Microelectromechanical Systems (MEMs)
Unit Processes for MEMs
Lithography

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9-18-2012 mem_lith.ppt

OUTLINE

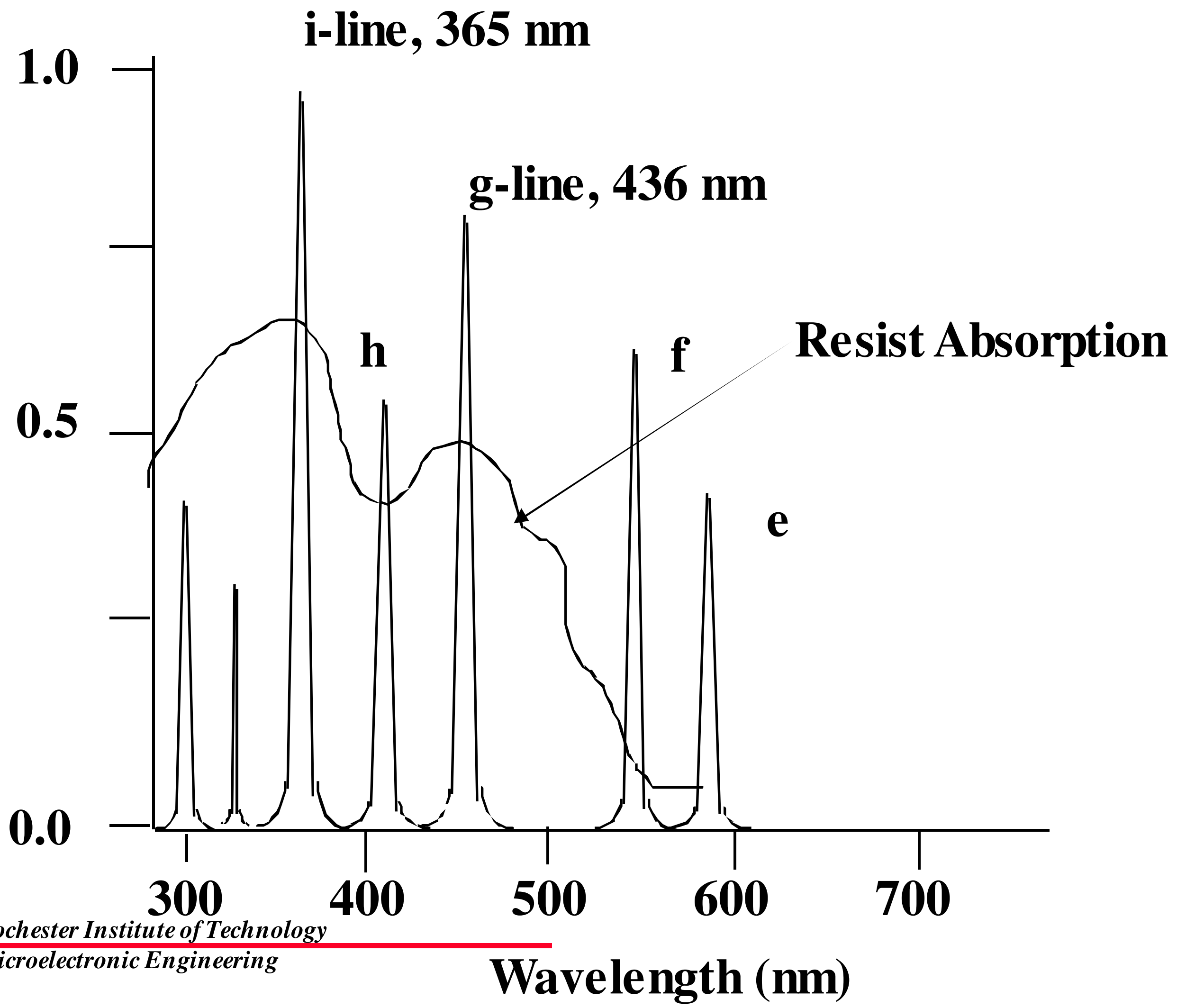
- Photolithography
- Resist Processing
- LIGA
- Thick Resists
- SU-8
- Maskmaking for MEMs
- Reversal Processing
- Lift-Off
- Tri-Layer Processes
- Imaging Polyimides
- References
- Homework

RAYLEIGH CRITERIA

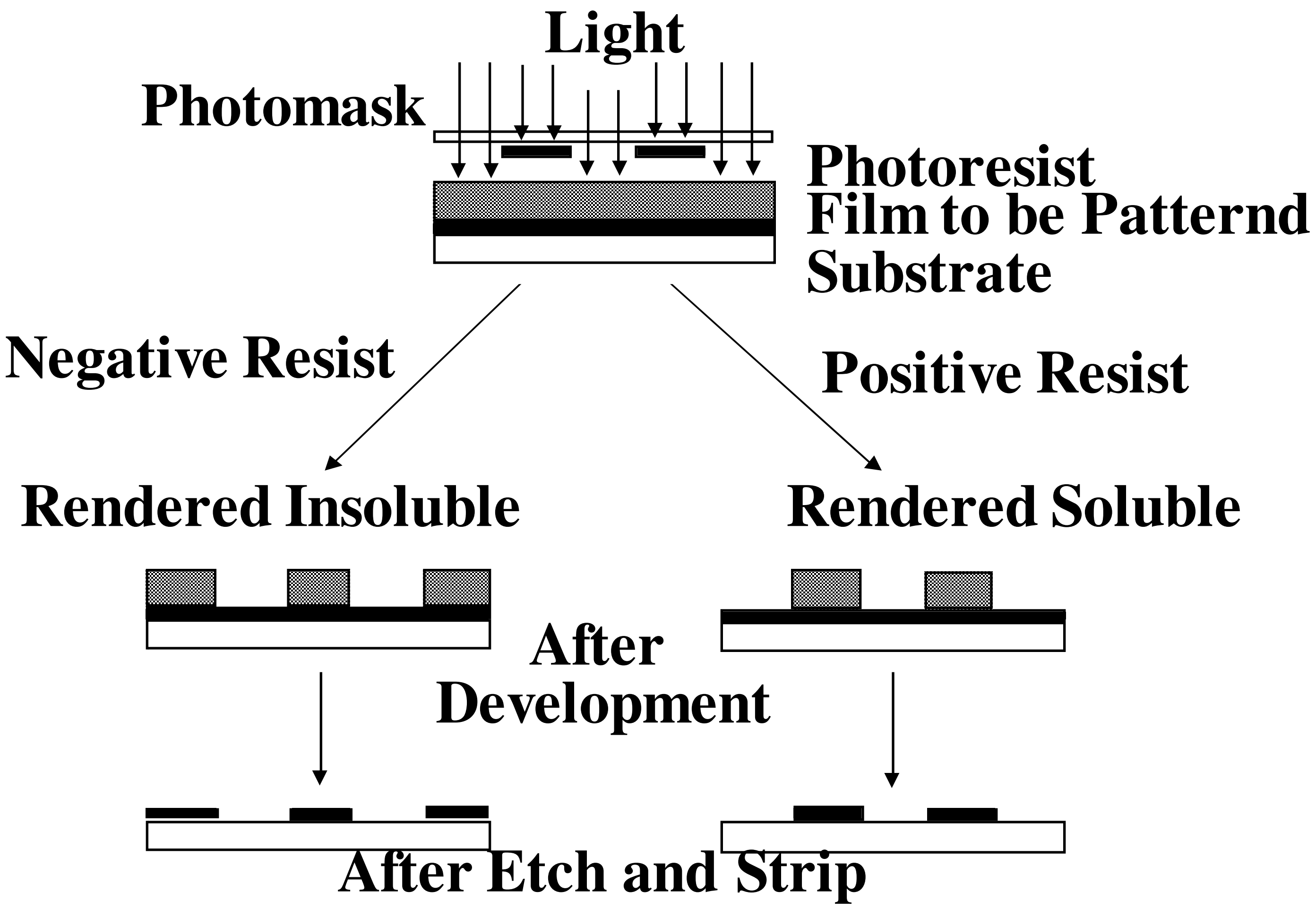
$$\mathrm{Lmin} = 0.61\ \lambda\ / \mathrm{NA} \qquad \mathrm{DOF} = \lambda\ / (2(\mathrm{NA})^2)$$

	g-line	i-line	KrF	ArF	ArF
λ	436 nm	365nm	248nm	193nm	193nm
NA	0.28	0.52	0.52	0.52	0.65
Lmin	0.95µm	0.50µm	0.30µm	0.23µm	0.18µm
DOF	2.78µm	0.8µm	0.46µm	0.36µm	0.23µm

EMISSION SPECTRA OF THE Hg VAPOR BULB



PHOTOLITHOGRAPHY



Light

Photomask

Photoresist
Film to be Patternd
Substrate

Negative Resist

Positive Resist

Rendered Insoluble

Rendered Soluble

After
Development

After Etch and Strip

PHOTORESIST PROCESSING

Substrate Cleaning
Priming
Spin Coating
Soft-Bake
Exposure
Post Exposure Bake
Develop
Rinse
Hard-Bake
Etching
Striping

SUBSTRATE CLEAN AND PRIME

Cleaning is done with a high pressure (2000 psi) water scrub

A dehydration bake is typically done on a hot plate at 250 °C for 1 min. (Wafers are clean and dry just after removing from oxide growth furnace)

HMDS (hexa-methyl-di-silizane), TCPS, BSA - Adhesion promoter or primer: Are commonly applied as a liquid or vapor. HMDS attaches to remaining OH molecules releasing ammonia gas and creating an organic-like surface improving adhesion

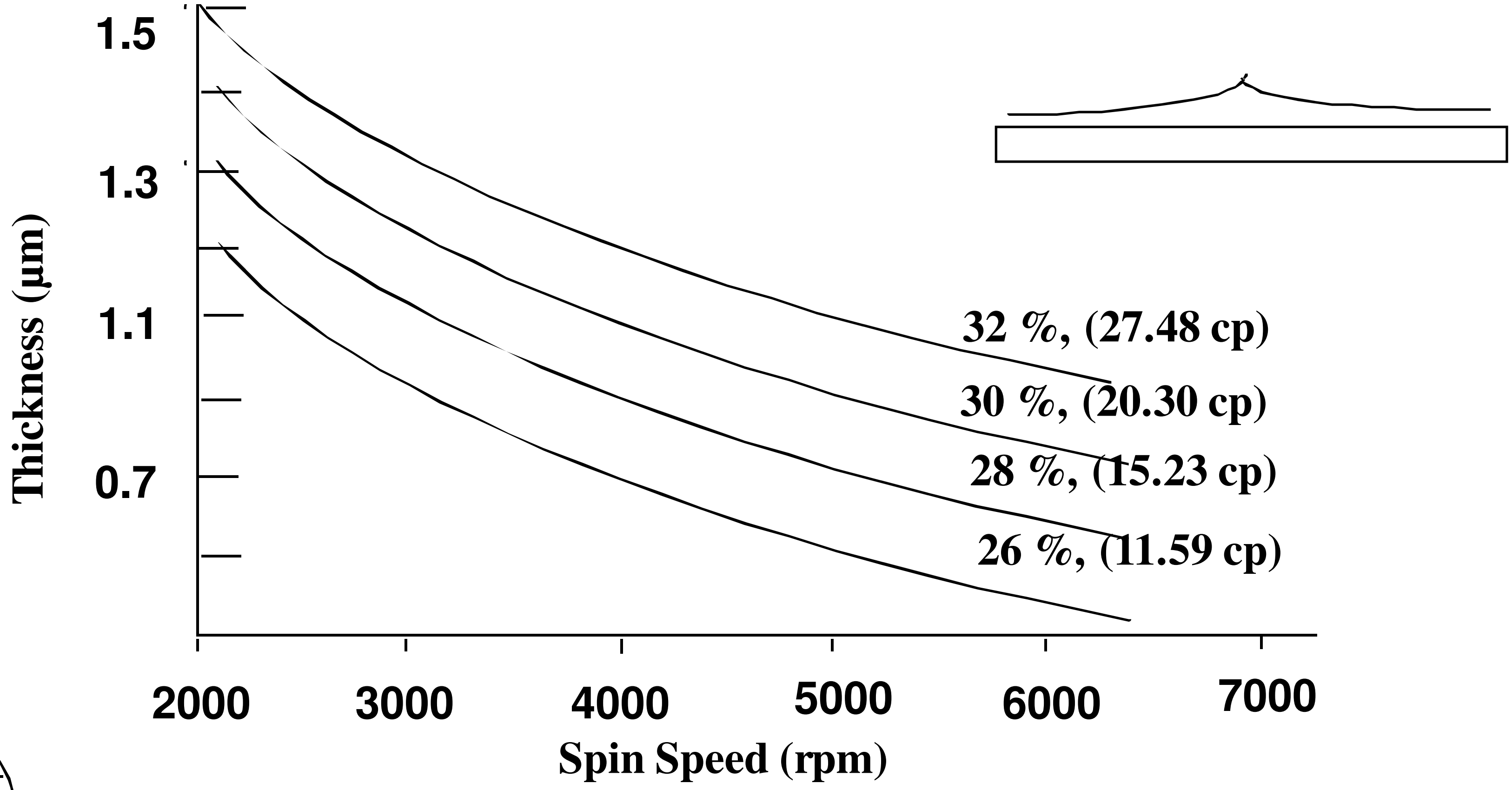
Too much HMDS is detrimental to sensitivity and adhesion.

