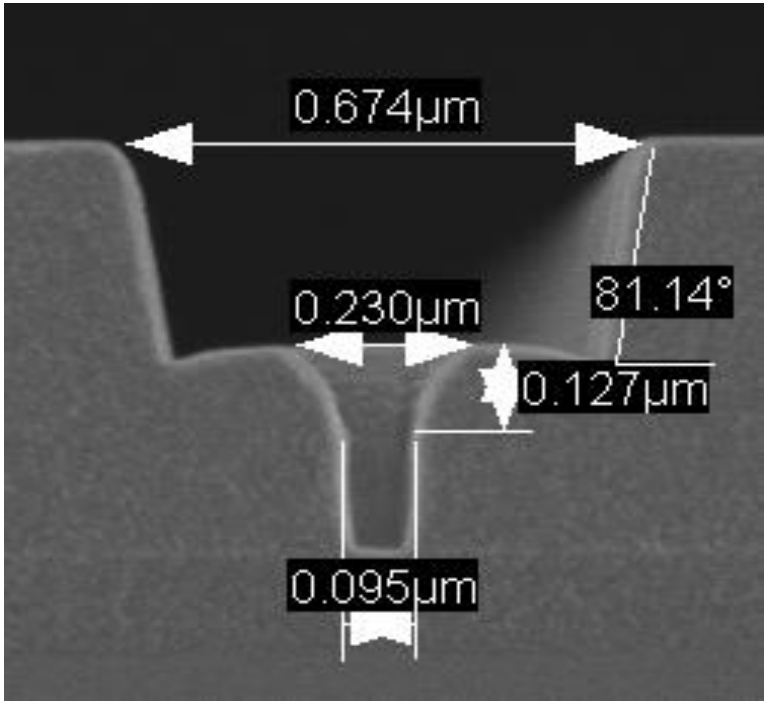
Trench Etch
$CF_4/C_4F_8/N_2$

Ash
N_2/H_2

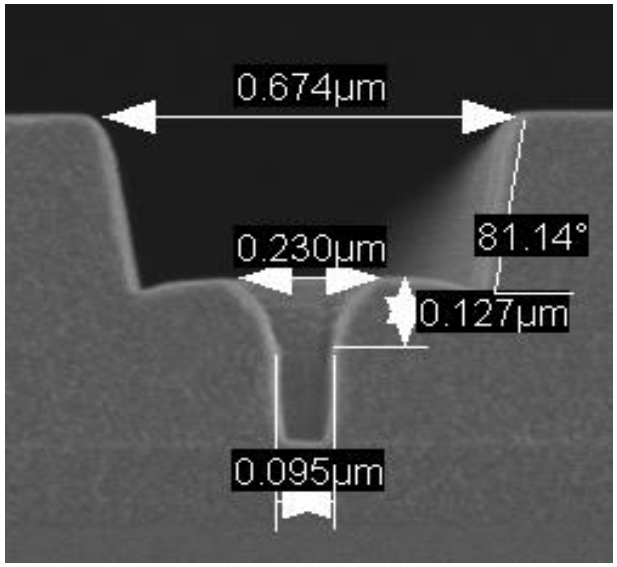


Both Coral® and Black Diamond® were processed

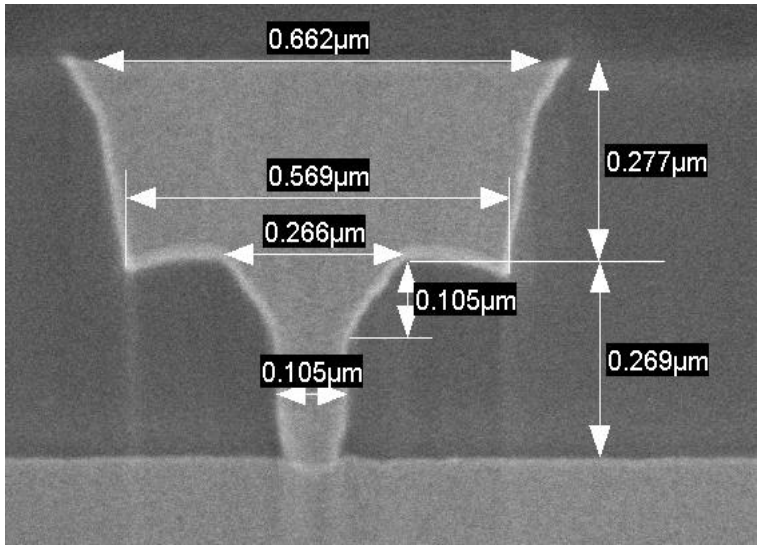
If this works, it saves more than 100 unit process steps from the manufacturing of a modern microprocessor and provides a saving of 20-50% (per studies by Infineon and SEMATECH)



