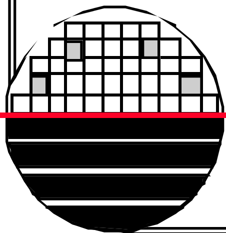
Lift-Off Metal Patterning

Dr. Lynn Fuller, Matt Filmer, Nicholas Liotta

Webpage: http://people.rit.edu/lffeee
Microelectronic Engineering
Rochester Institute of Technology
82 Lomb Memorial Drive
Rochester, NY 14623-5604
Tel (585) 475-2035
Fax (585) 475-5041
Email: Lynn.Fuller@rit.edu
Department webpage: http://www.microe.rit.edu

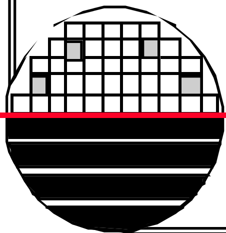


3-1-2012 lift-off.ppt

© March 1, 2012 Dr. Lynn Fuller

OUTLINE

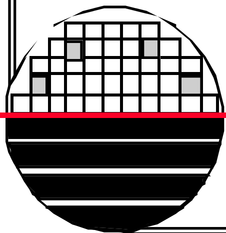
Introduction
Theory
Undercut by Isotropic Substrate Etch
Lift-Off Resist
Image Reversal Resist
No Hard Bake
Evaporation
Ultrasonic Acetone Lift-off
Process Details
Results
References
Homework



© March 1, 2012 Dr. Lynn Fuller

INTRODUCTION

Defining Metal Lines at sizes below 2 um is difficult by wet etch or by isotropic plasma etch. Lift-off offers a technique to create patterns at these sizes. Lift-off also has the advantage that it can work for many different thin films that can be deposited at low temperatures in a non conformal way. Thus creating and optimizing a large number wet etch chemistries and plasma etch recipes is not necessary. The main disadvantage is that the process can leave small flakes of metal on the wafer surface. Lift-off works best for thin films (~less than 1um thickness).

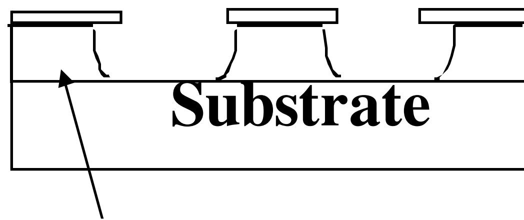


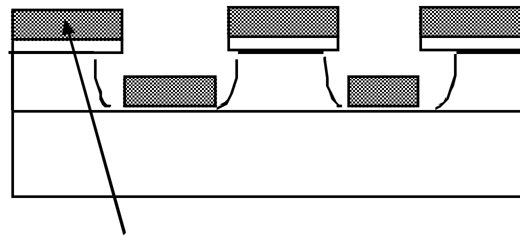
LIFT-OFF (THE BASIC IDEA)

1. Create a reverse slope or undercut resist edge profile

2. Deposit film by evaporation, (non-conformal)

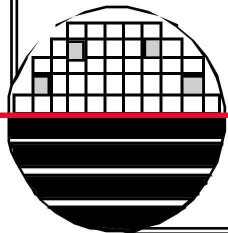
3. Wet chemical strip photoresist and lift off film, leaving film in desired pattern





These undercut resist profiles are created by several techniques:

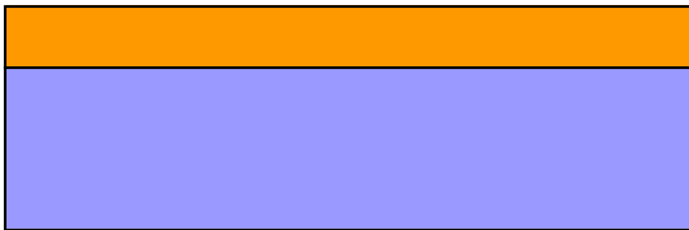
1. Chlorobenzene induced lip in single layer photoresist
2. Bilayer resists where top layer develops slower
3. Special under coatings that develop faster than resist in developer
4. Trilayer methods (shown above)
5. Image reversal resists with retrograde resist edge profiles
6. Single layer resist and substrate etch to form undercut