RESIST SELECTION

	Type	wavelength λ (nm)	Sensitivity (for 1 µm)	Resolution (µm)	Contrast	Thickness (µm) @ 4000 rpm	Softening Temperature	Boron and Iron (ppm)	Solvent Type
S 1400	Pos	g	50	0.6	1.8	0.1-2.8	120	1000	EGMEA
S 1800	Pos	g	100	0.6	1.8	0.1-2.8	120	1000	PMA
EL 2026	Pos	g, i	100	0.5	4.2	0.1-40			EL
OCG 825	Pos	g,i	160	0.6	3	0.8-3	140	500	EEP
OMR-83	Neg	i	30	2.5			175		Xylene
SAL 601	Neg	ebeam	1uC/cm2	0.1	4	0.2-1.5	120	1000	EEA

RESIST THICKNESS VS SPIN SPEED

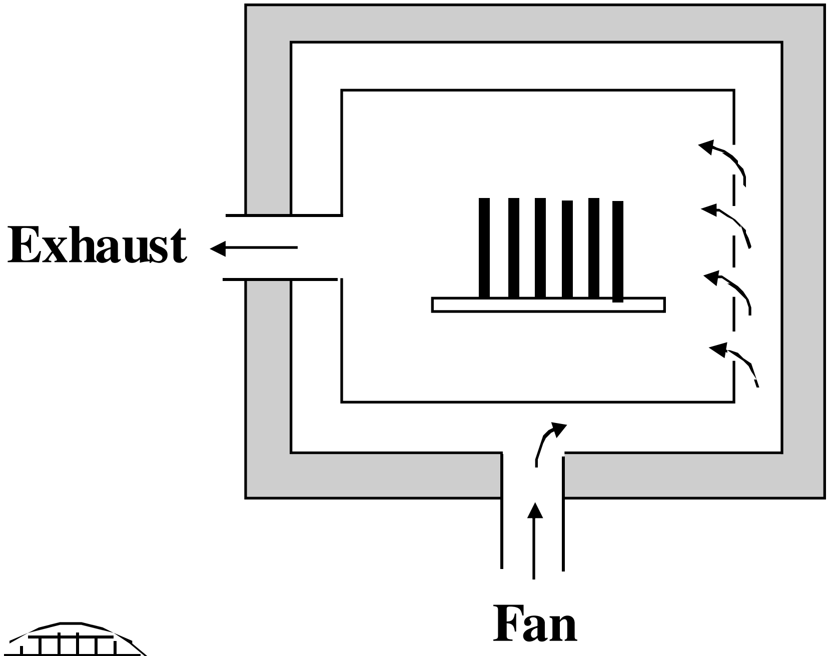
Most spin coating is performed at spin speeds from 3000 to 7000 RPM for 20 to 60 seconds, producing coating uniformities to +/- 100 Å

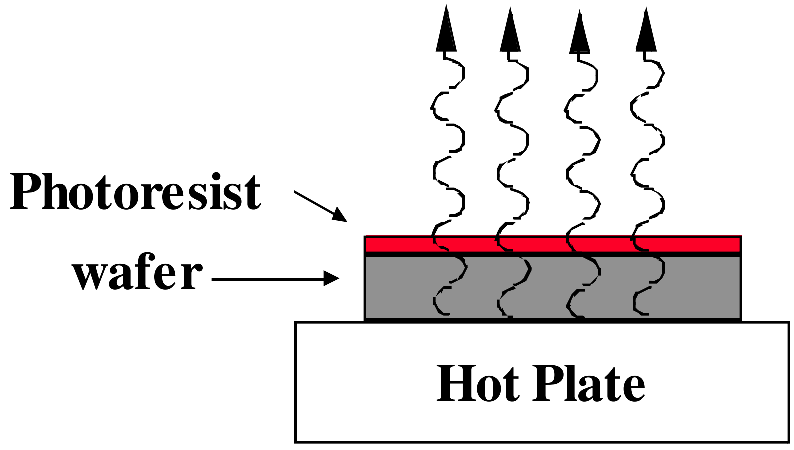


Example Only

SOFT BAKE

The main purpose is to reduce the solvents from a level of 20 - 30% down to 4 - 7%. Baking in a convection oven about 20 minutes is equivalent to hot plate baking for about 1 minute.


Forced Air Oven



90 TO 100 C

AUTOMATED COAT AND DEVELOP TRACK

COAT AND DEVELOP TRACK

DEHYDRATE BAKE/
HMDS PRIMING

HMDS Vapor
Prime
140 °C, 60 sec.

SPIN COAT

Shipley812
Resist
4500rpm, 60 sec.

SOFT BAKE

115 °C
60 sec.

RECIPE 1 for all Tracks

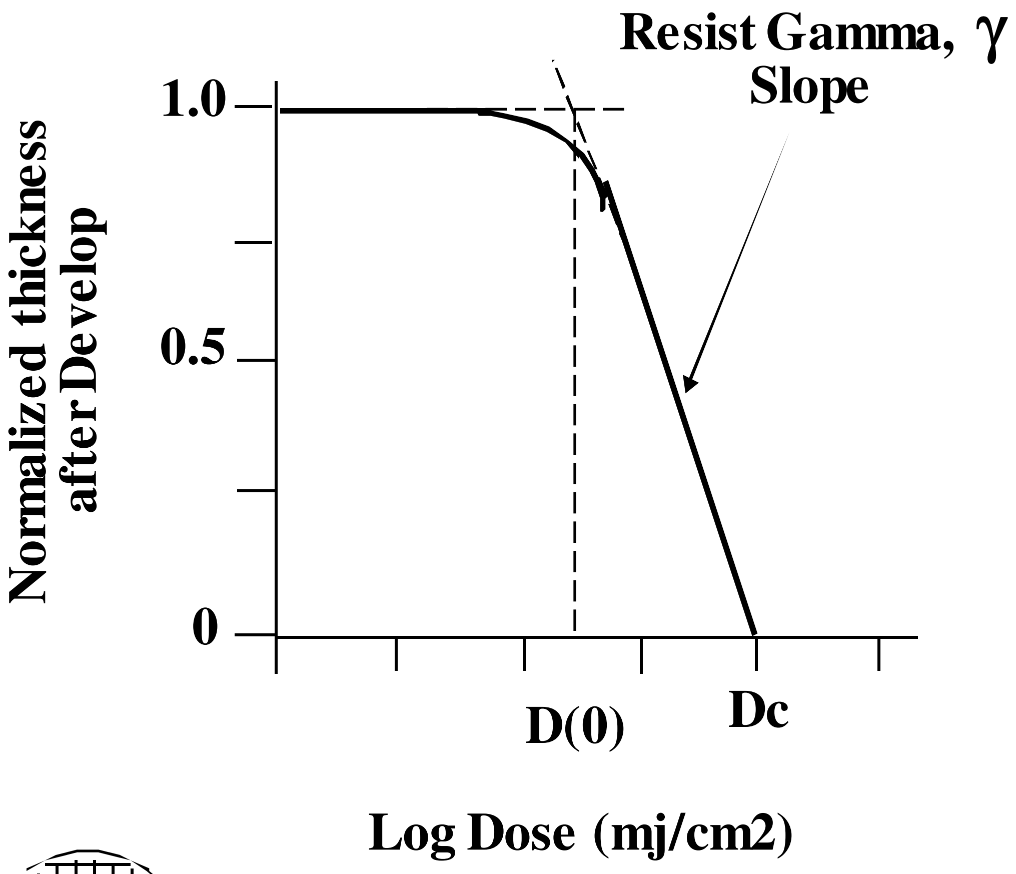
DEVELOP

DI Wet
CD-26 Developer
45sec. Puddle,
30sec. Rinse,
40sec., 4000rpm
Spin Dry

HARD BAKE

125 °C, 60 sec.

THICKNESS AFTER DEVELOP LOG DOSE



Dc is the dose to clear
D(0) is the max dose for unexposed areas

The higher the slope or contrast, gamma, then the smaller the difference needs to be between exposure in areas to be cleared and areas to leave resist. That is the required airal image modulation is smaller.

EXPOSURE

$$E = I\,t$$

where E is exposure dose in mj/cm2, I is irradianc in mw/cm2, t is exposure time in seconds

Humidity should be 45% the exposed PAC requires water to convert to carboxilic acid

Post exposure bake increases speed of resist

Post exposure bake reduces standing wave effects

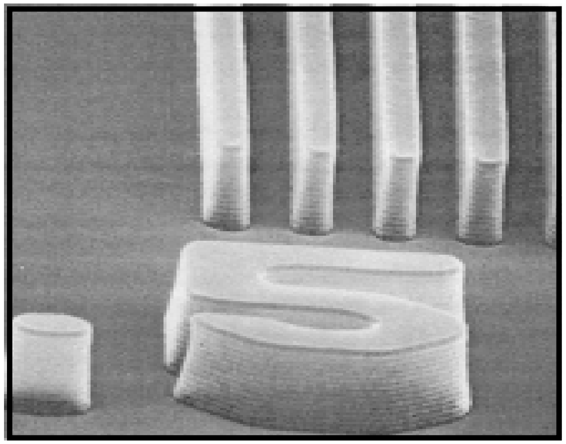
Post exposure bake is require for chemically amplified and image reversal resists (100 to 115 C for 1 min.)

GCA 6700 STEPPER

g-Line Stepper
$\lambda = 436$ nm
NA = 0.28
$\sigma = 0.6$
Resolution
$0.6\ \lambda / NA = \sim 1 \mu m$
20 x 20 mm Field Size
Depth of Focus
$= k_2\ \lambda/(NA)^2 = 3\ \mu m$

Stepper Job: [10,1]MEMS2000
Pass: 1 (poly1), 2 (via), 3 (anchor), 4 (poly2)

ASML 5500/200



NA = 0.48 to 0.60 variable

σ= 0.35 to 0.85 variable

With Variable Kohler, or Variable Annular illumination

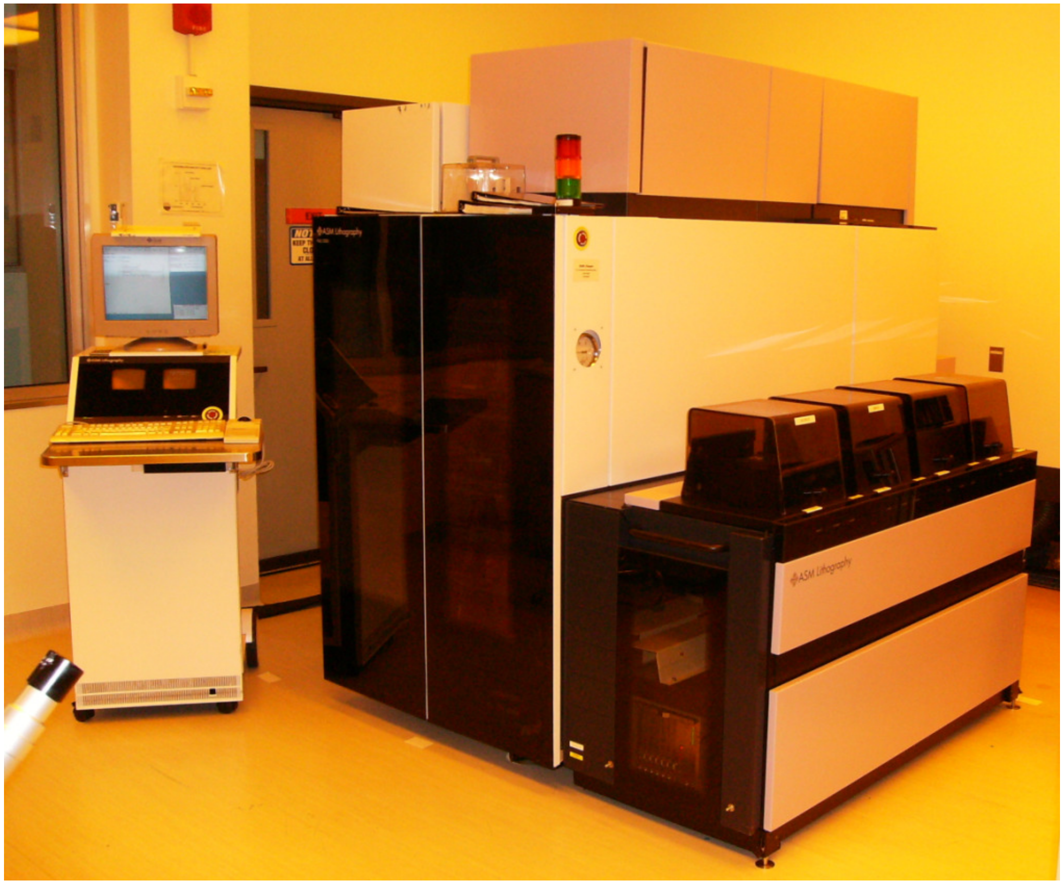
Resolution = K1 λ/NA

= ~ 0.35µm

for NA=0.6, σ =0.85

Depth of Focus = $k_2\ \lambda/(NA)^2$

= > 1.0 µm for NA = 0.6



i-Line Stepper λ = 365 nm

22 x 27 mm Field Size

EXPOSURE TOOLS

SEE www.suss.com
contact printers
with back side alignment

Karl Suss Aligner at RIT

DEVELOP

Develop is done in an alkali solution such as NaOH or KOH (Metal Containing Developers) Trace quantities of these metals can cause transistor threshold voltage shifts. These developers give higher contrast and are less expensive than metal ion free.

Metal Ion Free Developers are available.

Developer Concentration and Temperature of Developer are the most important parameters to control.

HARD BAKE

Hard Bake is done at or slightly above the glass transition temperature. The resist is crosslinked (and is toughened prior to plasma etch). The resist flows some as shown below. Pinholes are filled. Improves adhesion also. No flow should occur at the substrate. Photo stabilization involves applying UV radiation and heat at 110C for dose of 1000 mj/cm2 then ramping up the temperature to 150-200 C to complete the photostabilization process.

125 to 140 C for 1 min.

ETCH

Wet etches
- Acids – can be used
- Bases – can not be used with positive photoresist

Plasma etches
- Flourine based etches – etches photoresist at ~0.2 µm/min
  - Isotropic etches available
  - Anisotropic etches available

RESIST STRIP

O_2 + Energy = 2 O

O is reactive and will combine with plastics, wood, carbon, photoresist, etc.