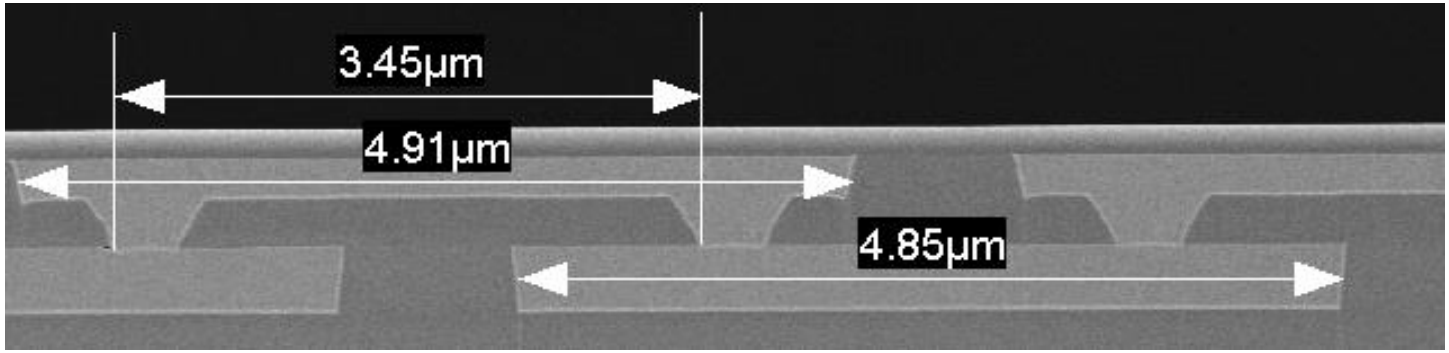
Wiring Level Complete



After etch

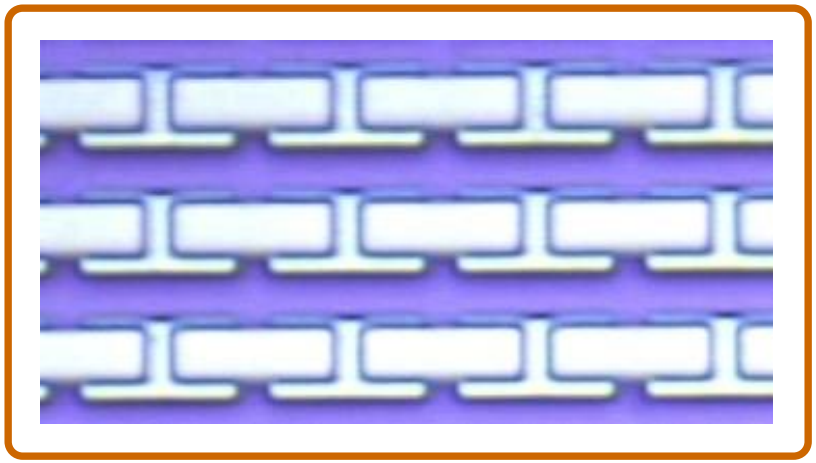


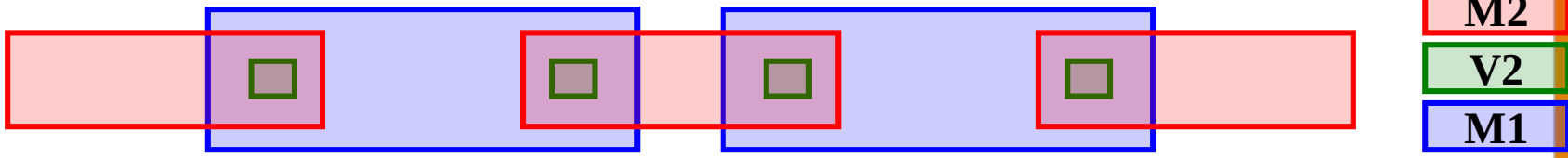
After metal

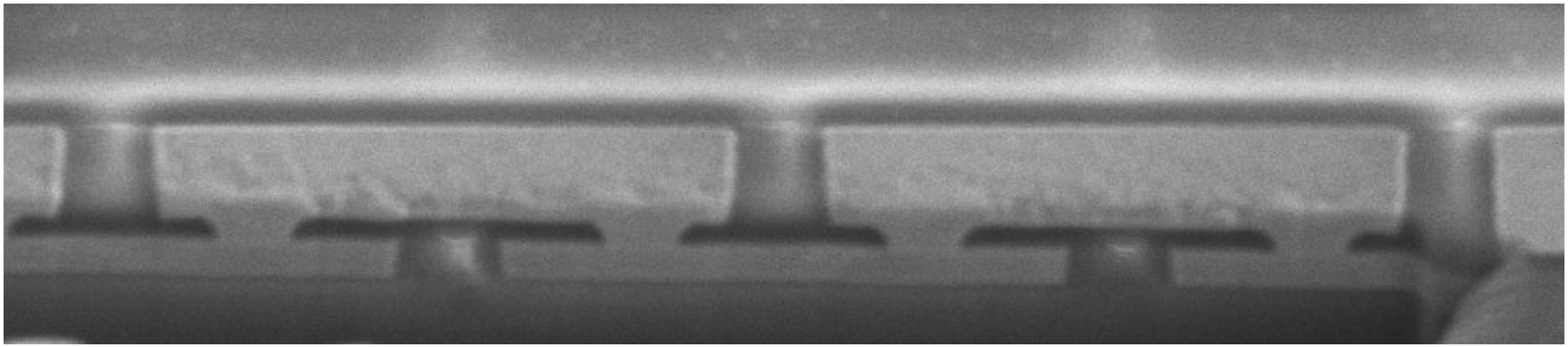


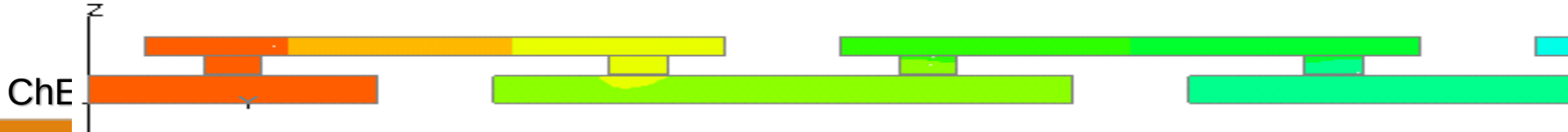
After metal

Completed Via Chains

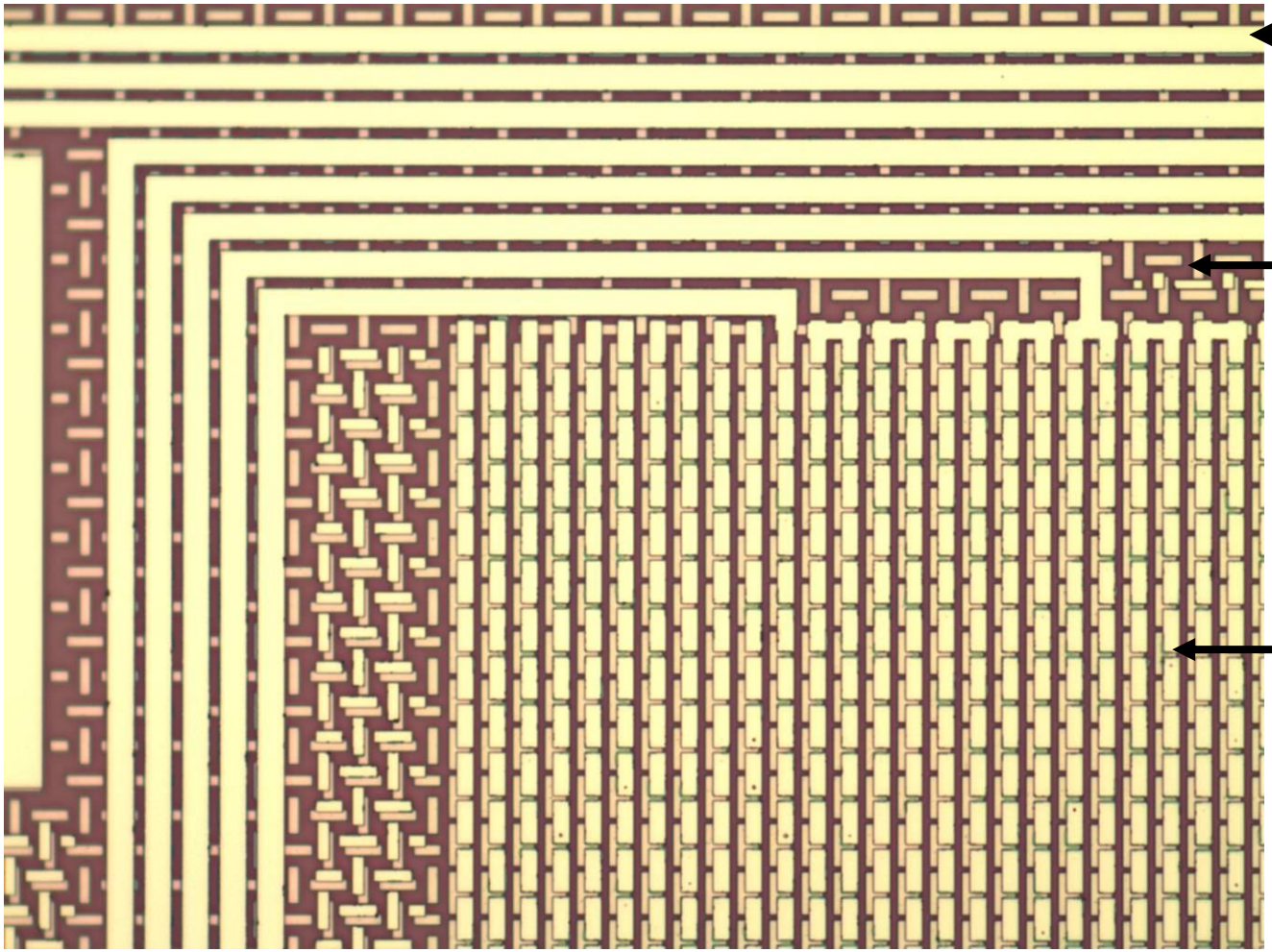






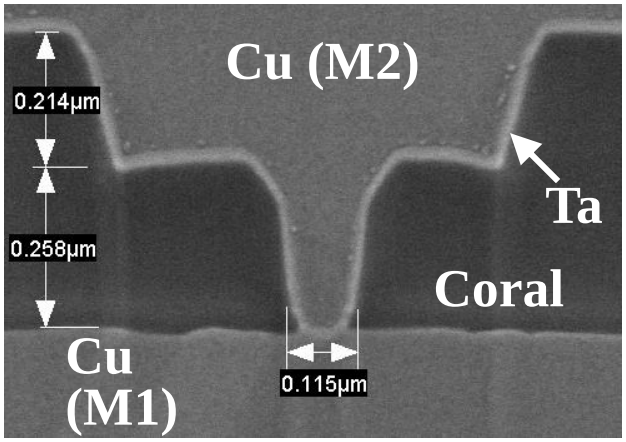


Metal Patterns (via chains)