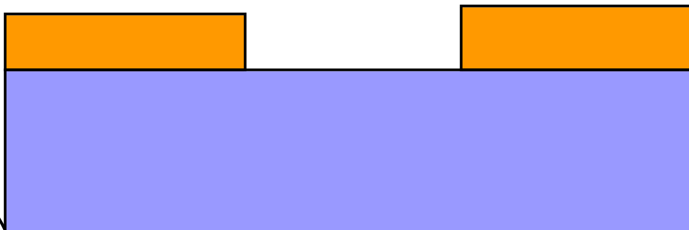


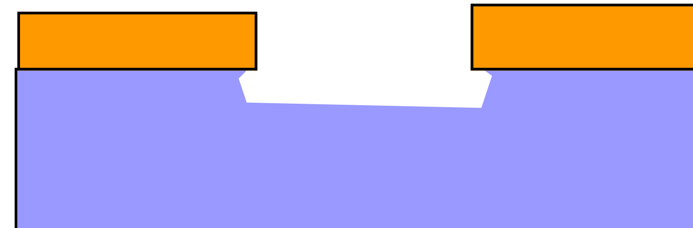
SINGLE LAYER RESIST AND SUBSTRATE ETCH

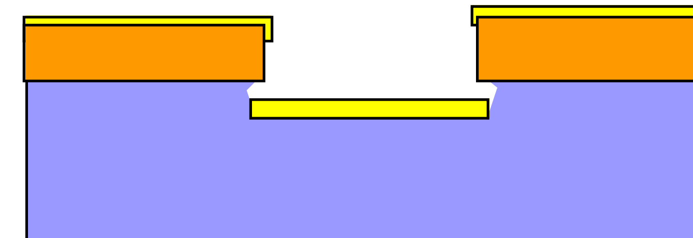
Single Layer Resist and Isotropic Substrate Etch Lift-off Technique