Asher

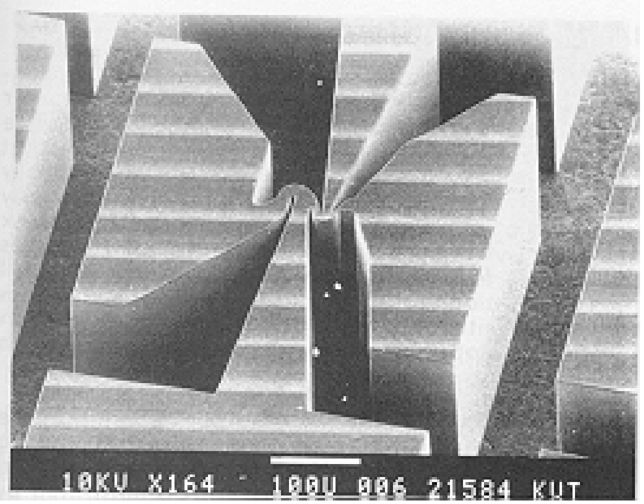
NOVEL RESIST PROCESSES

LIGA Process
SU-8
Thick Resists
Reversal Processing
Lift-off Processes
Tri-layer Processes
Electrodeposited Resist
Nano-imprint Technology

Maskmaking for MEMs

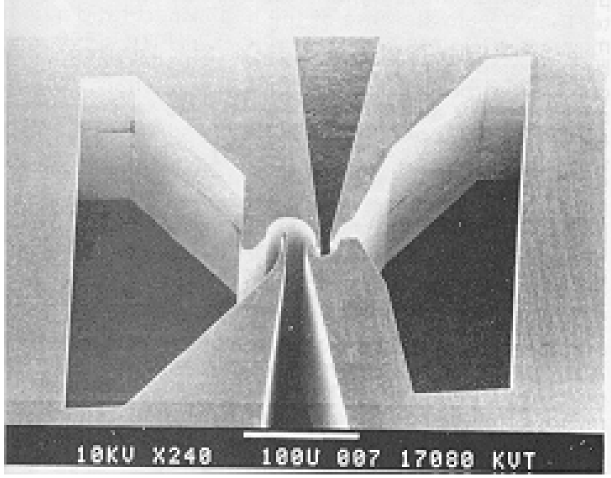
LIGA

LIGA method is based on a combination of deep-etch x-ray lithography, electroforming and molding. (in German: Lithographie, Galvanoformung, Abformung)

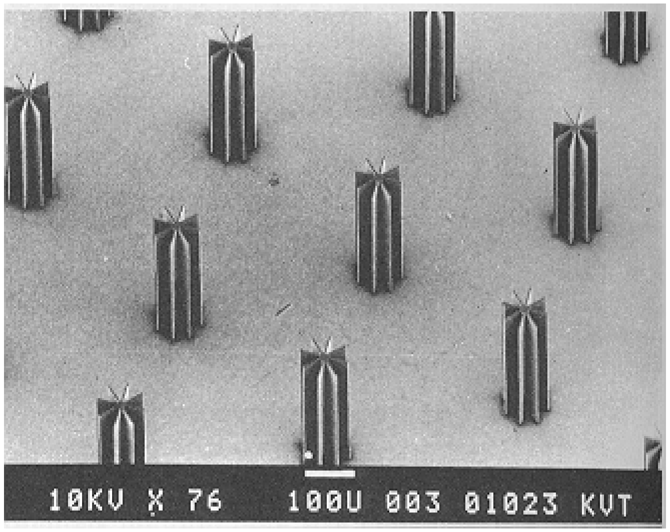


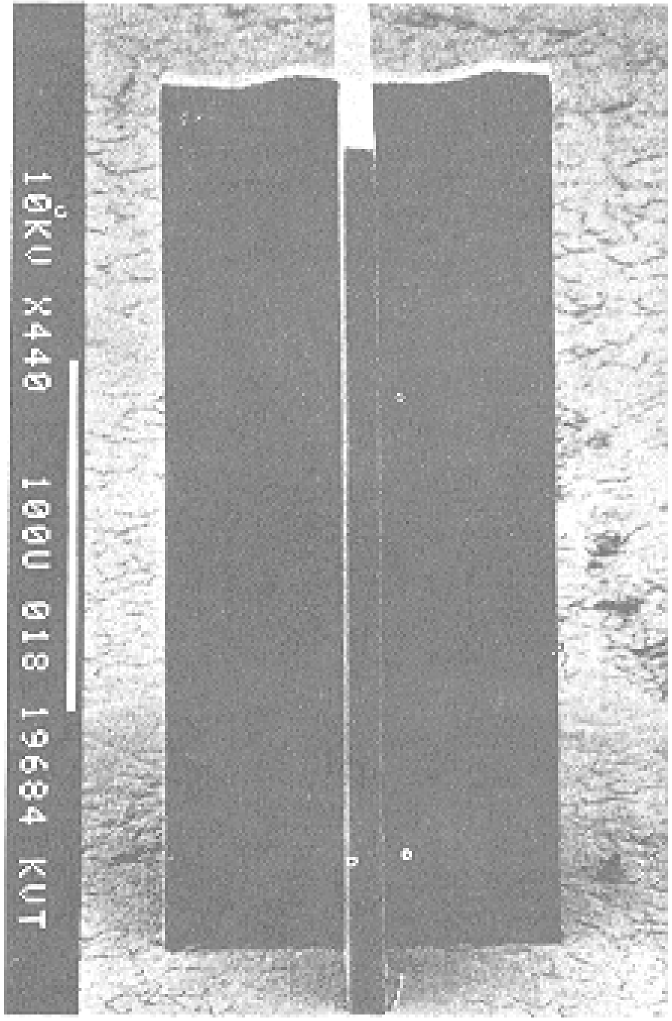
X-ray resist image

Electroplated nickel mold



LIGA

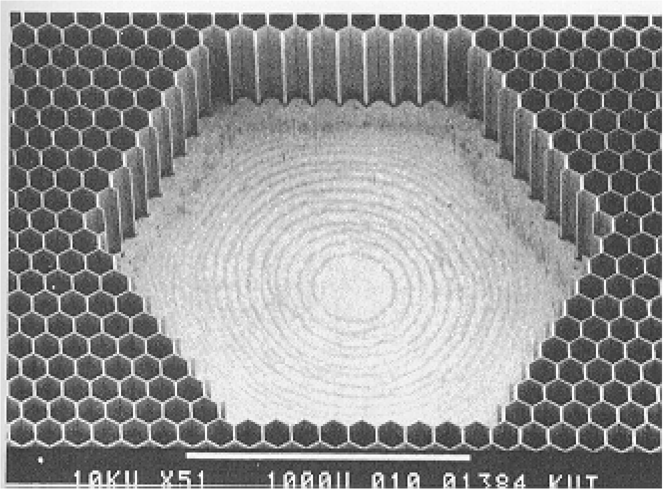


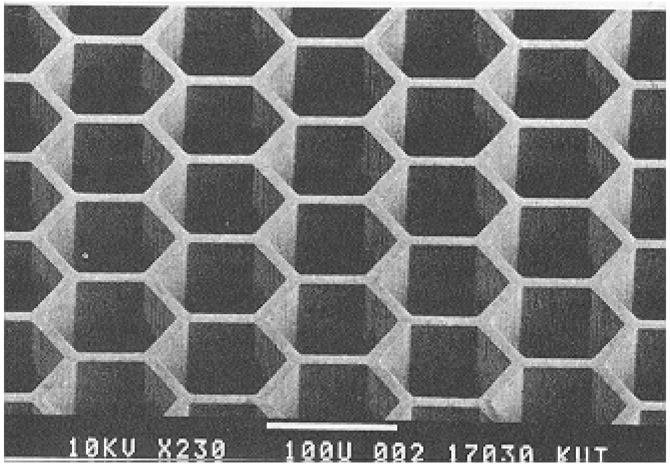


X-ray lithography has depth of focus that is measured in cm. This structure is ~400 µm in height

LIGA

Honeycomb structure in PMMA. Openings of 80 µm, wall thickness of 7 µm





SU-8 RESIST

Microlithography Chemical Company

MORE

MicroChem Corp.,
1254 Chestnut Street, Newton, MA 02464.
Tel: (617)965-5511
Fax: (617) 965-5818, makes SU-8, LOR and other resist systems

SU-8 is an Epoxy Photoresist coatings 50-500 um thickness

(does not strip in acetone, oxygen plasma strip is possible but takes 50 to 500 times longer than a 1 um coating so RIE oxygen plasma, high pressure water and other techniques are used.)

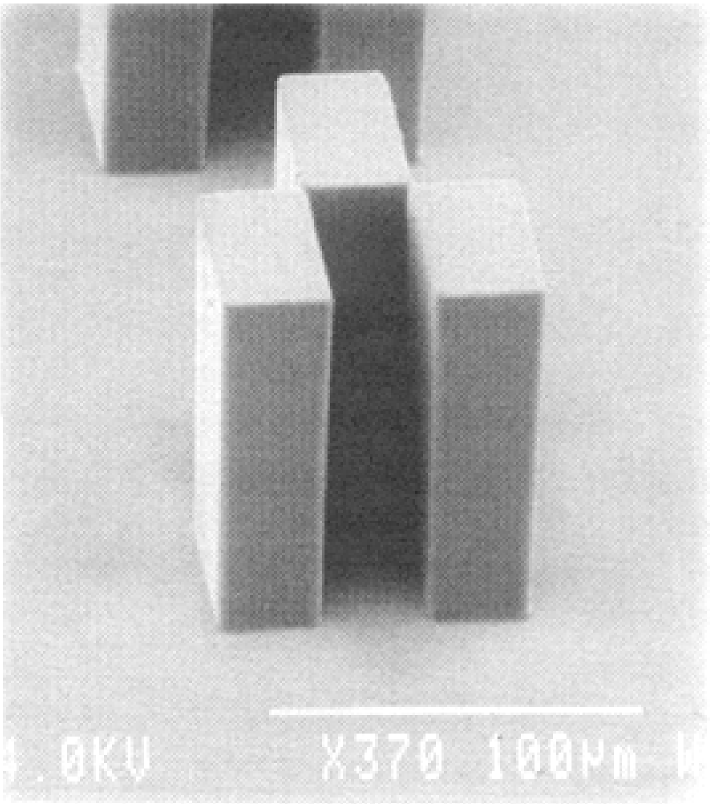
Electroplate nickel on 500 A chrome, 3000 A copper base layer

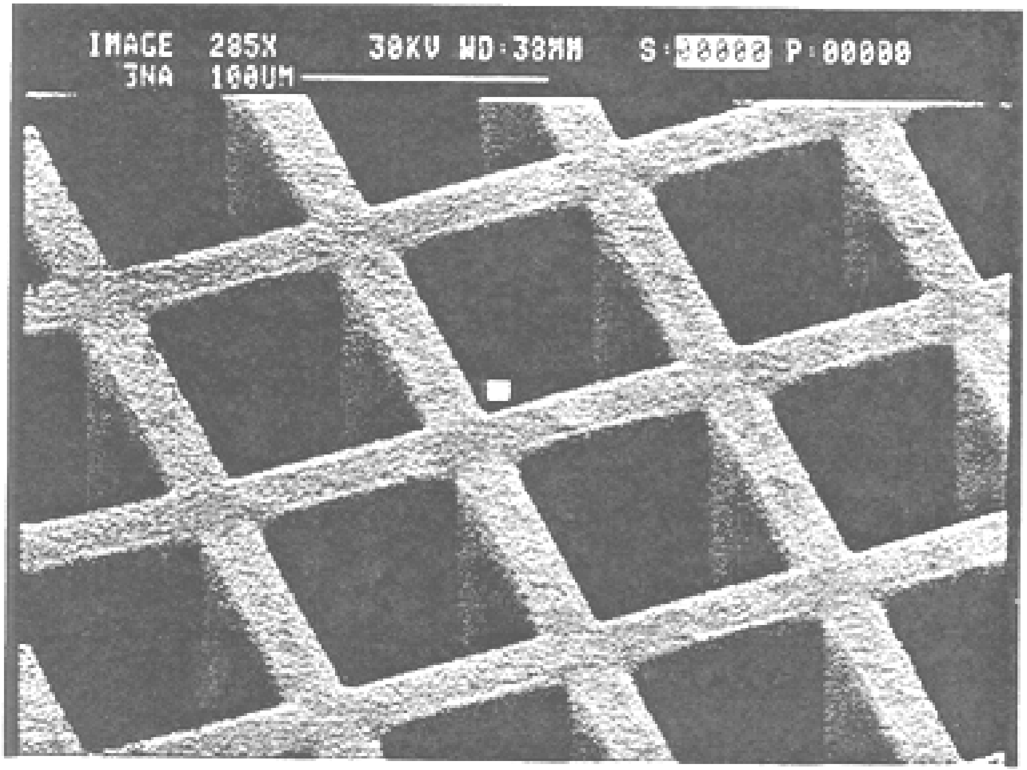
When using a mold use polydimethylsiloxane (PDMS) mold release

Jenoptik makes HEX 03 hot embossing system or do by homemade 150 C, vacuum forming, 45 min

SU-8 RESIST

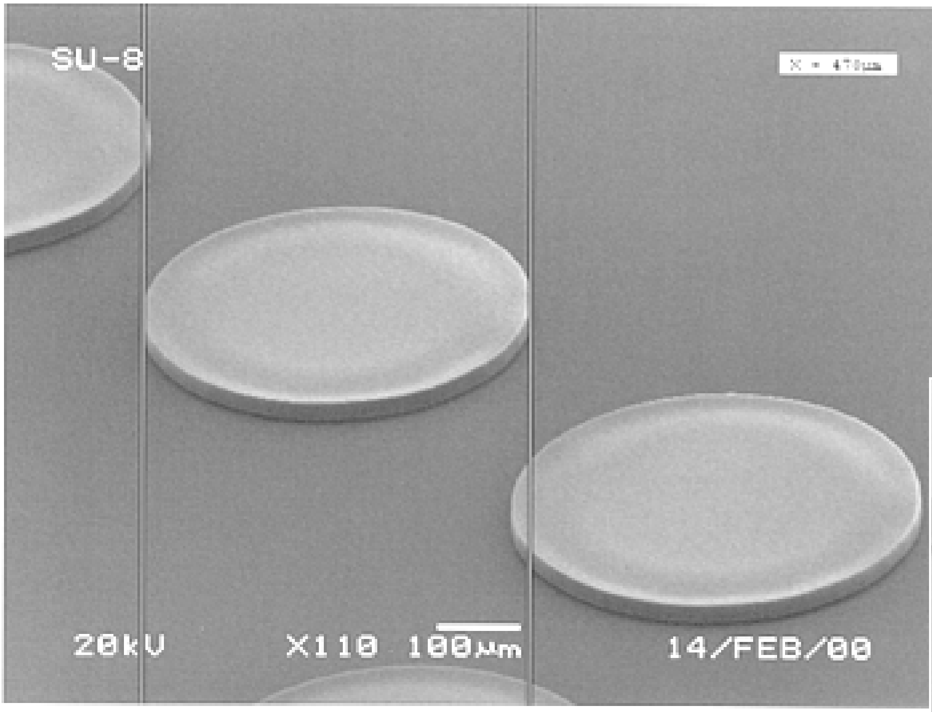
100 µm high in single spin coat.