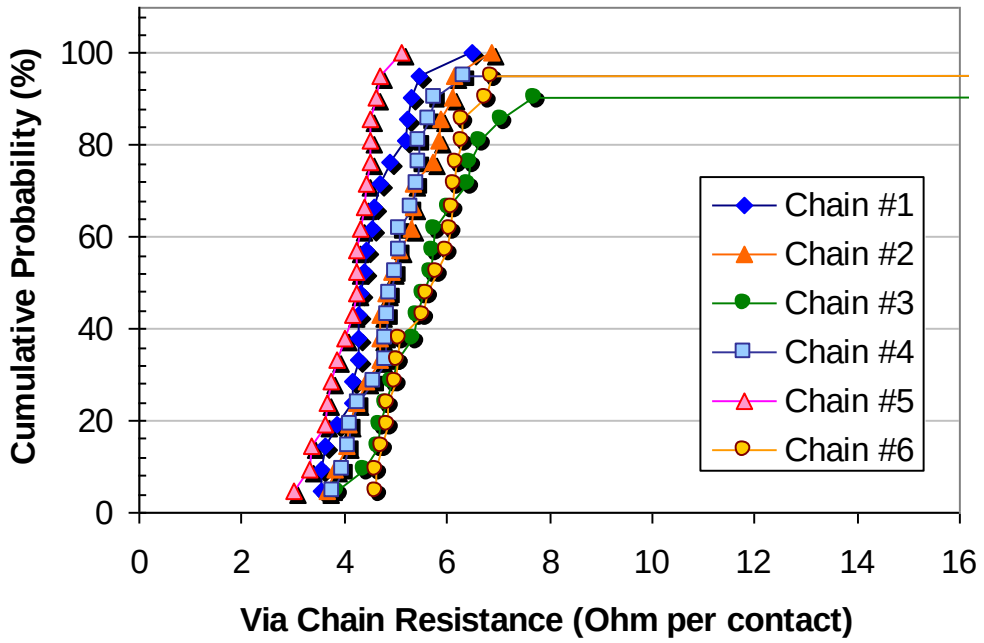


atdf

Via Chain – 120 nm 1000 Contacts

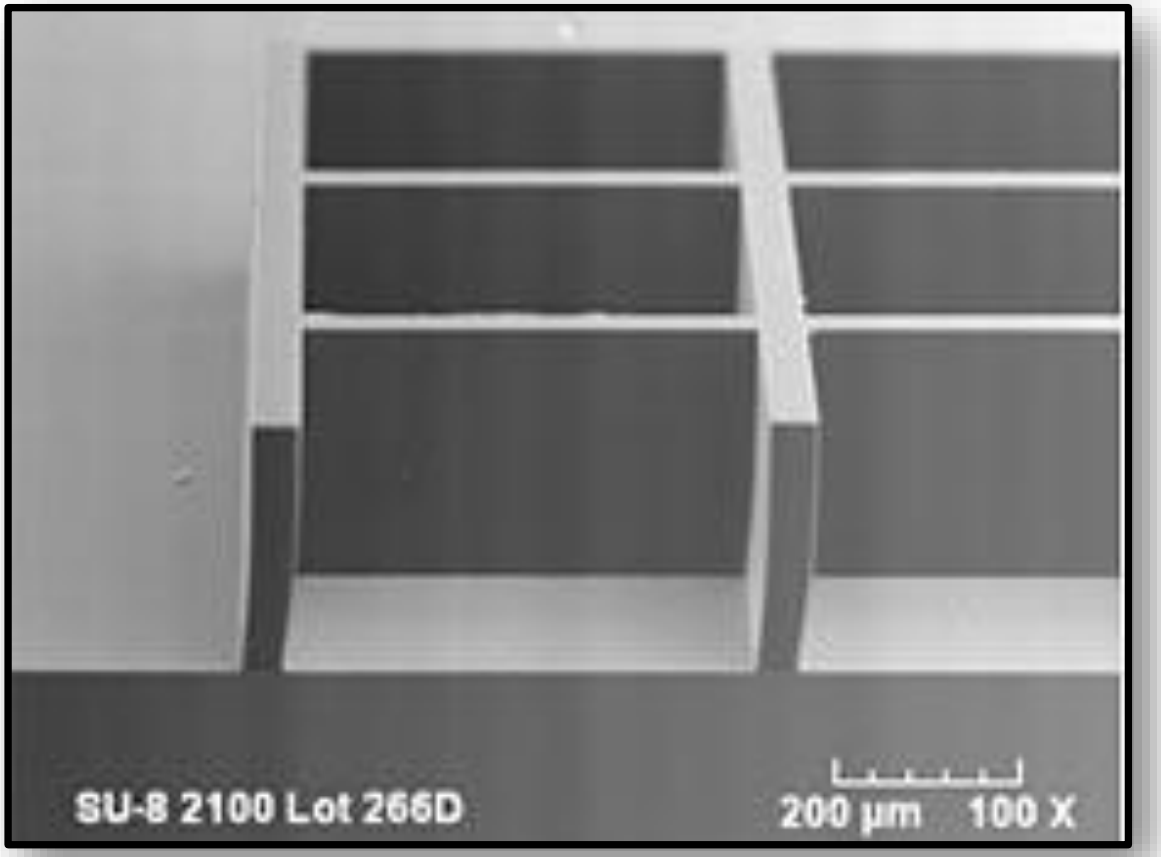


Template CD = 120 nm
Final CD = 115 nm

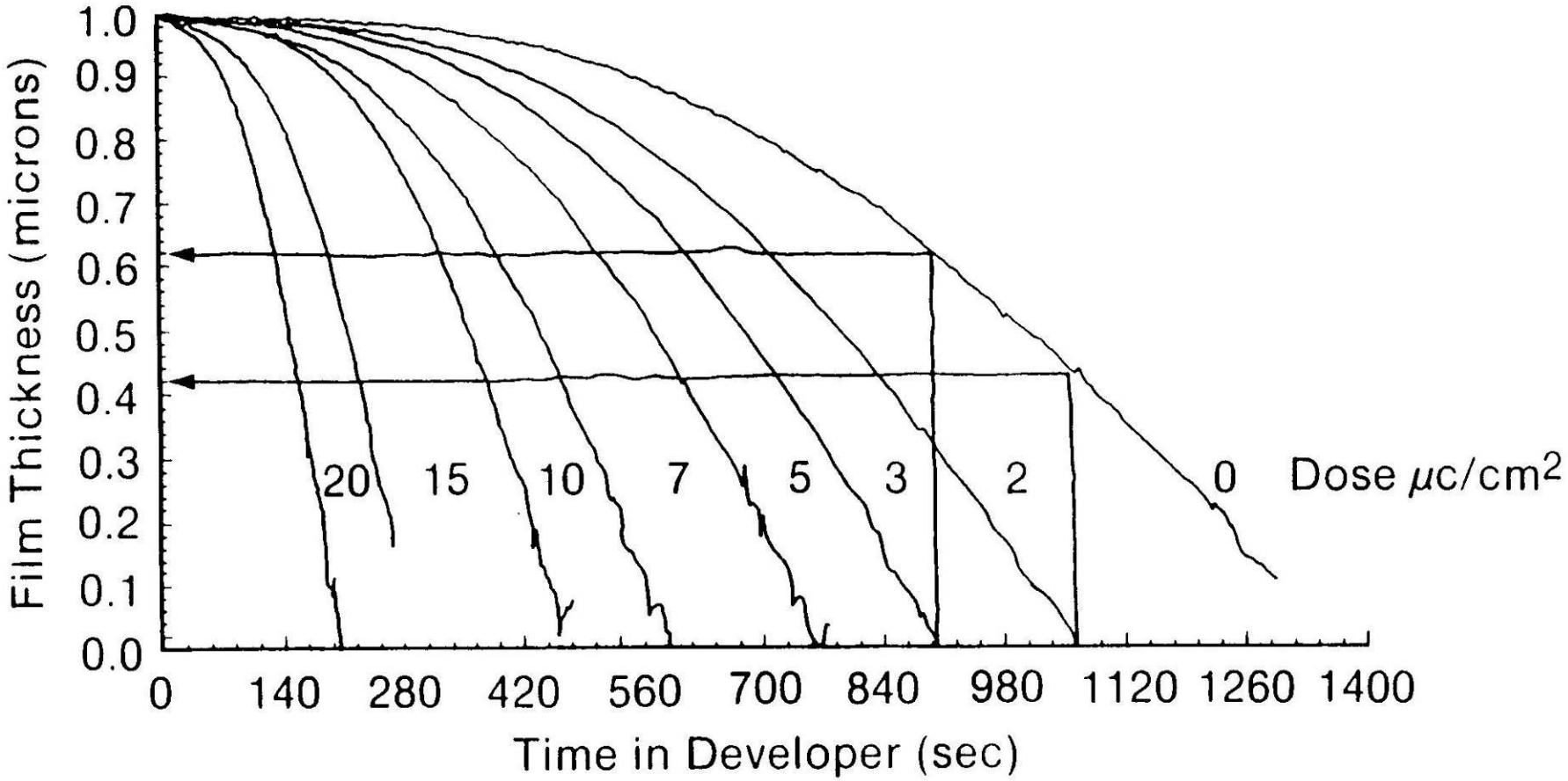


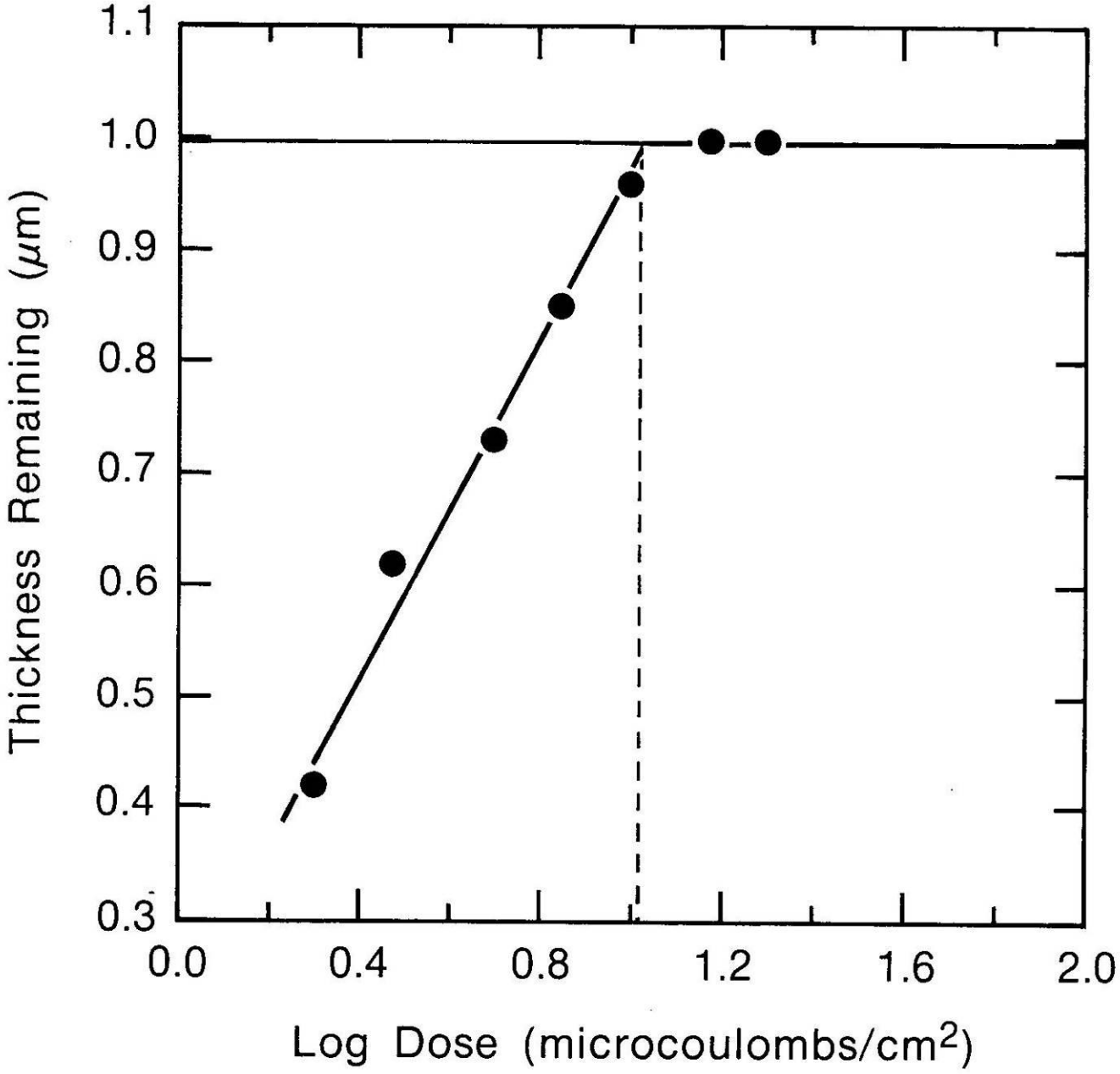
- Yield statistics (6 valid and identical chains tested)
  - Overall yield of 1000-contact chains with ***via CD 120 nm (nominal)*** / ***115 nm (final)*** – **96.83%**
  - Individual contact yield – **99.9968%**