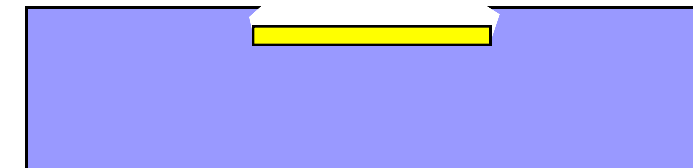
Starting glass wafer 500um thick

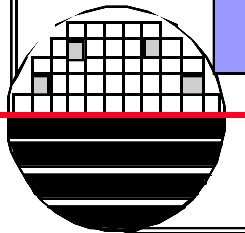

OIR-620-10 Positive Photoresist


After Expose and develop


BOE etch to create undercut

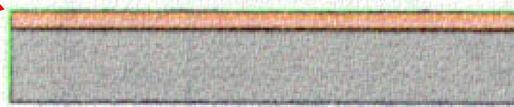

Deposit Cr and Au


Lift-Off in Acetone and ultrasonic



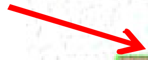
BI-LAYER LIFT-OFF USING MICRO-CHEM LOR

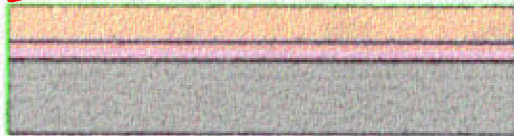
LOR (Lift-off resist) Coating



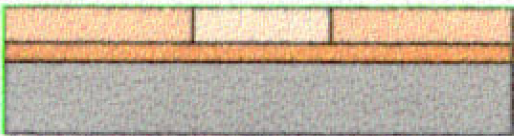
1. Coat and prebake LOR

Positive Photoresist Coating

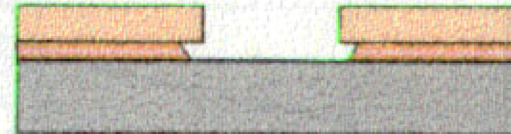




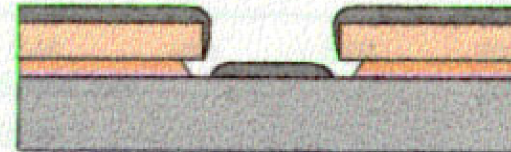
2. Coat and prebake imaging resist



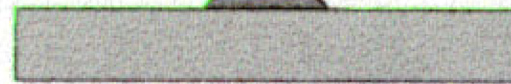
3. Expose imaging resist



4. Develop resist and LOR. LOR develops isotropically, creating a bi-layer reentrant sidewall profile

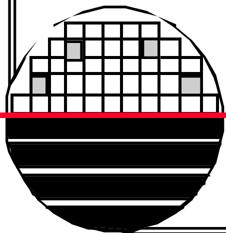


5. Deposit film. The re-entrant profile ensures discontinuous film deposition.



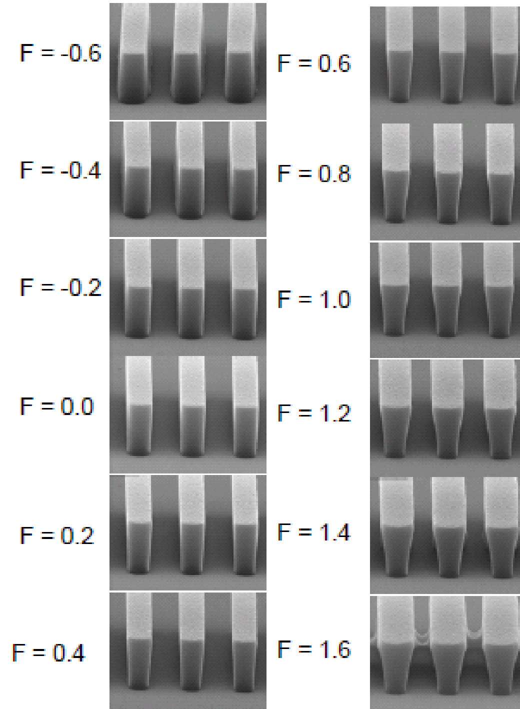
6. Lift-off bi-layer resist stack, leaving only desired film.

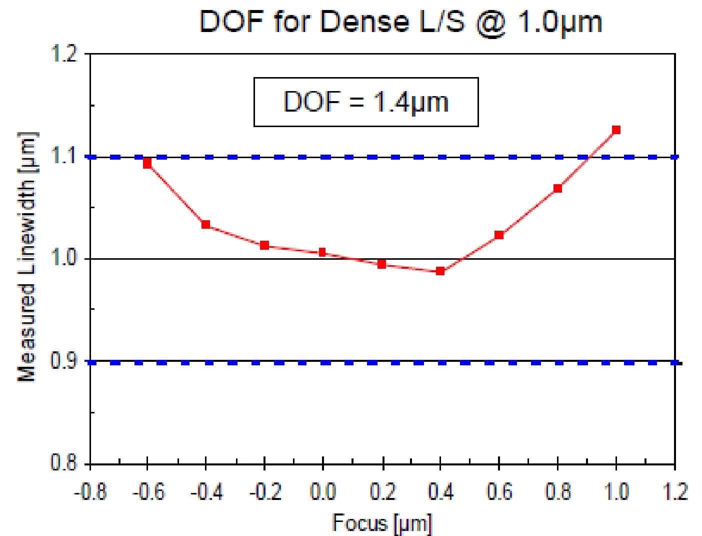
Microchem, 1254 Chestnut Street, Newton, MA 02464



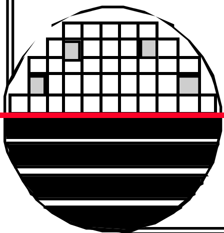
LIFT-OFF USING IMAGE REVERSAL RESIST

AZ nLOF 2020
Depth of Focus @ 1.0 µm CD





FT = 2.0µm, SB 110°C/ 60 sec, PEB 110°C/ 60 sec,
60 sec single puddle in AZ 300 MIF Developer @ 23°C
Nikon 0.54 NA I-line



AZ, the AZ logo, BARLi, Aquatar, nLOF, Kwik Strip, Klebosol, and Spinfil are registered trademarks and AX, DX, HERB, HiR, MiR, NCD, PLP, Signiflow, SWG. and TARP are trademarks of AZ Electronic Materials.