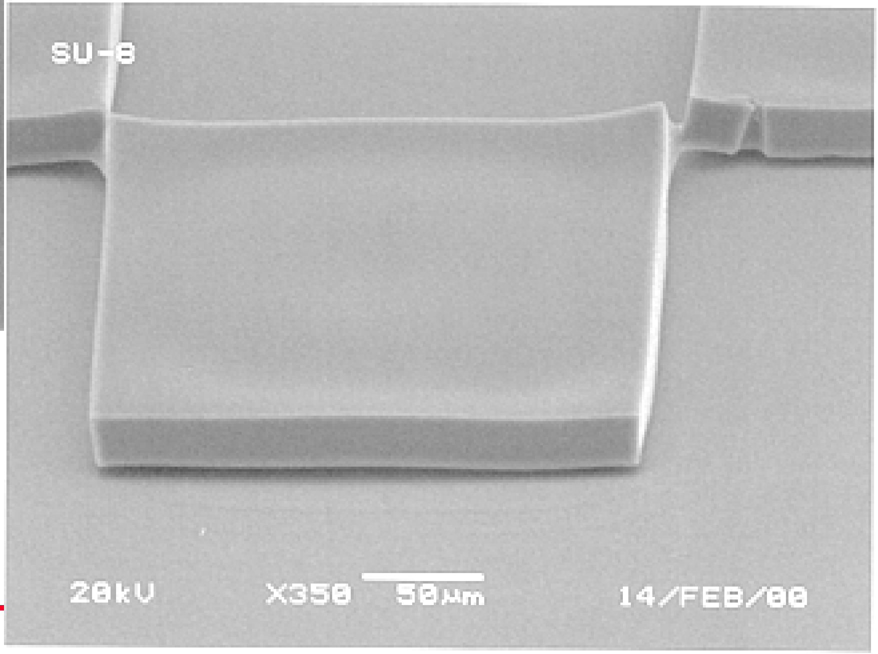




85 um by 85 um by 120 um deep
walls are 24 um thick

SU-8 RESIST at RIT





SU-8 RESIST PROCESSING at RIT

Dehydration Bake on Hotplate at 250 C for 5 min
Cool for 3 min
Dispense SU-8 10 by pouring out of the bottle. (we have SU-8-10, SU-8 2002, 2015 and 2050 material
Spread @ 500 RPM for 5 seconds
Spin @ 3000 rpm for 30 sec.
Leave on the wafer on the spinner to self planarize for 5 min.(no vacuum)
Pre Bake at 55 C for 5 min in a convection oven or Solitec 0.5 cm above 90 °C hot plate.
Soft Bake at 90 C for 6 min on a hotplate
Cool for 5 min
Expose using Karl Suss contact aligner
    E = 175 mJ/cm2 (for ~10 um thick resist)
PEB Bake 90 C on hotplate for 15 min in a convection oven or Solitec 0.5 cm above 90 °C hot plate for 5 min then 15 min on hot plate
    Cool for 15 min
Develop in RER 600 (100% PGMEA) Developer, for 3 min with constant vigorous agitation
Rinse with IPA
Spin or Blow Dry

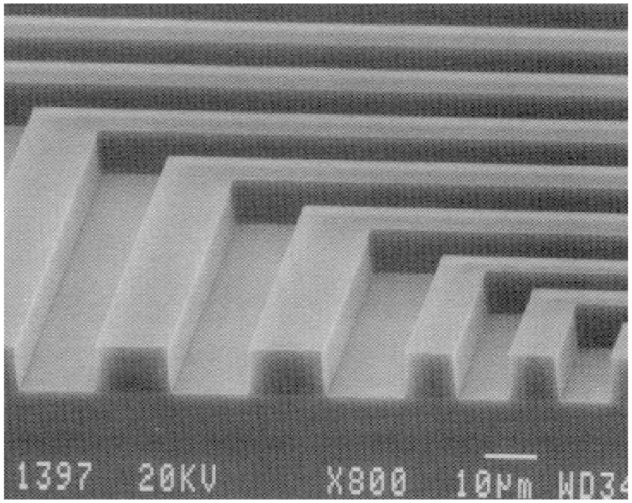
THICK PHOTORESISTS

Dynachem EL2026 Thick Film Positive Photoresist gives thickness between 2 and 100 µm. Bake in convection over at 90 C for 30 min. Best focus is 240 not the normal 250 for a 10 um coating. Exposure dose is 4500 mj/cm2. Develop is 0.35 Normal KOH developer for 10 min. Hardbake 100 C for 30 min in convection oven.

AZ 4000 Series Photoresists, Hoechst, 3070 Highway 22 West, Somerville, NJ 08876, (201) 231-3889, for Thick Film Applications: AZ4330 is 35.5 % solids for 2.9 µm @ 5000 rpm, AZ4400 for 3.5 µm @ 5000 rpm, AZ4620 for 5.6 µm @ 5000 rpm and 7.1 µm at 3000 rpm. AZ P4620 gives 30 µm thickness, AZ PLP 100 gives 50 µm thickness, Develop with AZ400K diluted 1:3. AZ4901 is formulated for spray and can coat up to 50 µm thick.

Multiple coatings give thicker resist layers. In between each coating bake at 90 C for 30 seconds on the hot plate. Use low spin speeds even as low as 1240 rpm.

Exposure needs to be increased start with 100 mj/cm2 for each 1µm thickness of resist.

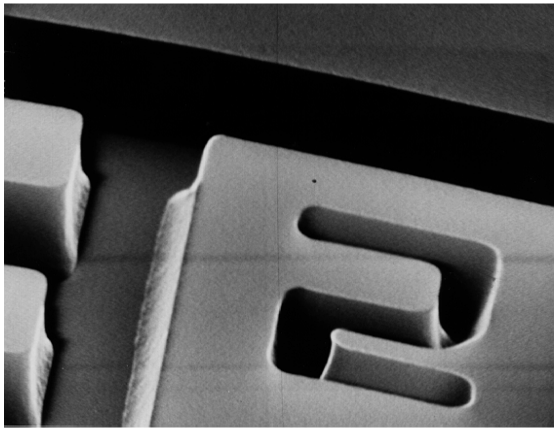


AZ P4620 (10 µm)

THICK PHOTORESISTS

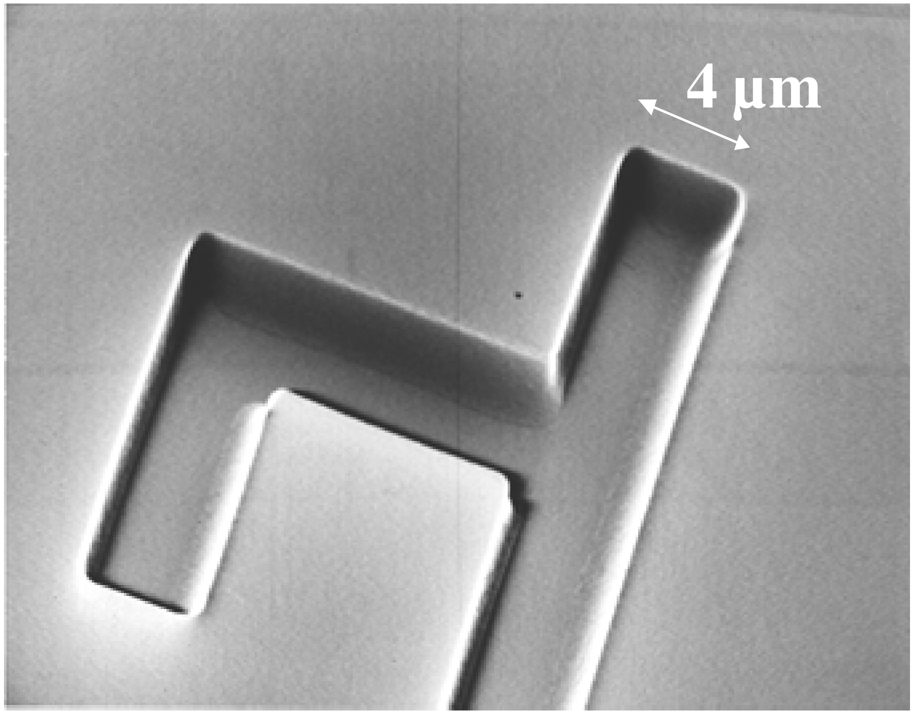
We tried coating Shipley system 8 resist at low spin speed to see how thick of a coating we could get. We got 1.7um @ 2000rpm, 1.2um @ 3000rpm and 1.0um @ 4000rpm. Exposure on the stepper at 200 mj/cm2 (0.8 seconds in integrate mode) worked with hand develop of 1 min. using Shipley 321 developer.

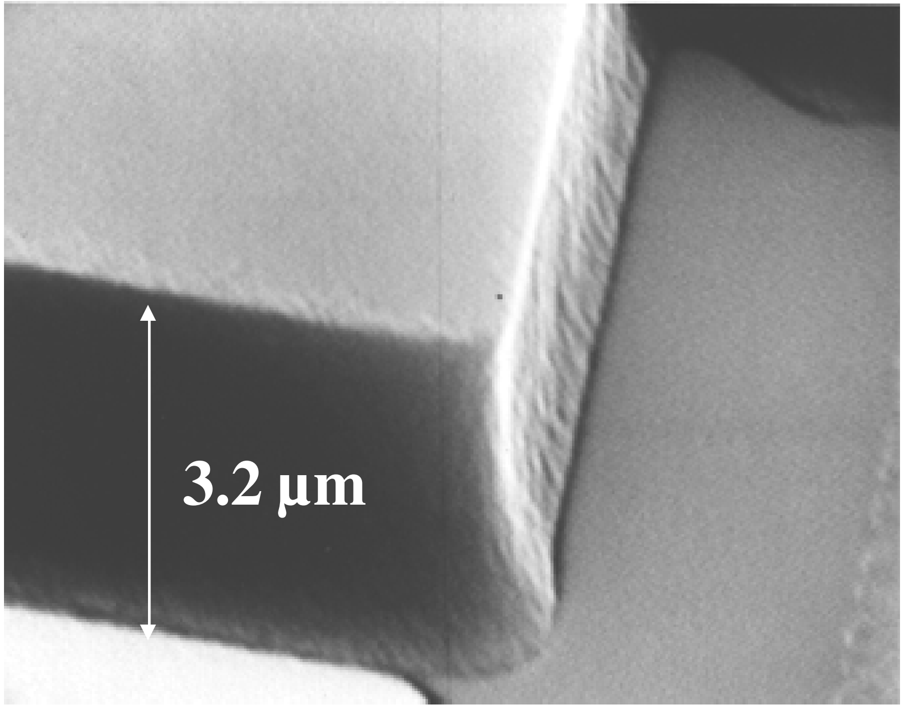
We also tried OCG ASPR-528 at RIT, the resist coated at 4500 rpm gave a thickness of 2.9 µm after a soft bake of 115 C for 1 min, and 1 sec exposure on the stepper for 250 mj/cm2 in integrate mode and develop in straight Shipley 321 developer for 1 min 30 seconds gives good images.



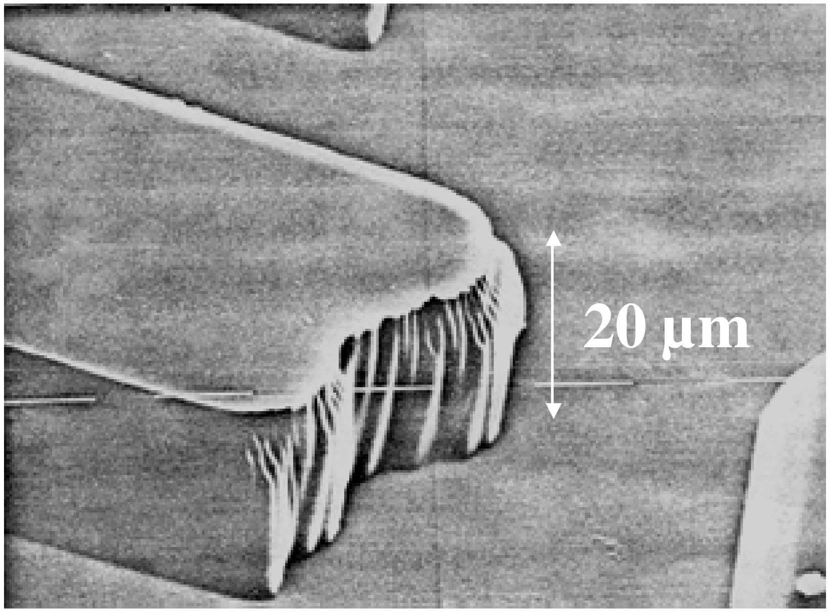
Speed	Thickness	Exposure Dose
5000 rpm	25,000 Å	400mj/cm2
4500	27,300	
4000	31,550	500
3500	33,100	
3000	35,500	600
2500	37,600	
2000	41,000	700

THICK PHOTORESISTS

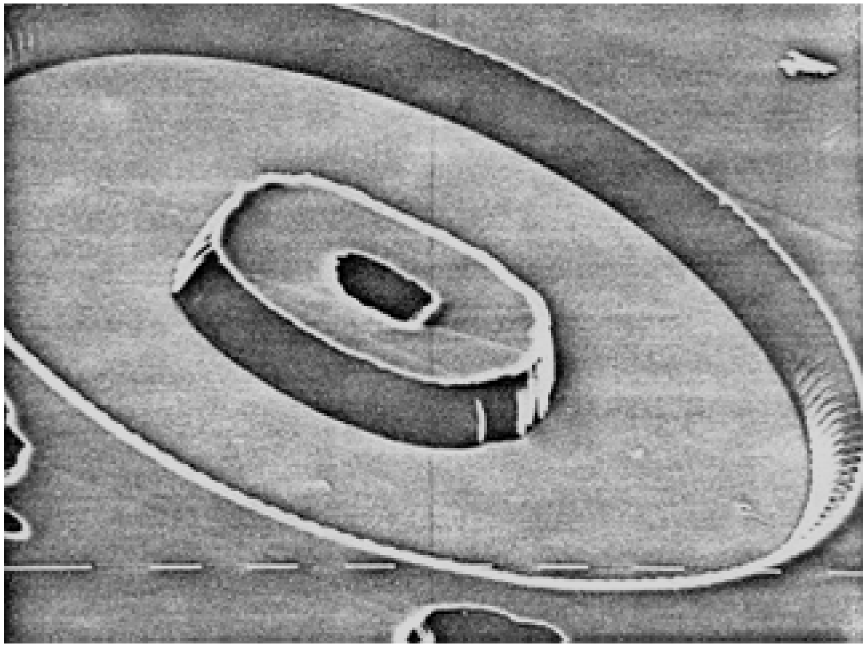




THICK RESISTS

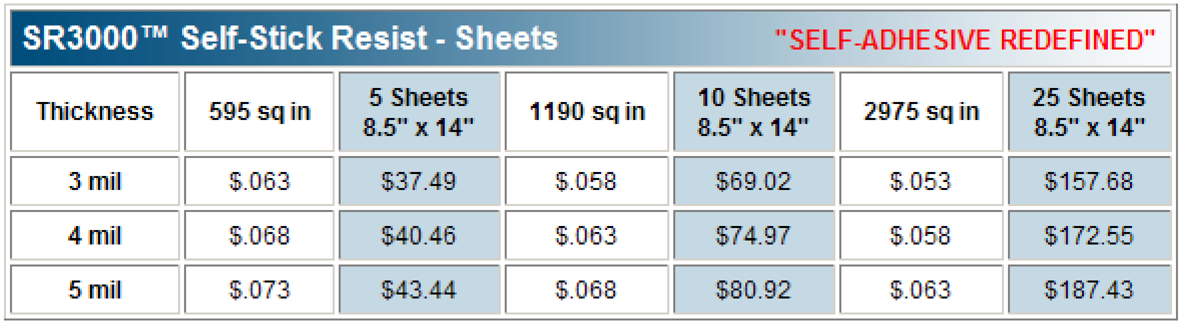


Molds for electroplated MEM structures



PHOTOSENSITIVE FILMS

http://www.rayzist.com/



SR3000™ Self-Stick Resist - Sheets "SELF-ADHESIVE REDEFINED"