Back to Resists

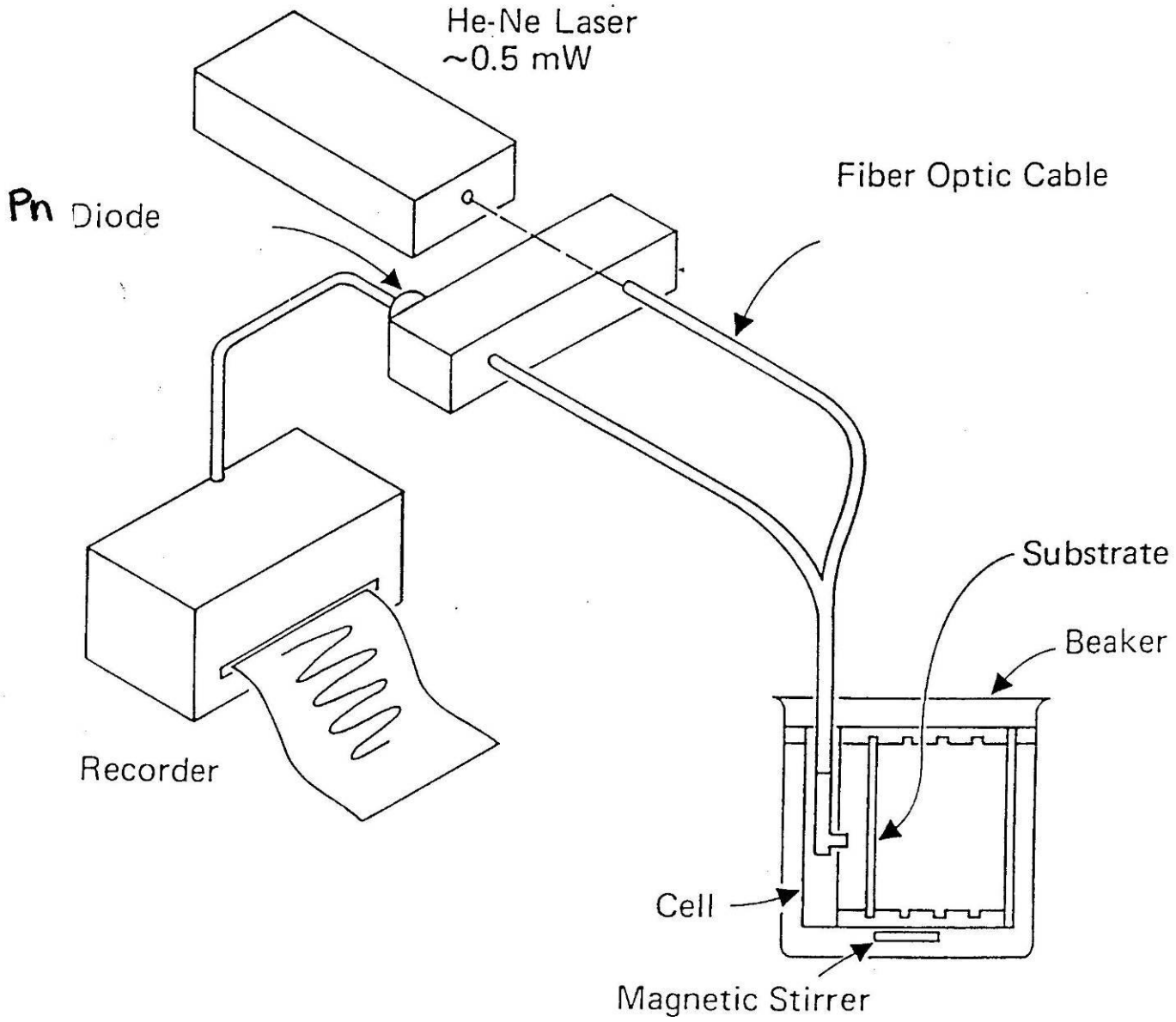


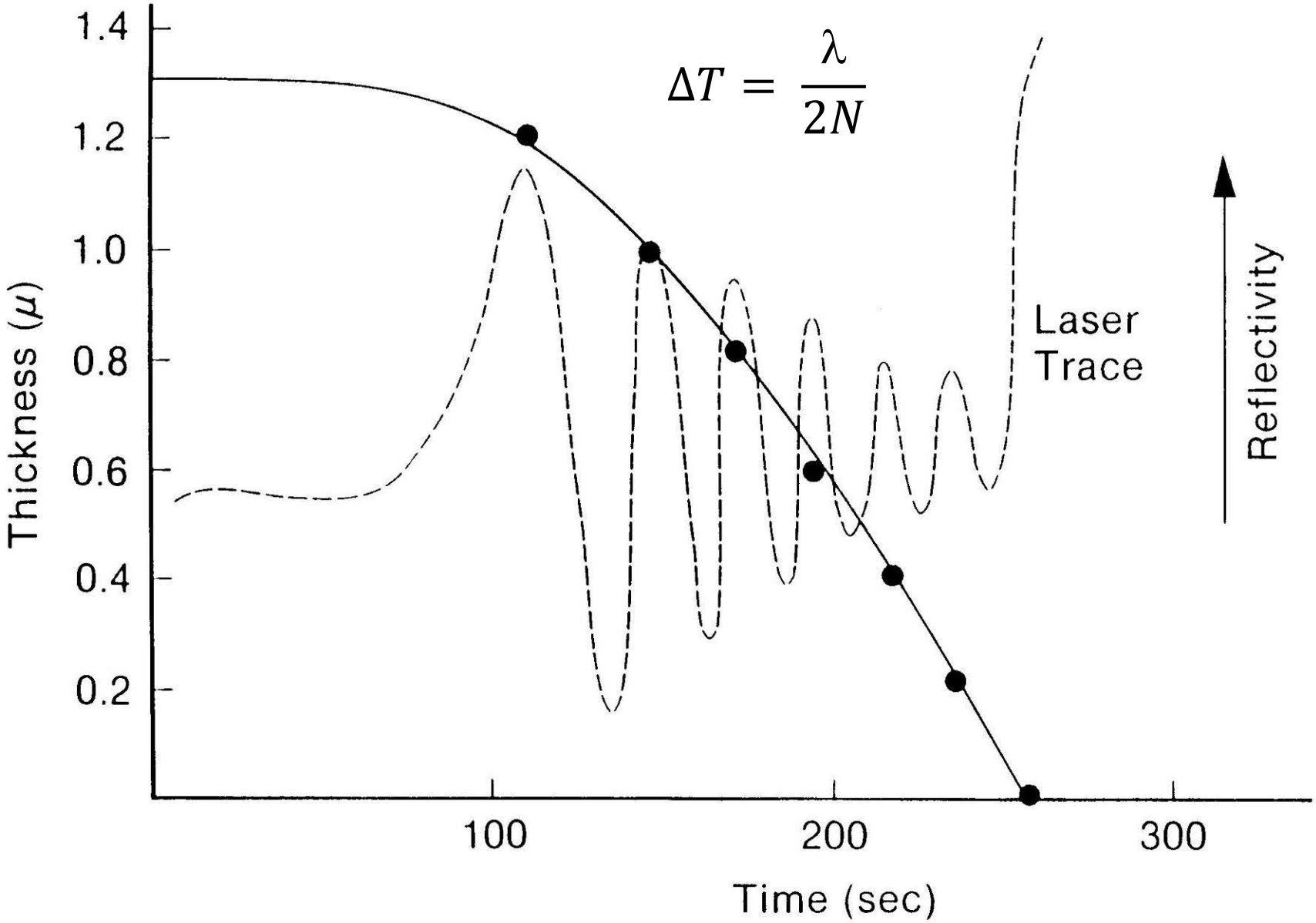
Fundamental Measure of Resist Response




1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Thickness Remaining (μm)
0.0
0.4
0.8
1.2
1.6
2.0
Log Dose (microcoulombs/cm2)

Laser end point detection system

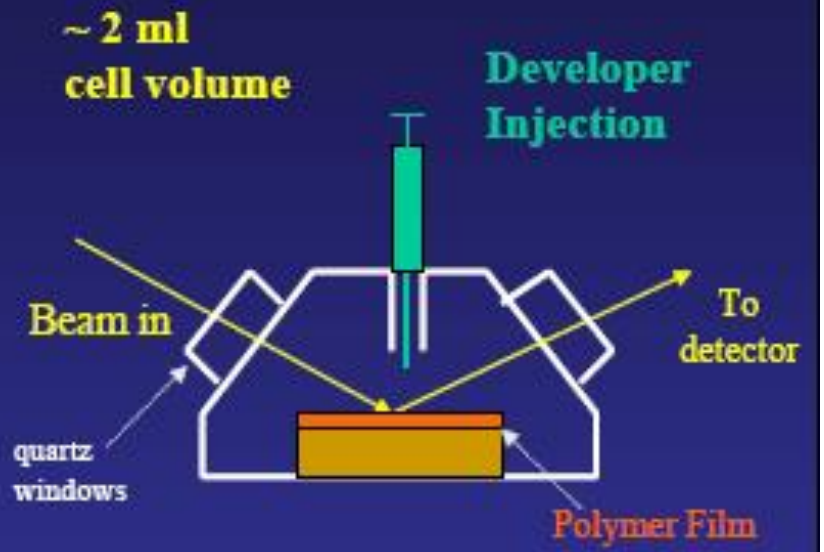



$\Delta T = \frac{\lambda}{2N}$
1.4
1.2
1.0
0.8
0.6
0.4
0.2
Thickness (μ)
100
200
300
Time (sec)
Laser Trace
Reflectivity