LIFT-OFF USING IMAGE REVERSAL RESIST

1. Coat wafers with n-LOF-2020 Image Reversal Resist, Use COATNLOF recipe on the SSI track
   - HMDS prime: 140C, Dispense for 30s, Prime for 60s
   - Manually dispense photoresist
   - Spin at 2500 RPM, Spin for 60s, Thickness ~2500nm
   - Soft Bake at 110C, Bake for 60s
2. Expose on the ASML Stepper – use same mask as for etch process (clear field mask)
   - Dose = 66 mJ/cm^2 i-line (365nm), Focus = 1.5, NA= 0.60, Sigma=0.625
3. Develop on SSI Track using recipe DEVNLOF
   - PEB (Image Reversal Bake) at 110C for 60s
   - Spin and dispense developer for 5s, Dispense developer for 5s, Puddle develop for 70s
   - Spin and rinse for 30s at 1000 RPM. Spin dry for 30s at 3750 RPM
   - Do not hard bake. It can damage the sidewall profile. Hard Bake time = 0s
4. Deposit Metal using the CVC evaporator
   - One Aluminum/1%Si pellet deposits about 300nm of aluminum (see calculation below)
   - Do not use the CHA evaporator, the rotating planetaries are designed to deposit a more conformal coat
5. Remove Photoresist and Lift-off metal using the ultrasonic wet bench with acetone
   - Metal starts lifting off almost immediately, takes ~ 5 minutes to remove all photoresist and metal
   - A cotton swab can be used to brush metal off the wafer (Nickel flakes can be collected using magnet)
     - To avoid metal re-deposition on wafer
     - Rinse thoroughly with acetone squirt bottle after photoresist removal and lift-off
     - Let wafer sit in DI water for 5 minutes after acetone
     - Then spray wafer with water to remove any re-deposited metal, Spin Rinse Dry
     - Filter acetone for reuse after each wafer to remove metal and minimize re-deposition

© March 1, 2012 Dr. Lynn Fuller

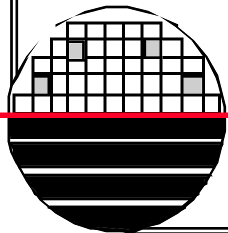
AVOID HARD BAKE WHEN DOING LIFT-OFF

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.

After Develop

After Hard Bake

140 to 150 °C hotplate for 1 min.



EVAPORATION

Substrate

f

h

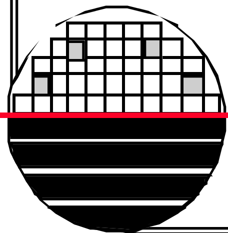
Sources :
Resistance Heated
Wire Basket
Dimpled Boat
Electron Beam Heated