Thickness	595 sq in	5 Sheets 8.5" x 14"	1190 sq in	10 Sheets 8.5" x 14"	2975 sq in	25 Sheets 8.5" x 14"
3 mil	$.063	$37.49	$.058	$69.02	$.053	$157.68
4 mil	$.068	$40.46	$.063	$74.97	$.058	$172.55
5 mil	$.073	$43.44	$.068	$80.92	$.063	$187.43

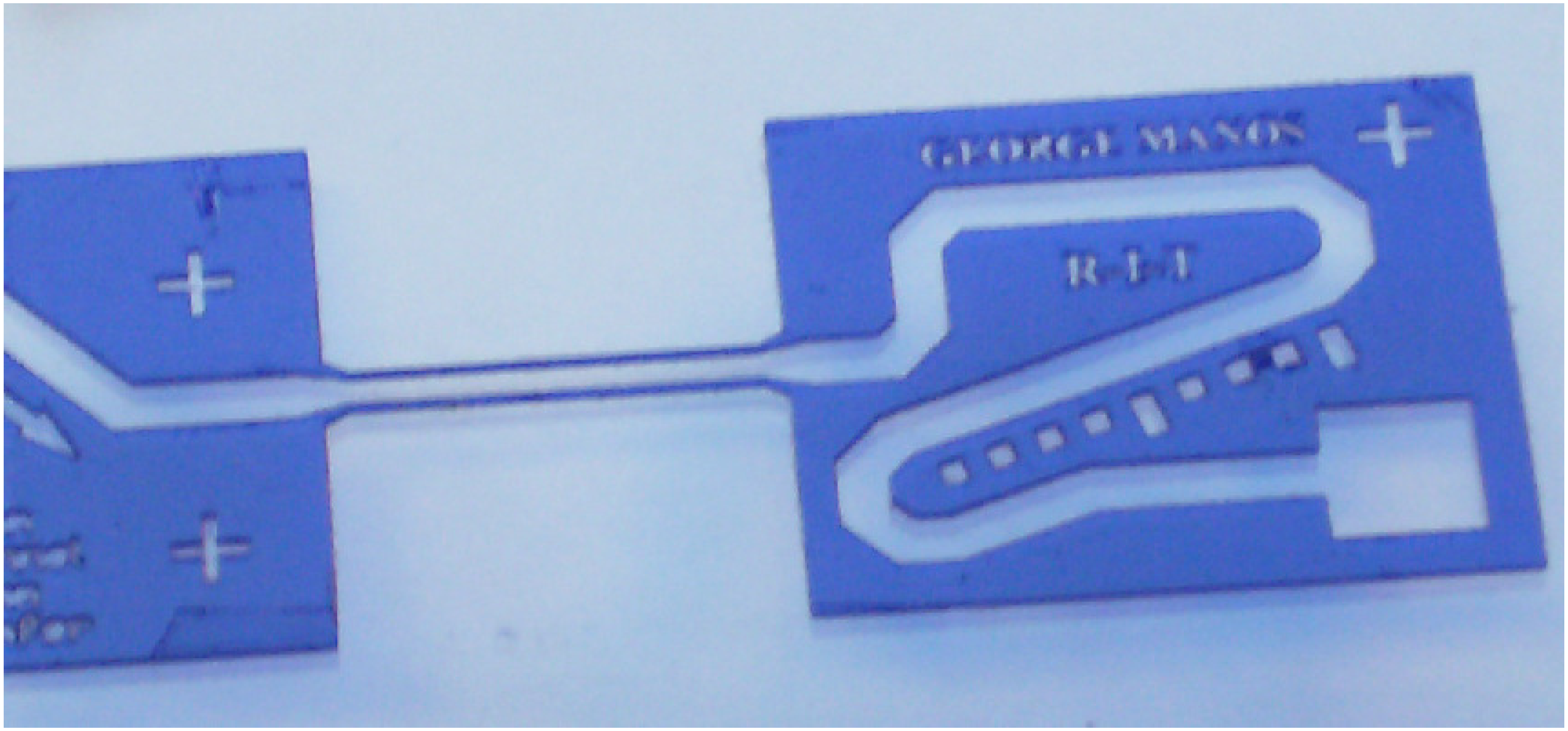
Also ImageOn from
RIT Bookstore 12”x10’x0.002” thick
for $18

NEGATIVE PHOTORESIST FILM PROCESSING

ImageOn Processing –negative working resist, 50µm Thick

Wet Substrate
Remove mylar film from the non-shiny side of the resist
Place resist on the wet substrate
Remove water from center to edge, remove top mylar film
Repeat to get 100, 150, 200 µm total thickness
Heat cure the resist to improve adhesion???
Expose: Dose = ~50 mj/cm2,
Iradiance = 3.5mW/cm2 x 15 sec
30 for 100µm, 45 for 150µm, etc.
Remove top mylar film
Develop for 60sec in CD26 (develop 15 sec, spray DI water,
repeat every 15 sec until clear
Rinse with water and dry
Hard bake

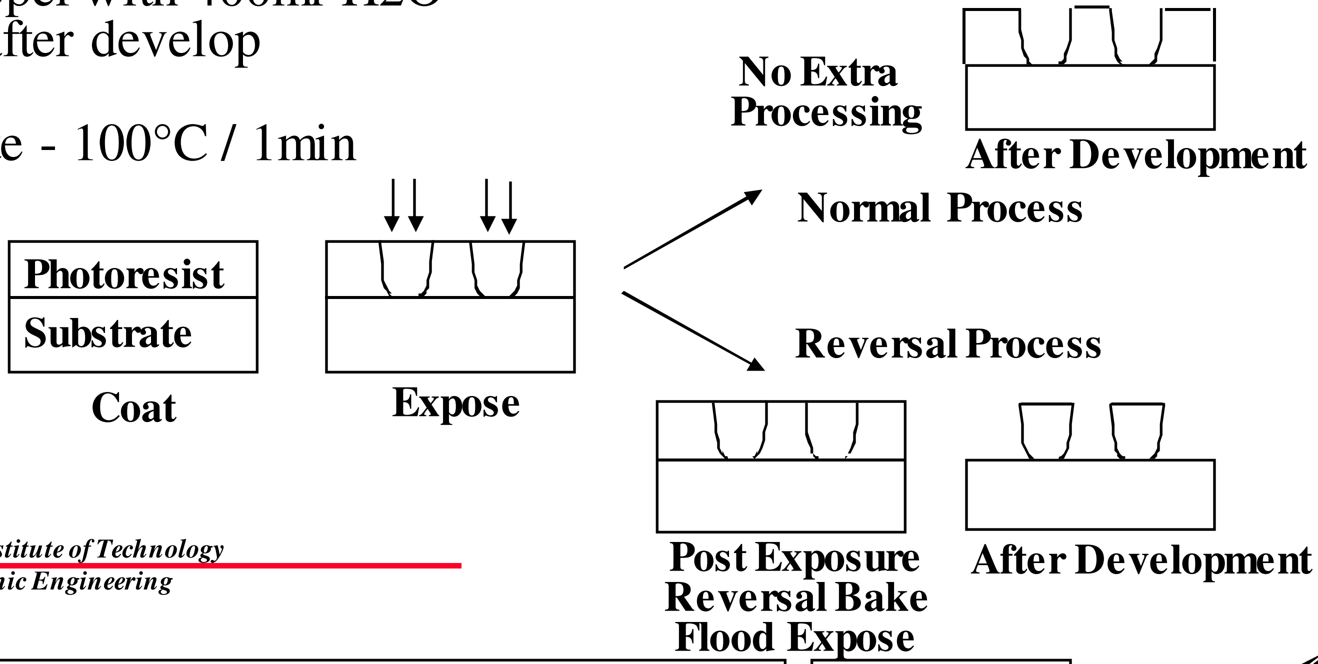
150µm DEEP CHANNELS



REVERSAL PROCESSING

MORE

1 Dehydration Bake at 200 °C, 3 minutes.
2 Spin coat AZ-5214-E photoresist - 4000rpm / 45sec
3 Pre-bake on hotplate - 100°C / 45sec
4 Expose 80 mj/cm2, (about 10 seconds on Kasper contact aligner) or (800 mj/cm2 on the stepper, because stepper is G-line and Kasper is wide band exposure)
5 Post exposure bake, image reversal (PEB) on hotplate - 115°C / 90sec
6 Flood expose on Kasper aligner - 30sec
7 Develop 20 sec. in Shipley 351 + H_2O (1:4 ratio) in petri dish
- mix 100ml developer with 400ml H_2O -
rinse immediately after develop
8 Blow Dry.
9 Postbake on hotplate - 100°C / 1min

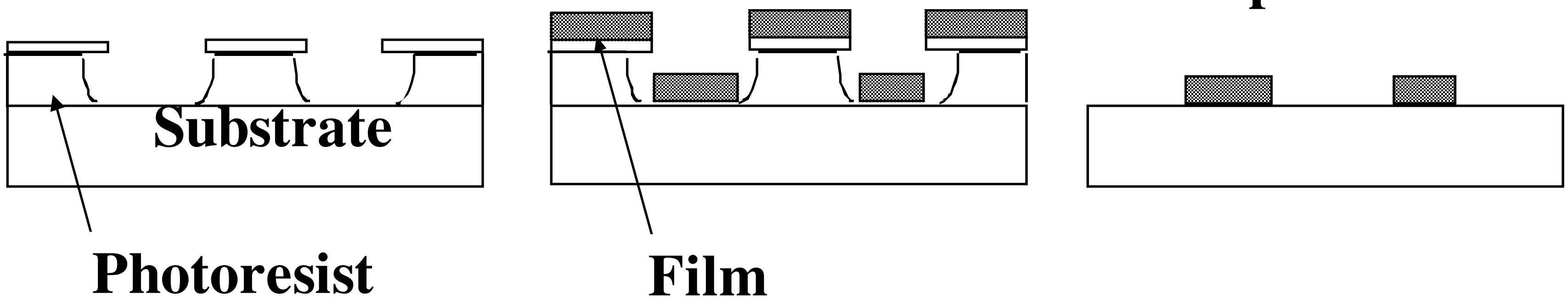


LIFT-OFF

1. Create a reverse slope or undercut resist edge profile

2. Deposit film by evaporation

3. Chemically strip photoresist and lift off film, leaving film in desired pattern



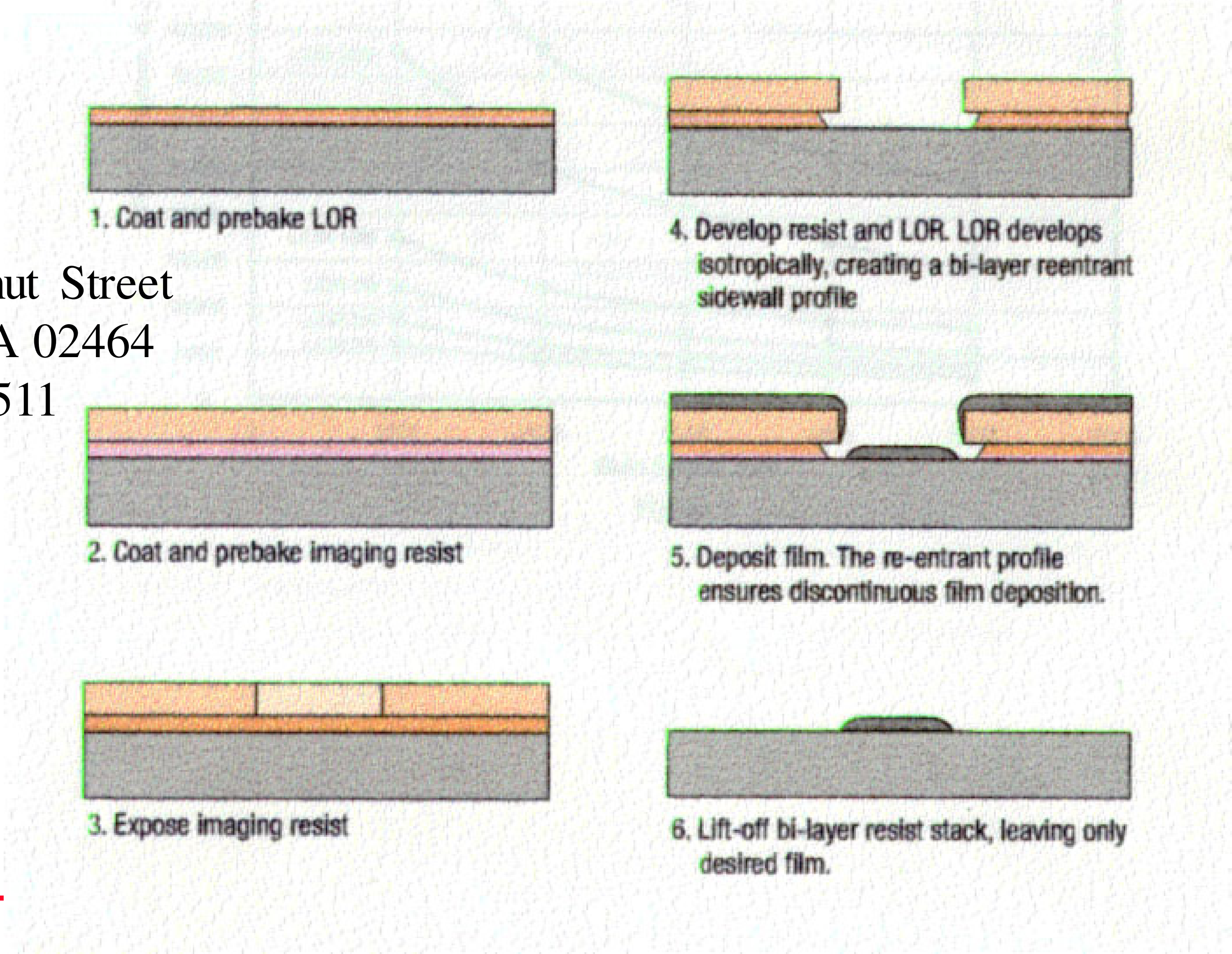
These undercut resist profiles are created by several techniques:

1. Chlorobenzene induced lip in single layer photoresist
2. Bilayer resists where top layer developes slower
3. Special undercoatings that develop faster than resist in developer
4. Trilayer methods
5. Image reversal resists

MORE

LIFT-OFF USING MICRO-CHEM LOR

Microchem
1254 Chestnut Street
Newton, MA 02464
(617)965-5511



1. Coat and prebake LOR
2. Coat and prebake imaging resist
3. Expose imaging resist
4. Develop resist and LOR. LOR develops isotropically, creating a bi-layer reentrant sidewall profile
5. Deposit film. The re-entrant profile ensures discontinuous film deposition.
6. Lift-off bi-layer resist stack, leaving only desired film.