Spectroscopic Ellipsometry as a Tool for Studying Dissolution

Operates at >40Hz and measures thin films

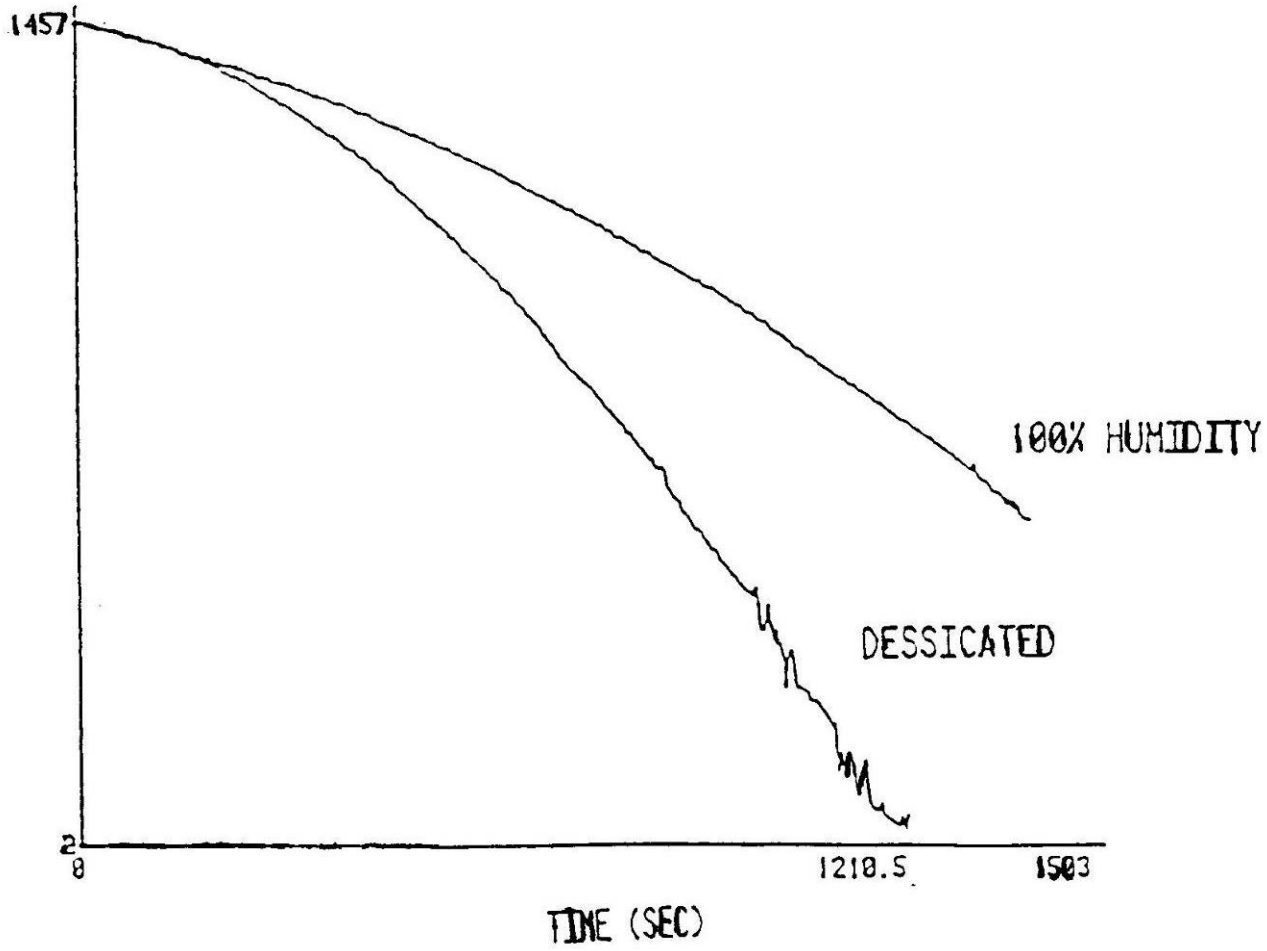
O



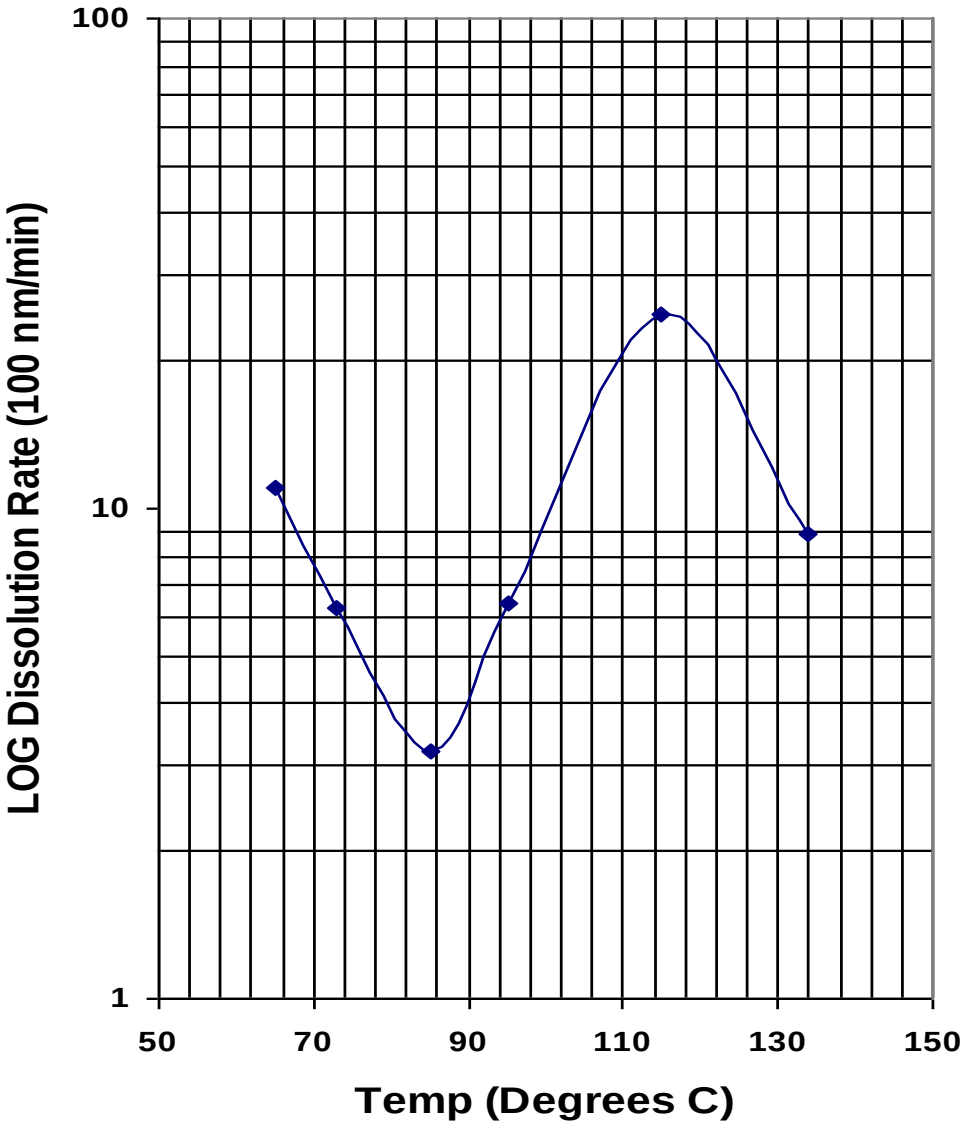
- Measure dissolution rate of bulk and thin films
- Study swelling and interfacial layers during dissolution

Data rate > 40Hz and measures very thin films

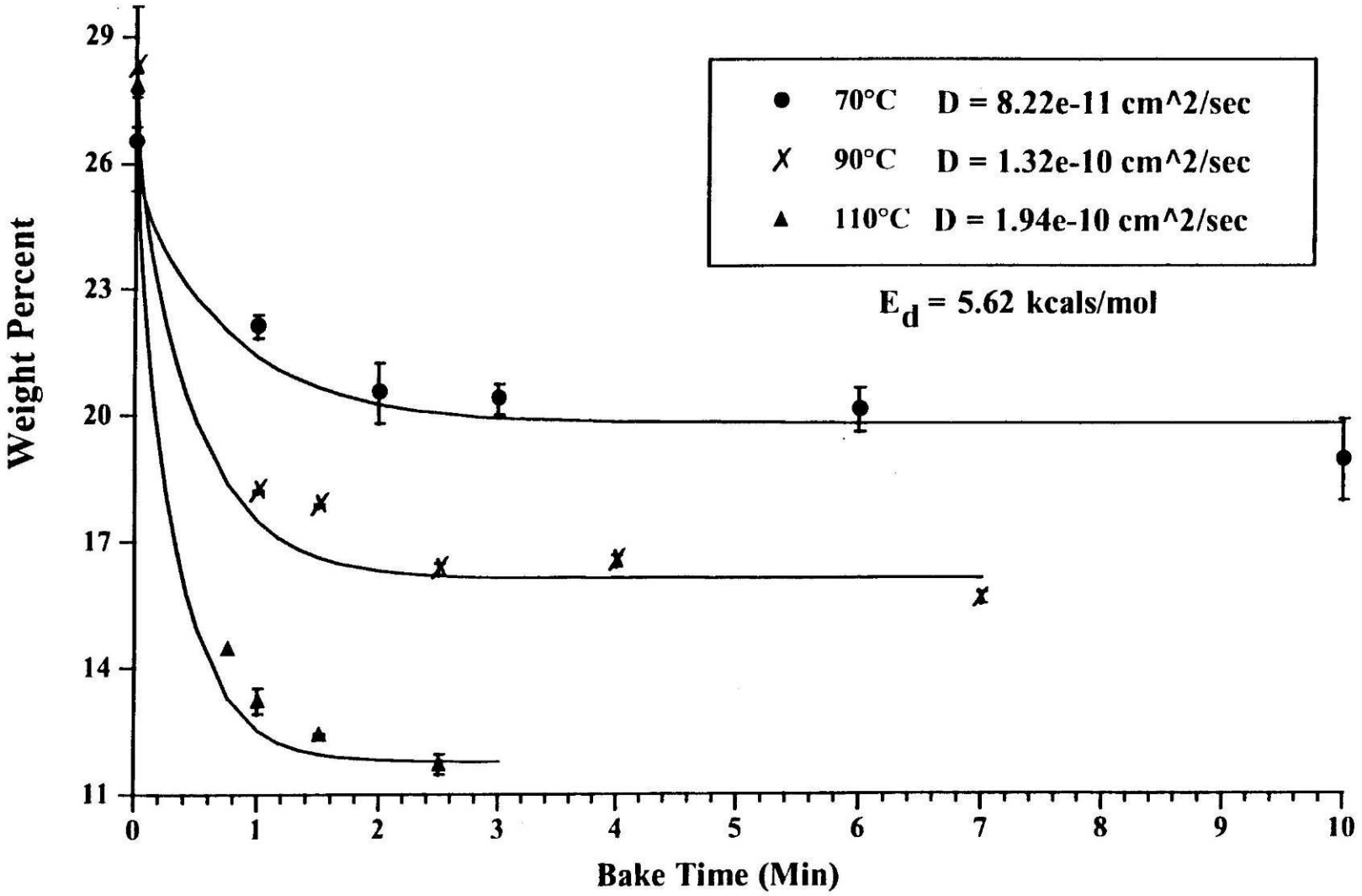
Effect of Humidity on dissolution rate



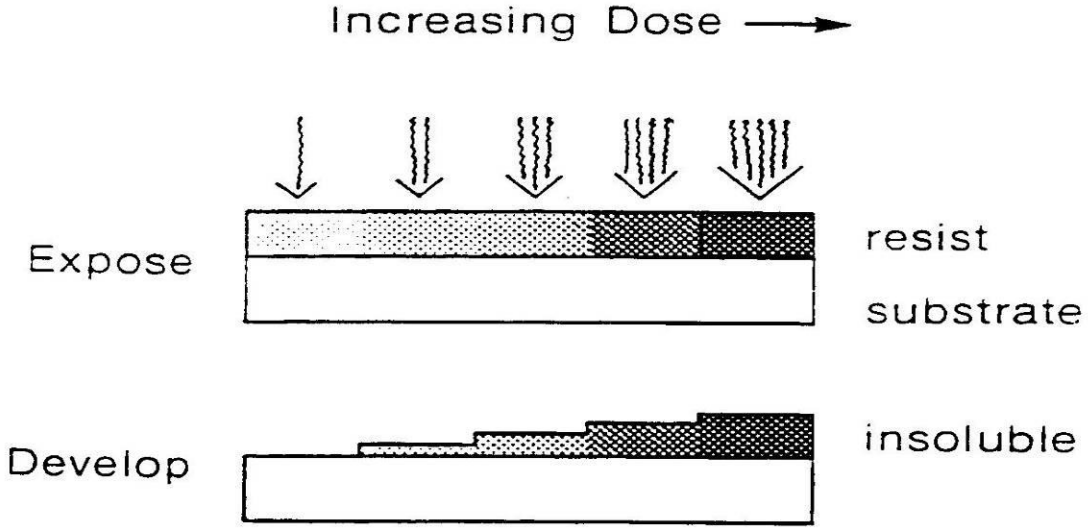
Dissolution Rate vs Post Apply Bake Temperature