LIFT-OFF USING MICRO-CHEM LOR

Spin speed vs thickness for LOR B series resists.

Other film thicknesses available upon request.

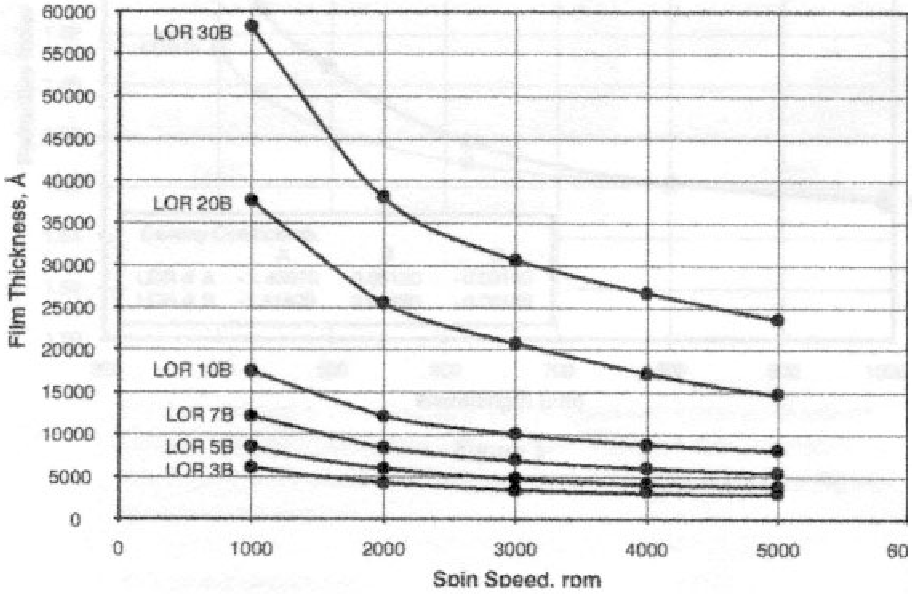


Figure 2

Spin speed vs film thickness for LOR A series resists.

Other film thicknesses available upon request.

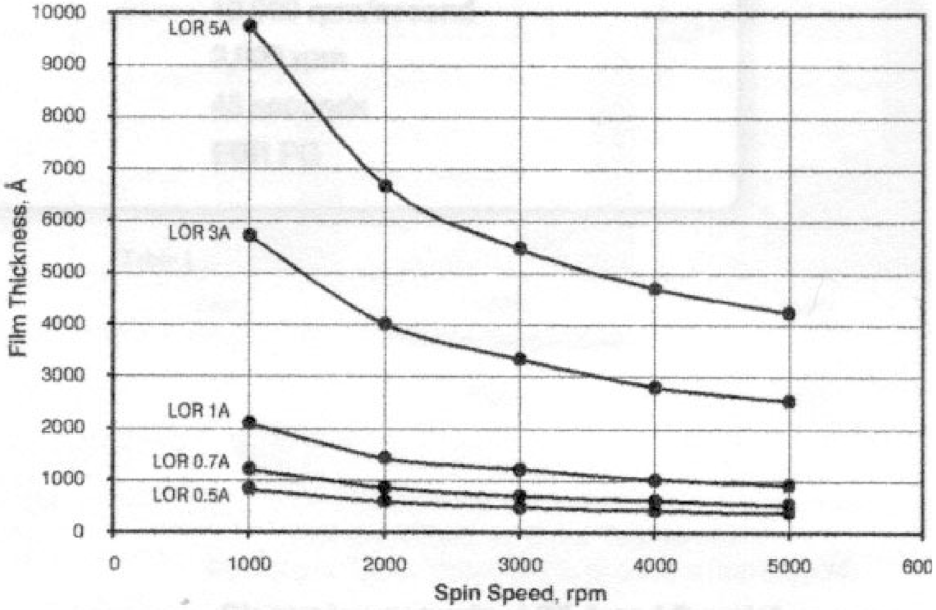


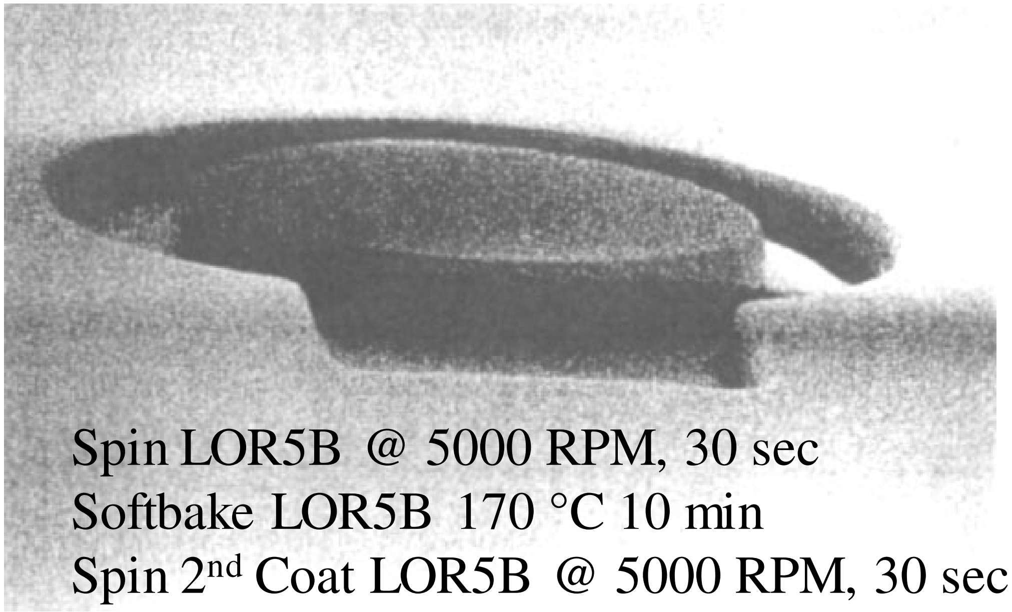
Figure 1

LIFT-OFF USING MICRO-CHEM LOR

Microchem
1254 Chestnut Street
Newton, MA 02464
(617)965-5511

0.5L Bottle LOR5B $365

4 gal Shipley MIF 319 $185



Spin LOR5B @ 5000 RPM, 30 sec
Softbake LOR5B 170 °C 10 min
Spin 2nd Coat LOR5B @ 5000 RPM, 30 sec
Softbake LOR5B 170 °C 10 min
Spin Shipley System 8 Resist @5000 RPM 1 min
Softbake 110 °C, 1 min.
Expose System 8 resist 150 mj/cm2
Develop CD-26, 1 min.
Rinse, Dry

AZ nLOF 2000 Photoresist

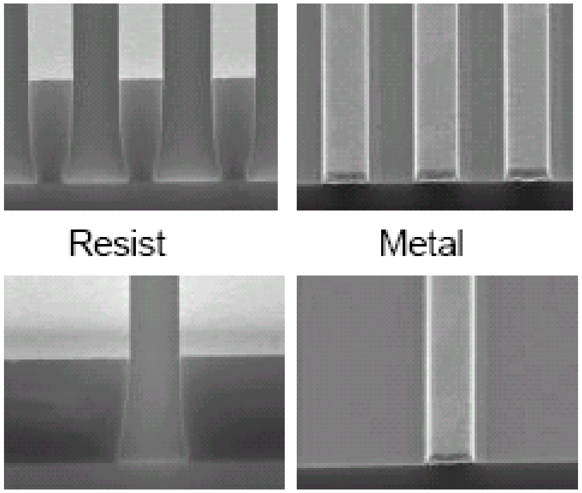
Standard Process Conditions

Coat:	1.0µm resist thickness
Softbake:	110°C for 60sec
Exposure:	Nikon Stepper @ NA=0.54 DTP = 65-80mJ/cm^2
PEB:	110°C for 60sec
Develop:	AZ® 300MIF Developer for 120sec single puddle @ 23°C

RIT process, spin at 3000rpm 30 sec, bake 95°C for 90 s, Expose 120 mj/cm2 on Canon, Develop.rcp on SSI track

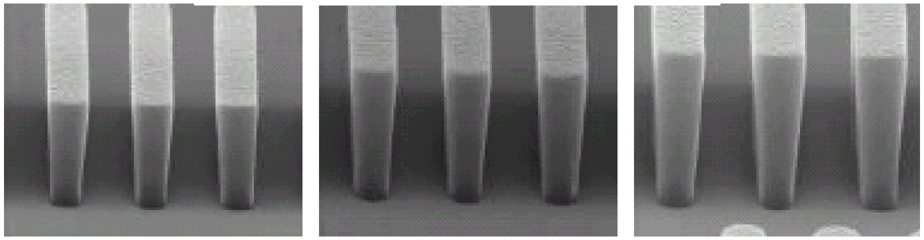
Metal Lift-off Process Results

AZ *n*LOF 2035 Photoresist, 1.5µm CD



AZ *n*LOF 2020 Photoresist

2.0µm thickness, DTP – 66mJ/cm2



0.80 µm 0.75 µm 0.70 µm

AZ® *n*LOF™ 2000 Photoresist

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Product Description

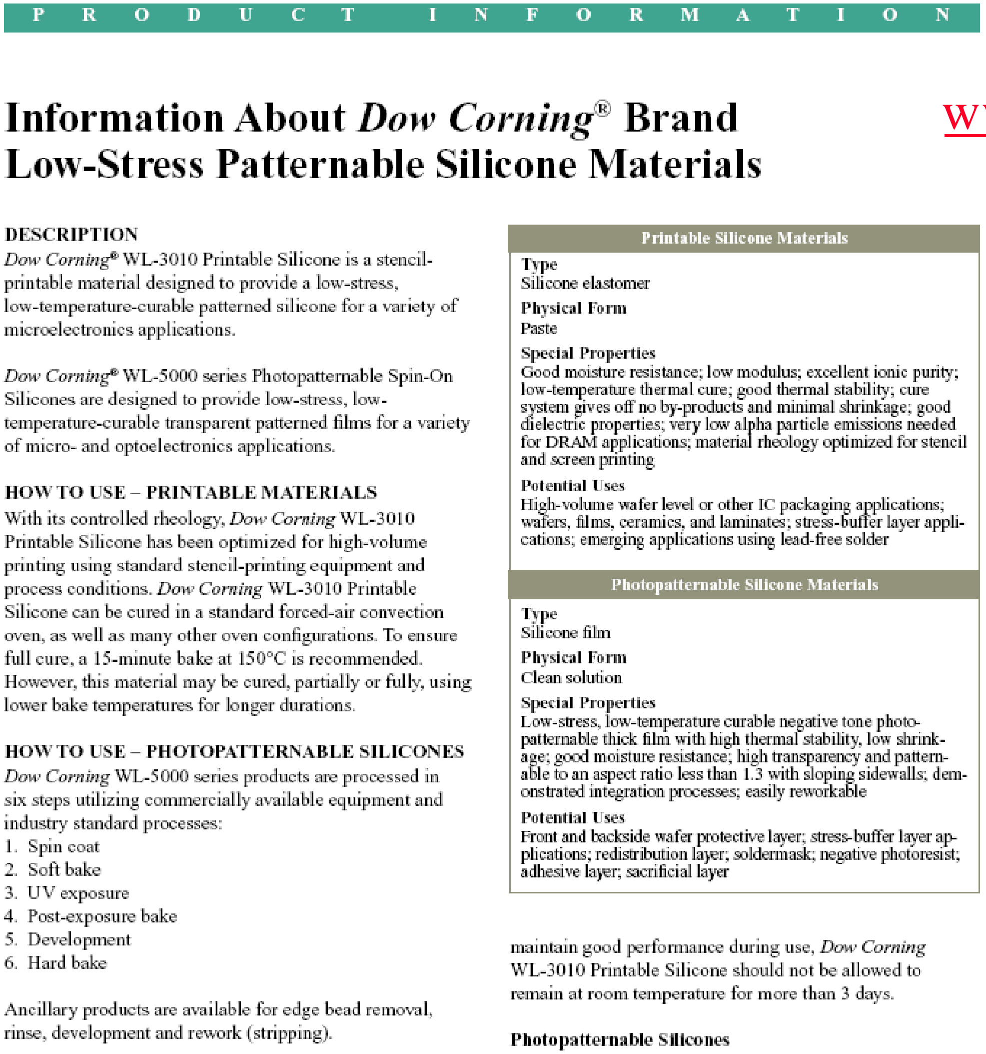
AZ® *n*LOF™ 2000 Series I-line photoresists are uniquely formulated to simplify the historically complex lift-off lithography process. You can now run a standard lithography process to get the desired lift-off profiles. The fast *n*LOF resists work well in both surfactant and surfactant-free TMAH developers using standard conditions.

*n*LOF 2000 Series resists can be used for coating thickness beyond 7.0um, achieving aspect ratios of up to 4:1!!

Features	Benefits
High Throughput	i-line DTP < 100mj (2.0µm-3.5µm thickness)
Streamlined Lift-Off Process	Standard single-layer lithography process to achieve lift-off profiles. No extra steps required!!
Process Compatibility	Easy integration into an existing process with standard processing conditions!
Process Versatility	Obtain Lift-off profiles with resist thickness above

PHOTOPATTERNABLE SILICONE MATERIALS

www.DowCorning.com



PRODUCT INFORMATION

Information About *Dow Corning*® Brand Low-Stress Patternable Silicone Materials

DESCRIPTION

Dow Corning® WL-3010 Printable Silicone is a stencil-printable material designed to provide a low-stress, low-temperature-curable patterned silicone for a variety of microelectronics applications.

Dow Corning® WL-5000 series Photopatternable Spin-On Silicones are designed to provide low-stress, low-temperature-curable transparent patterned films for a variety of micro- and optoelectronics applications.

HOW TO USE – PRINTABLE MATERIALS

With its controlled rheology, *Dow Corning* WL-3010 Printable Silicone has been optimized for high-volume printing using standard stencil-printing equipment and process conditions. *Dow Corning* WL-3010 Printable Silicone can be cured in a standard forced-air convection oven, as well as many other oven configurations. To ensure full cure, a 15-minute bake at 150°C is recommended. However, this material may be cured, partially or fully, using lower bake temperatures for longer durations.

HOW TO USE – PHOTOPATTERNABLE SILICONES

Dow Corning WL-5000 series products are processed in six steps utilizing commercially available equipment and industry standard processes:

1. Spin coat
2. Soft bake
3. UV exposure
4. Post-exposure bake
5. Development
6. Hard bake

Ancillary products are available for edge bead removal, rinse, development and rework (stripping).

Printable Silicone Materials

Type
Silicone elastomer

Physical Form
Paste

Special Properties
Good moisture resistance; low modulus; excellent ionic purity; low-temperature thermal cure; good thermal stability; cure system gives off no by-products and minimal shrinkage; good dielectric properties; very low alpha particle emissions needed for DRAM applications; material rheology optimized for stencil and screen printing

Potential Uses
High-volume wafer level or other IC packaging applications; wafers, films, ceramics, and laminates; stress-buffer layer applications; emerging applications using lead-free solder

Photopatternable Silicone Materials

Type
Silicone film

Physical Form
Clean solution

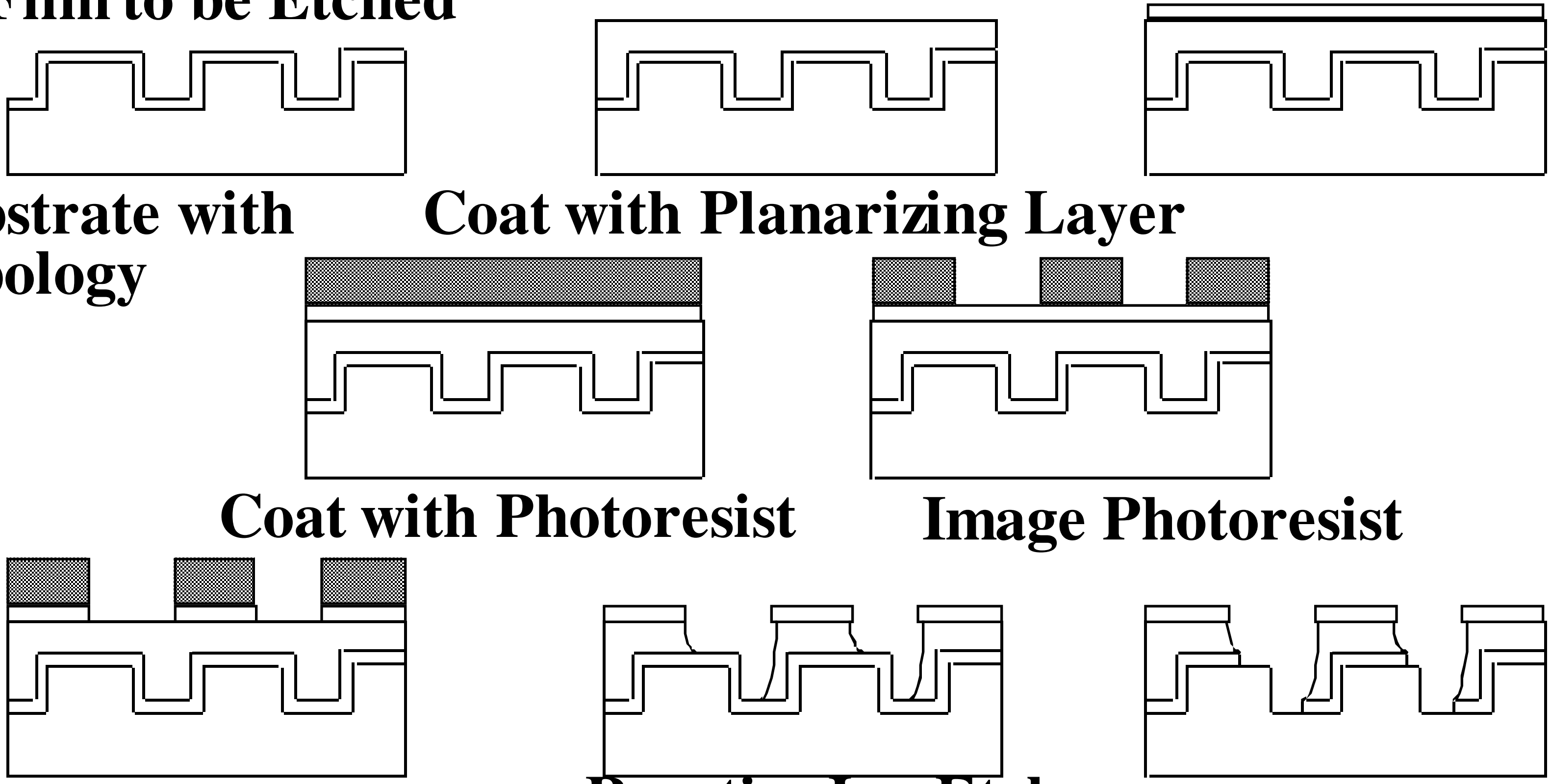
Special Properties
Low-stress, low-temperature curable negative tone photopatternable thick film with high thermal stability, low shrinkage; good moisture resistance; high transparency and patternable to an aspect ratio less than 1.3 with sloping sidewalls; demonstrated integration processes; easily reworkable

Potential Uses
Front and backside wafer protective layer; stress-buffer layer applications; redistribution layer; soldermask; negative photoresist; adhesive layer; sacrificial layer

maintain good performance during use, *Dow Corning* WL-3010 Printable Silicone should not be allowed to remain at room temperature for more than 3 days.

Photopatternable Silicones

TRILAYER RESIST PROCESSES



Film to be Etched

Substrate with Topology

Coat with Planarizing Layer

Coat with Barrier Layer

Coat with Photoresist

Image Photoresist

Etch Barrier Layer

Reactive Ion Etch Planarizing Layer

Etch Film

POLYIMIDE

Polyimide has a melting point of 450 C, can be spin coated and imaged with lithographic processes making it useful for many applications.

Using DuPont Corporations PI-2555 we can get film thickness between 2.5 µm @ 5000 rpm and 5.0 µm @ 1500 rpm. It is cured by placing on 120 °C hot plate for 30 min. and then on a 350 °C hot plate for 30 min. Multilayer coatings can give thickness greater than 10 µm. (a 500 gm bottle costs ~$250) Du Pont Co., Electronic Materials Division, Barley Mill Plaza, Reynolds Mill Building, Wilmington, DE 19898 (800)441-7543

OCG Microelectronic Materials, Belgium, makes a polyimide “Proimide 114A” which we have used.

These film are easily imaged using an aluminum barrier layer and conventional photoresist (such as Shipley System-8) followed by Oxygen Reactive Ion Etch.

ETCHING OF POLYIMIDE IN GEC CELL

Use GEC Cell, Time=75 min, Pressure=300 mTorr, Power = 60 watts, Flow = 50 sccm, Gas=Oxygen, Give an Etch Rate of 1300 Å/min (7.8 um/hr)

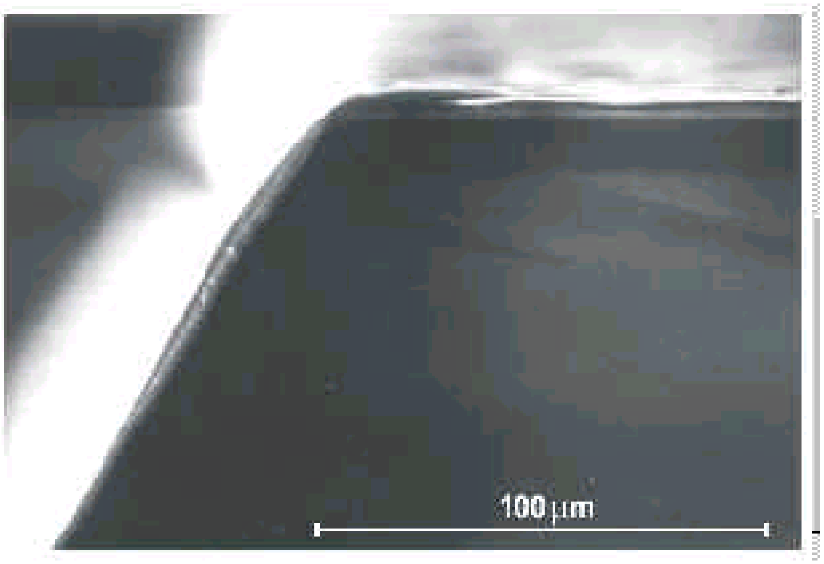
Higher etch rates can be obtained with addition of a small amount of CF4. Note: CF4 also etches silicon, silicon dioxide, and silicon nitride.

GEC cell at 300 mTorr, 45 sccm O2, 5 sccm CF4, 60 watts, 30 min for 10 µm of Polyimide, (~20µm/hr)

CONFORMAL RESIST COATINGS

http://www.elvisions.com
Electronic Visions Inc.
(602 437-9492

Uniform conformal coatings on sidewalls and in cavities.



ELECTRODEPOSIED RESIST COATINGS

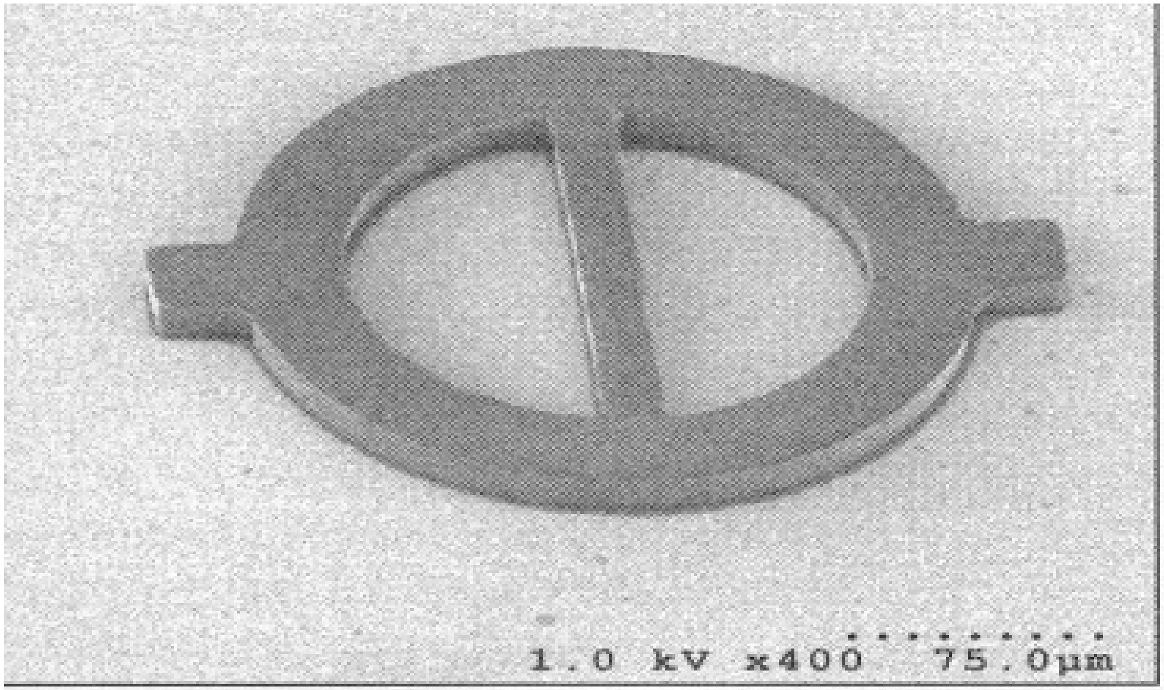
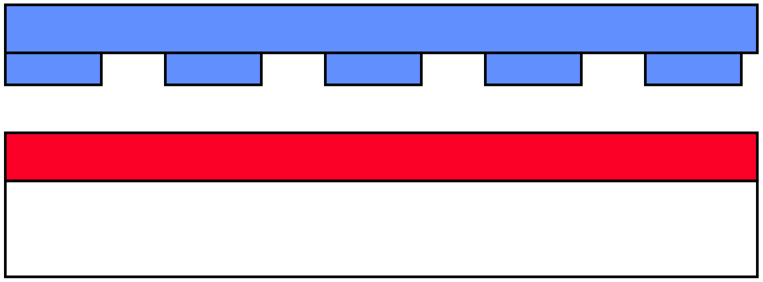
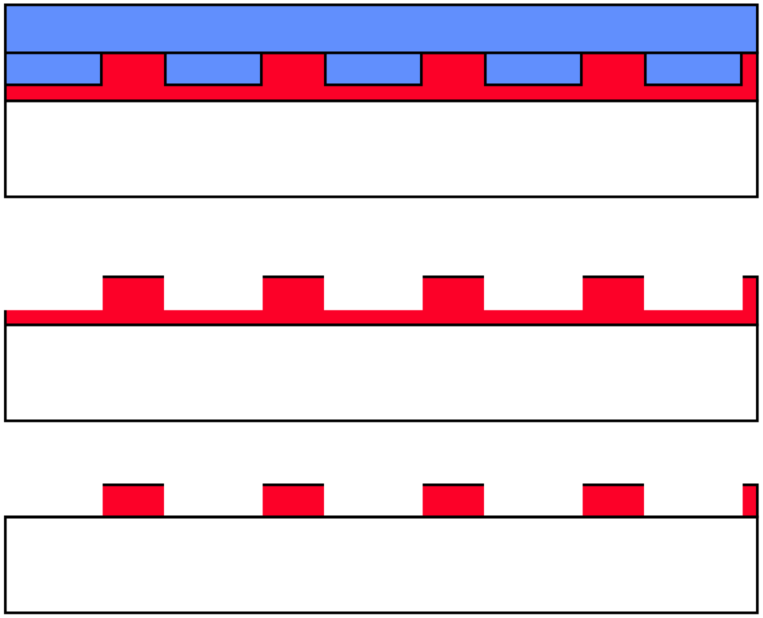


Fig. 5. X-ray lithography-defined Shipley Eagle 2100ED electrodeposited resist on smooth sputtered copper-coated silicon wafer. Photo courtesy of F.T. Hartley, Jet Propulsion Laboratory, California Institute of Technology.