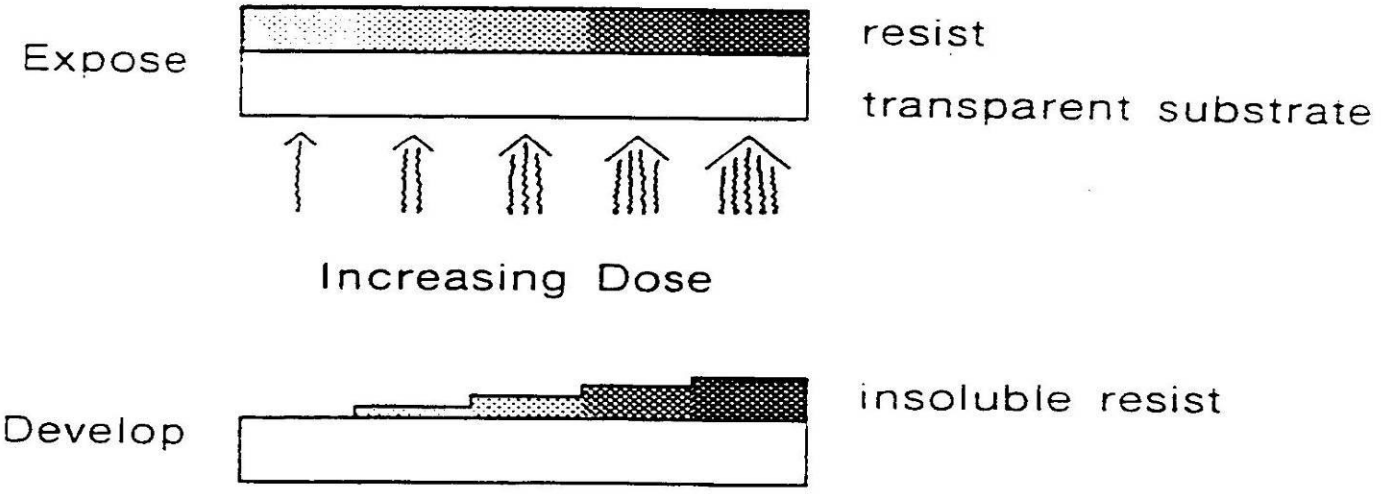
Weight Percent vs. Bake Time Data for PGMEA



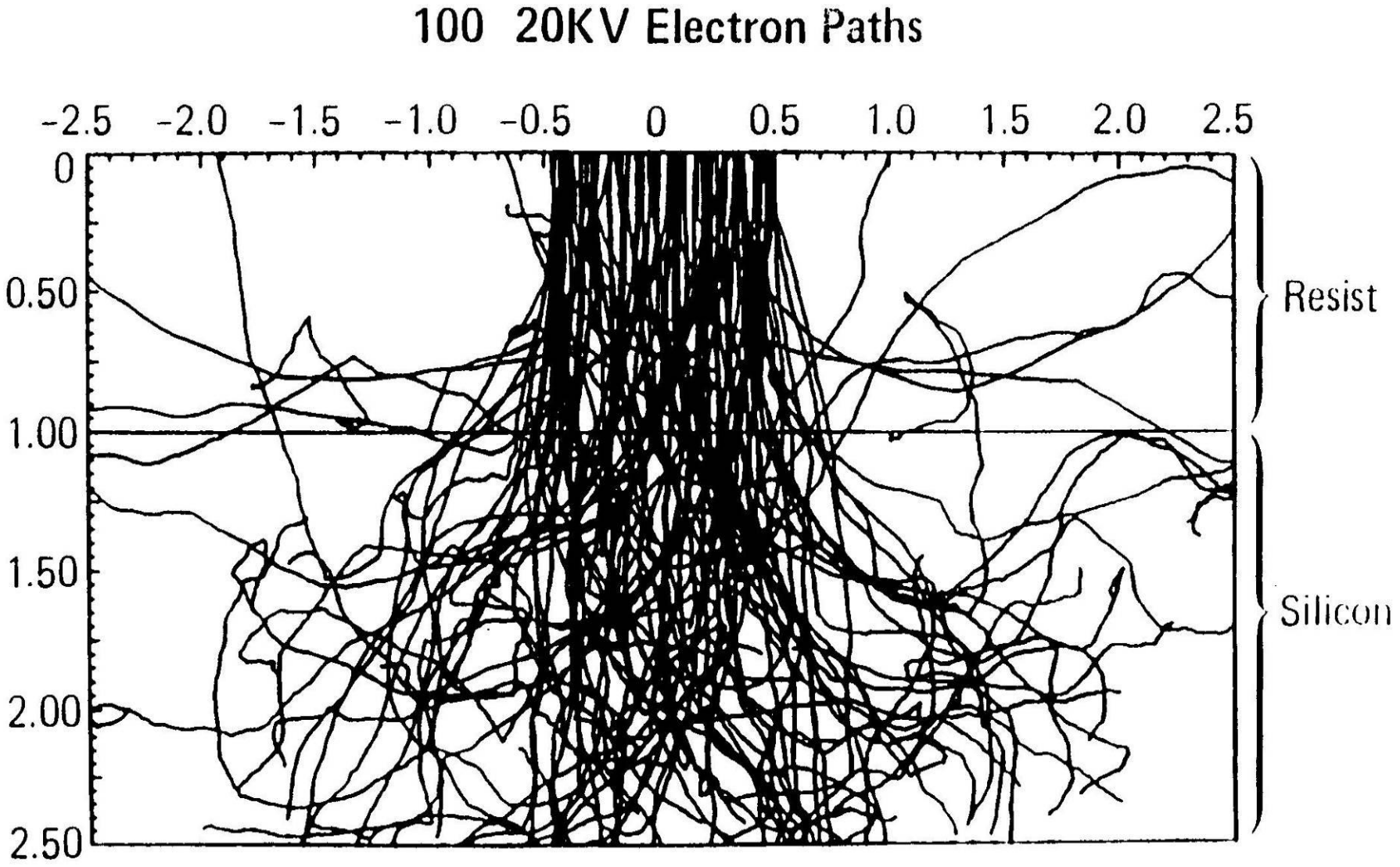
X-Ray & E-Beam Experiment



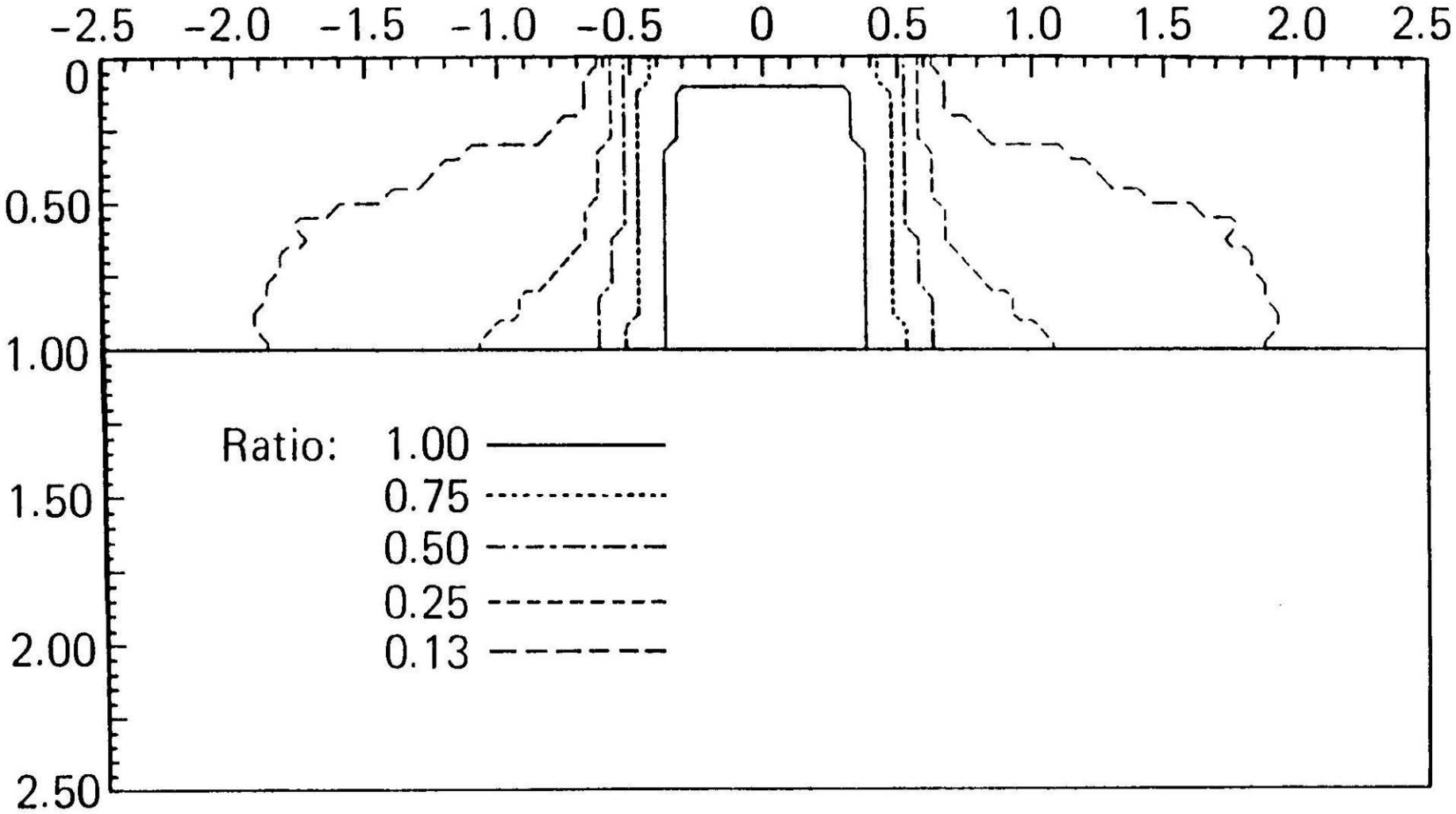
Optical Experiment



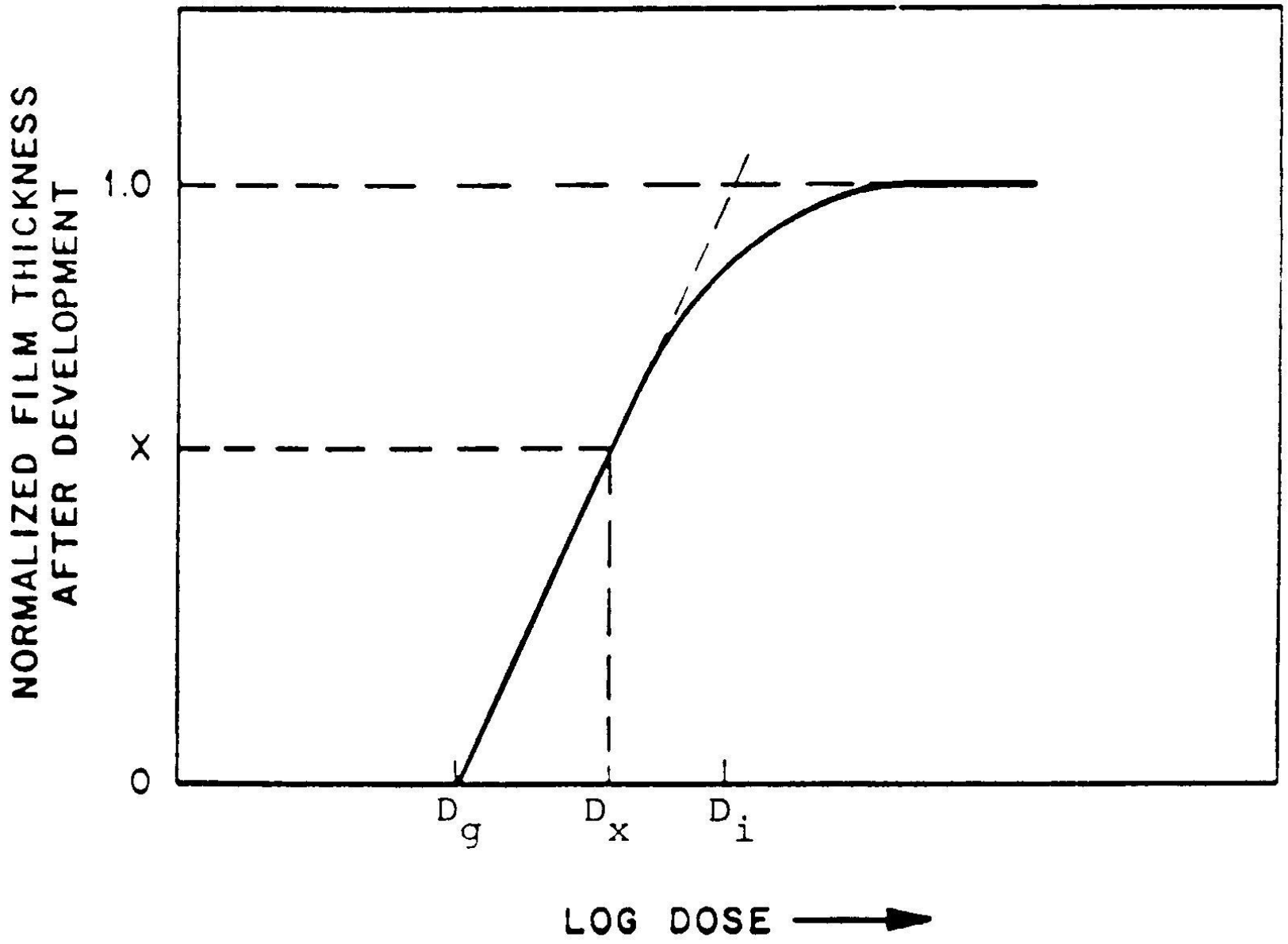
Simulated Electron Beam Exposure

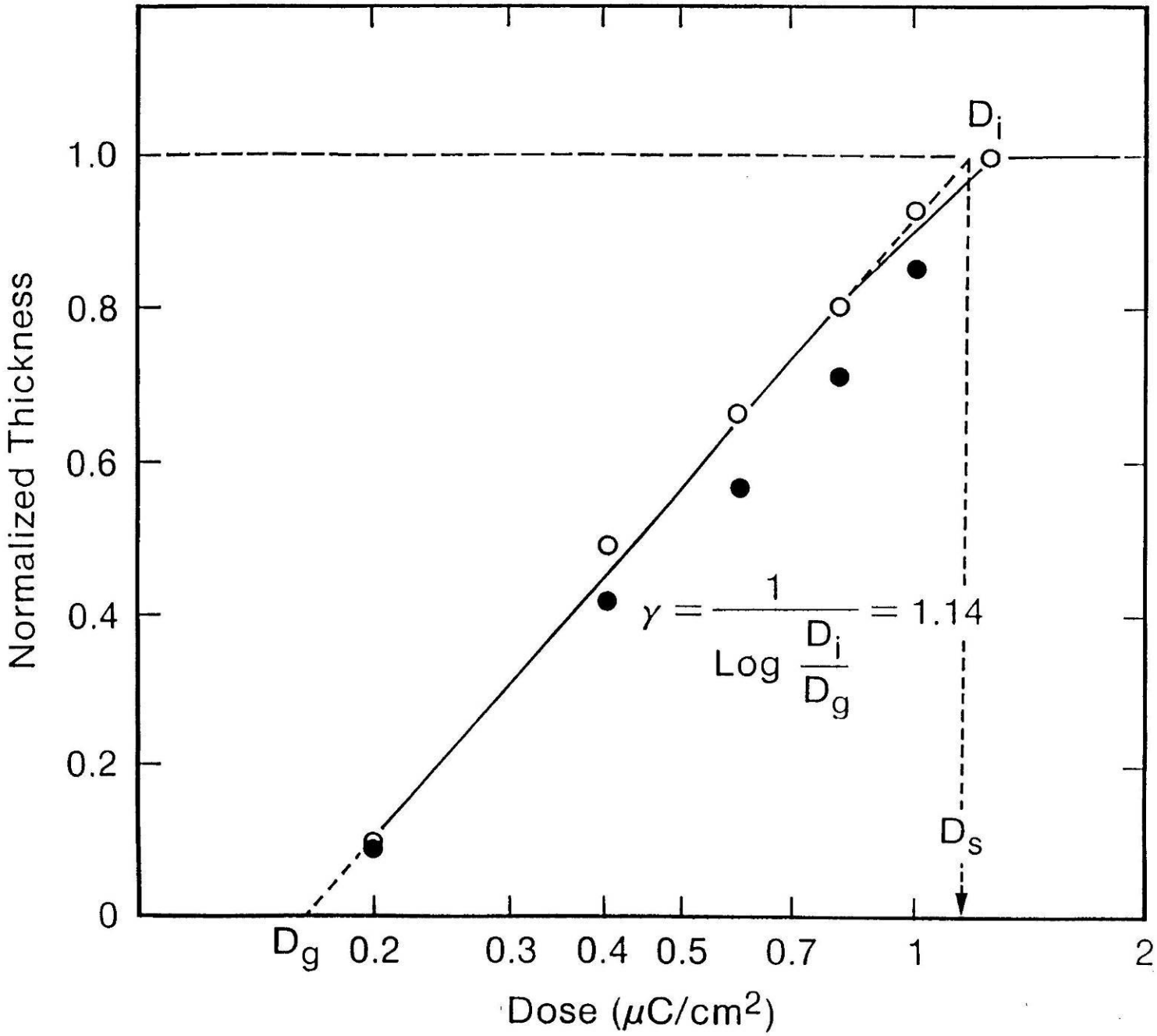


Energy Distribution Plot



Negative Resist Characterization



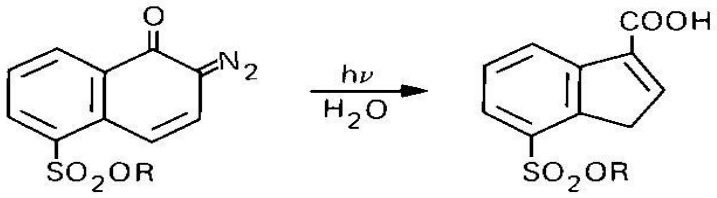

Normalized Thickness
1.0
0.8
0.6
0.4
0.2
0
D_i
$\gamma = \frac{1}{\text{Log } \frac{D_i}{D_g}} = 1.14$
D_s
D_g
0.2
0.3
0.4
0.5
0.7
1
2
Dose ($\mu C/cm^2$)