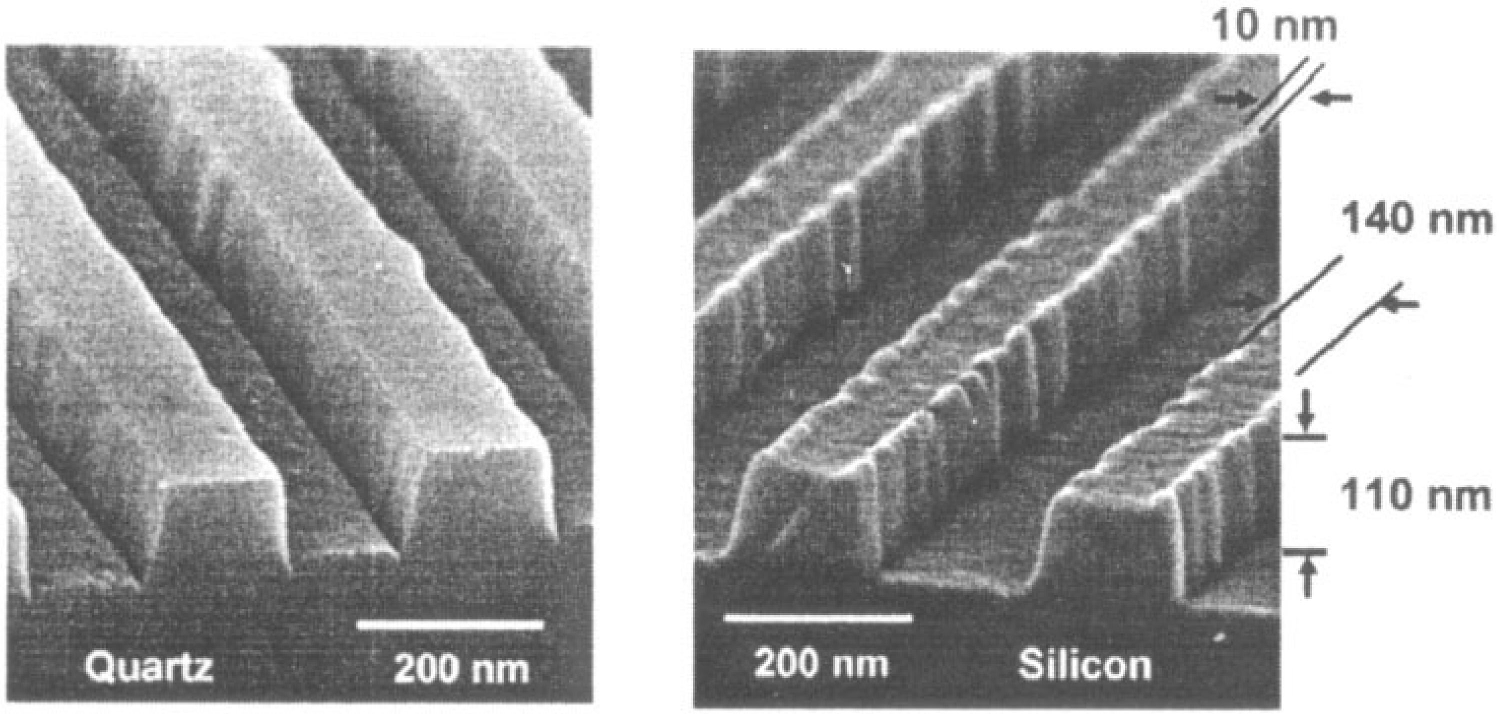
NANOIMPRINT LITHOGRAPHY

1. Substrate is coated with photoresist.
2. Substrate is heated above the glass transistion temperature.
3. A hard mold is pressed against the substrate deforming the resist.
4. The substrate and resist is cooled
5. The hard mold is removed
6. The resist is plasma etched (RIE) in Oxygen to remove residual resist.
7. Substrate is etched.





NANOIMPRINT



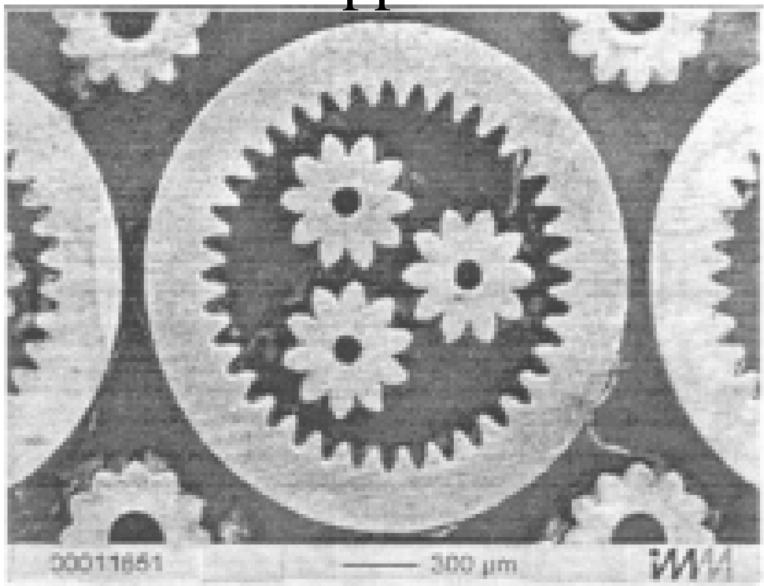
Nature

IMPRINT Chips may someday be made by using quartz molds like the one at left to stamp patterns in molten silicon. (Nm is short for nanometer, one-billionth of a meter.)

PLATING

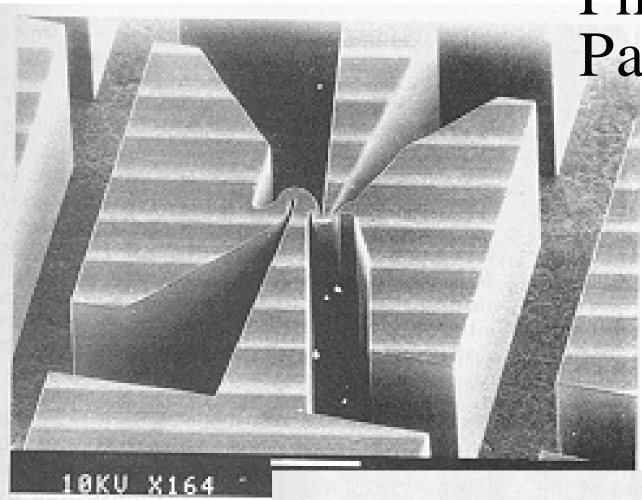
Using a patterned photoresist layer. Wafers can be electroplated in those areas creating structures without etching.

Plated Copper Gears

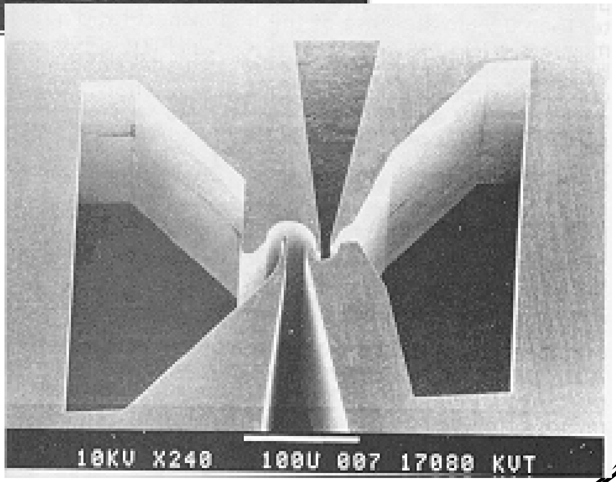


1 mm

Photoresist Pattern

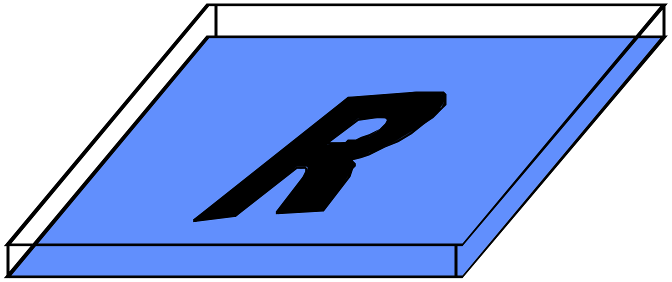


Electroplated nickel



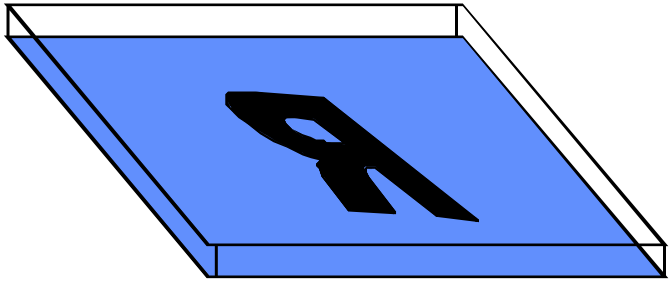
MASKMAKING FOR MEMS

Maskmaking is normal except for mask sets that include masks to image the backside of the wafer. In order to get alignment, the masks for the back side need to be mirrored with respect to the front side masks.

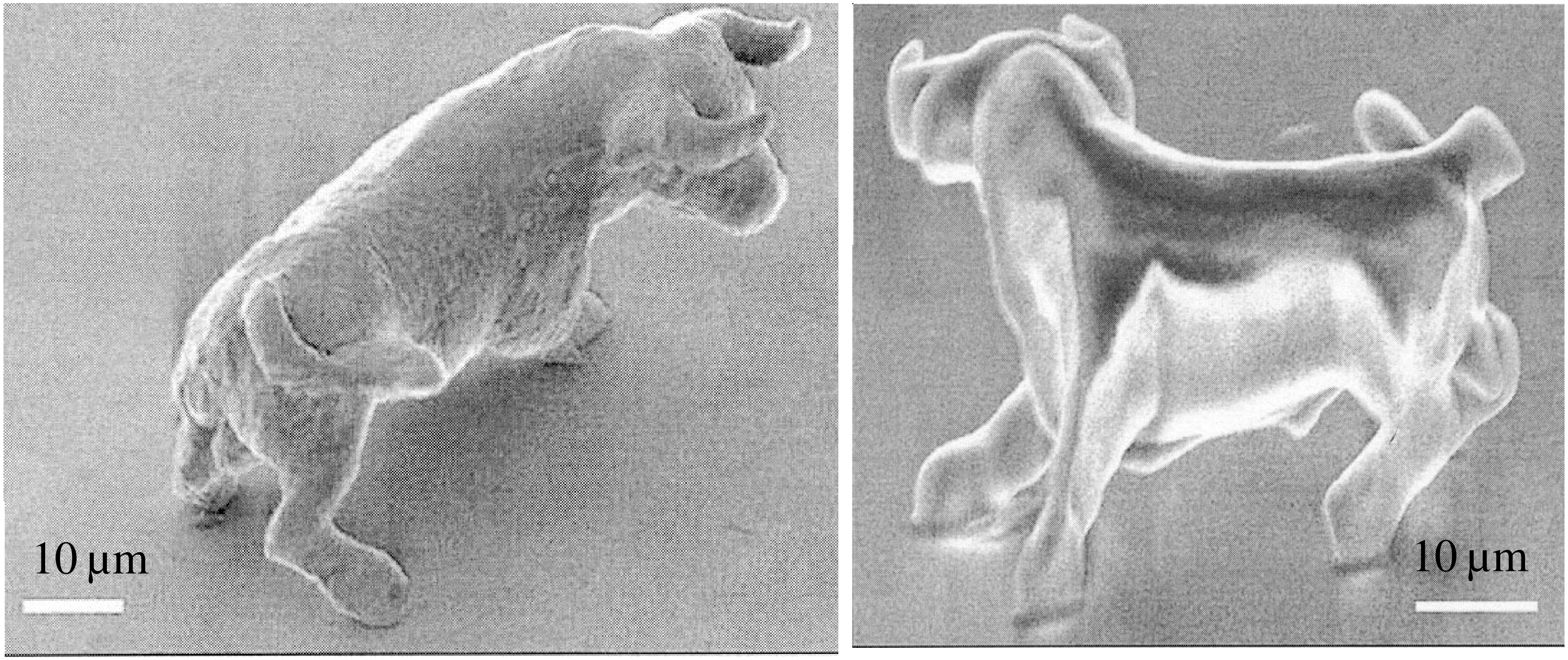


Letter R on top of wafer
requires a mask that is
wrong reading from
chrome side

Letter R on bottom of
wafer aligned with R on
top requires correct
reading mask image
from chrome side



STEREO LITHOGRAPHY



Two infrared lasers causes plastic resin to polymerize. Professor Satoshi Kawata of Osaka University

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3. "Image Reversal Resist for g-line Exposure: Chemistry and Lithographic Evaluation," Gerhard Buhr, Helmut Lenz and Siegfried Scheler, R & D Informationstechnik-Division, Hoechst Aktiengesellschaft Werk Kalle, D-6200 Wiesbaden

4. "Single-Step Otical Lift-Off Process," M. Hatzakis, B.J. Canavello, J.M. Shaw, IBM J. Res, Develop, Vol 24, No.4, July, 1980.

5. www.microchem.com

6. Dupont

HOMEWORK – MSMS LITHOGRAPHY

1. What makes lithography for MEMs different than lithography for integrated circuits?

2. Compare the depth of focus for RIT's g-line stepper with RIT's i-line stepper.

3. What resist thickness is needed to plasma etch a 2µm thick silicon dioxide layer? (assume SiO2 etch rate = 350Å/min and Photoresist etch rate = 220Å/min.)

4. What is the purpose of the hard bake? When would you not do hard bake? Why?

5. Explain how lift-off works. What are the advantages of using lift-off?