Negative Resist

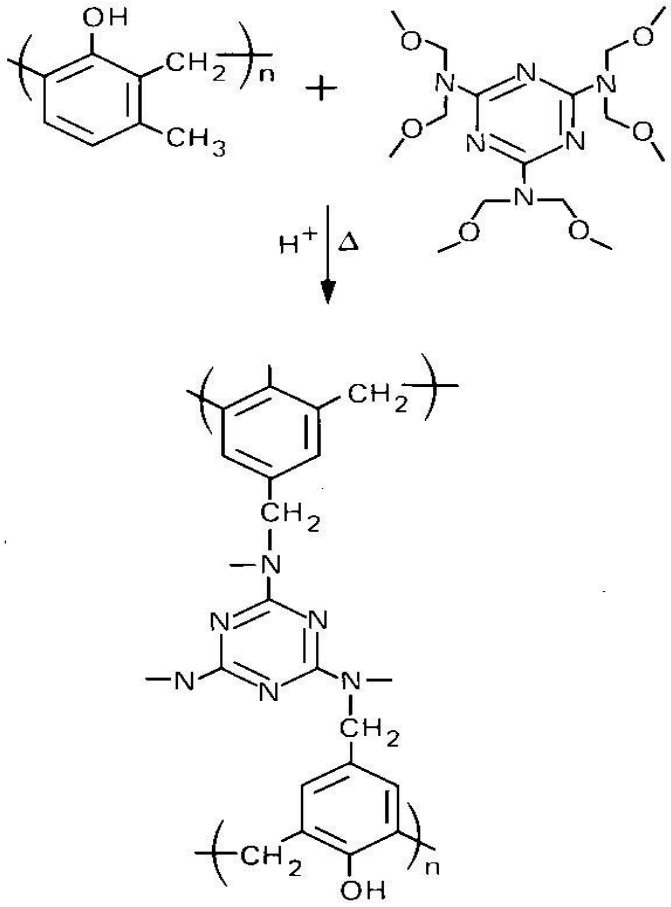
Wayne Feeley

Rohm and Haas

1. Photoacid generation



2. Acid catalyzed crosslinking

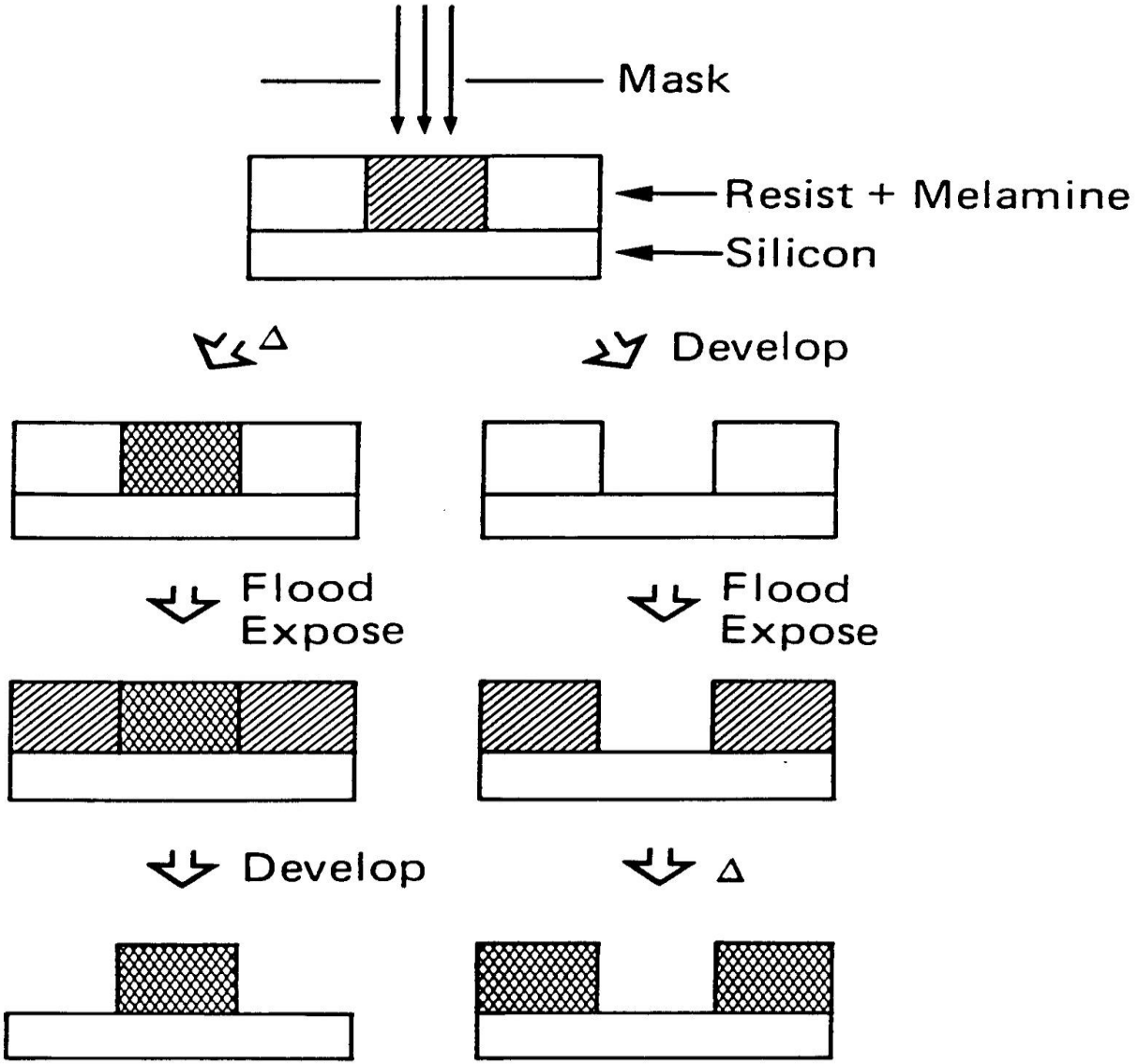


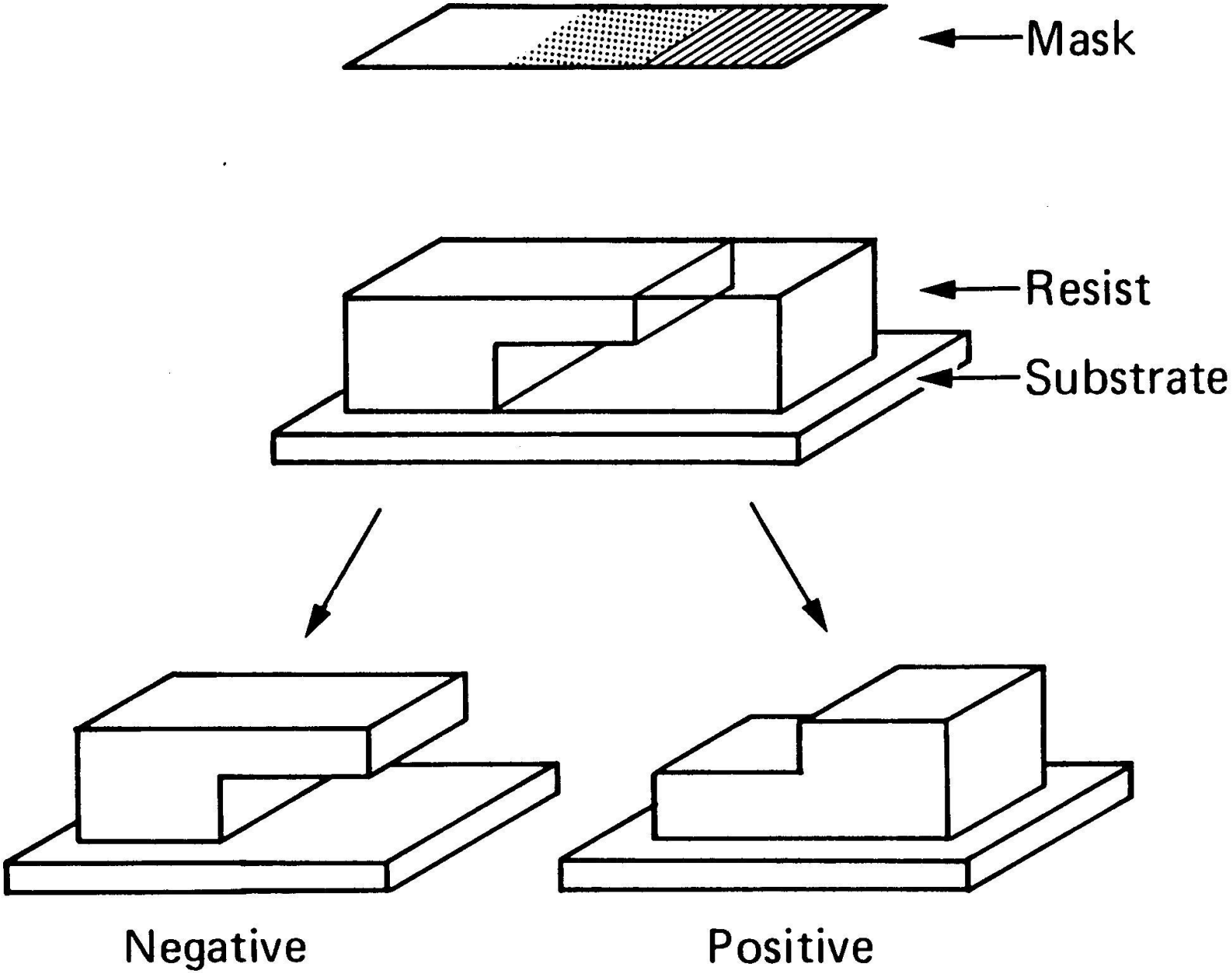

Melamine Resin - Formica

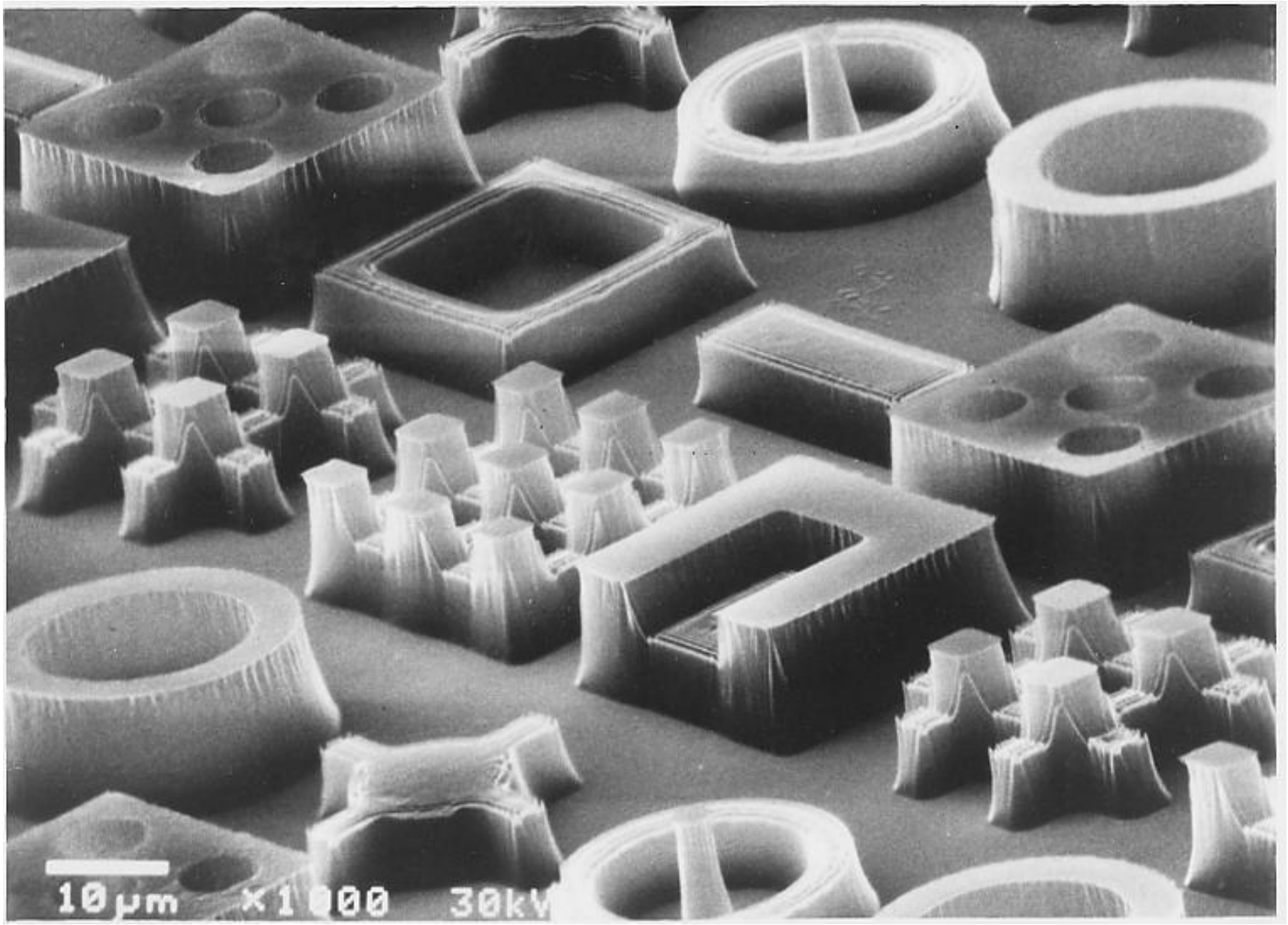
The **2008 Chinese milk scandal** was a food safety incident in China. The scandal involved milk and infant formula along with other food materials and components being adulterated with melamine.

China reported an estimated 300,000 victims in total. Six babies died from kidney stones and other kidney damage and an estimated 54,000 babies were hospitalized. The chemical gives the appearance of higher protein content when added to milk, leading to protein deficiency in the formula. In a separate incident four years prior, watered-down milk had resulted in 12 infant deaths from malnutrition.

Acid Catalysis of Crosslinking




Mask
Resist
Substrate
Negative
Positive


10µm
30kV