Current

Source

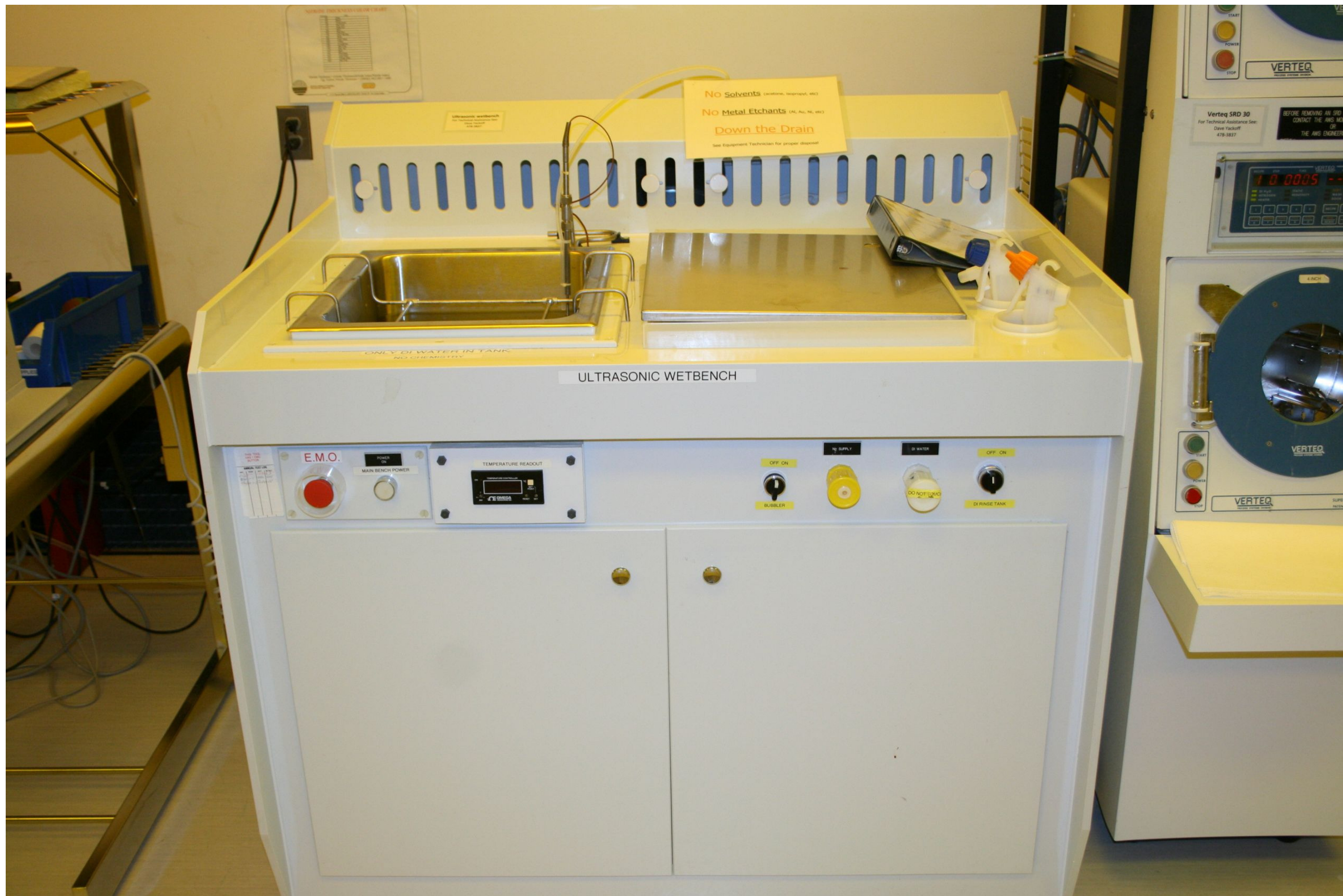
$$f = \frac{m}{4d\,\pi\,h^2}$$

f = film thickness
d = density
h = height
m = mass



© March 1, 2012 Dr. Lynn Fuller

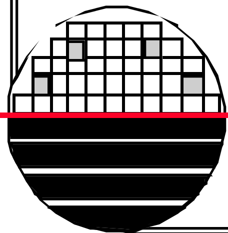
ULTRASONIC BATH (RIT) - ACETONE



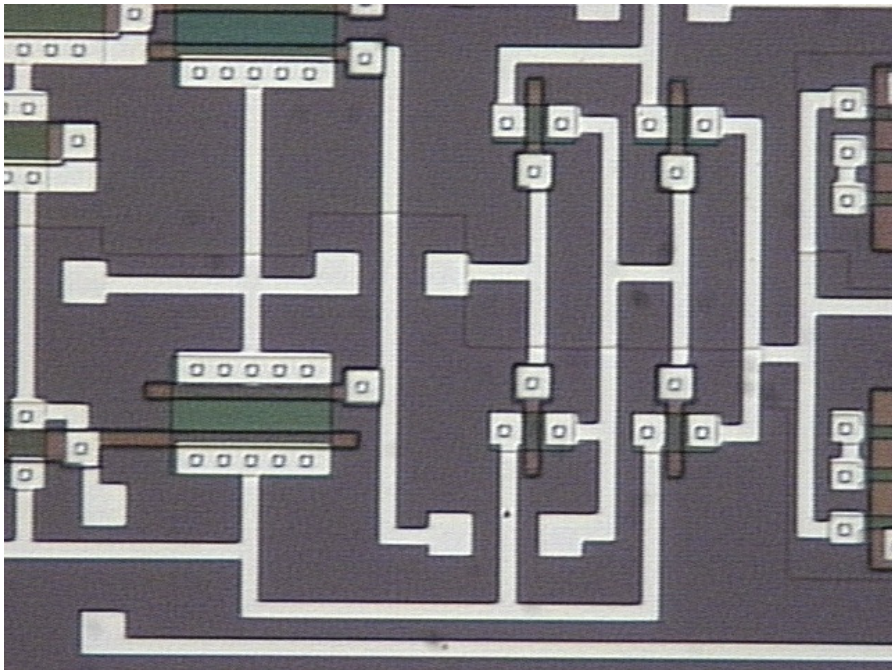
MOVIE SHOWING LIFT-OFF OF Ti/Ni FILM

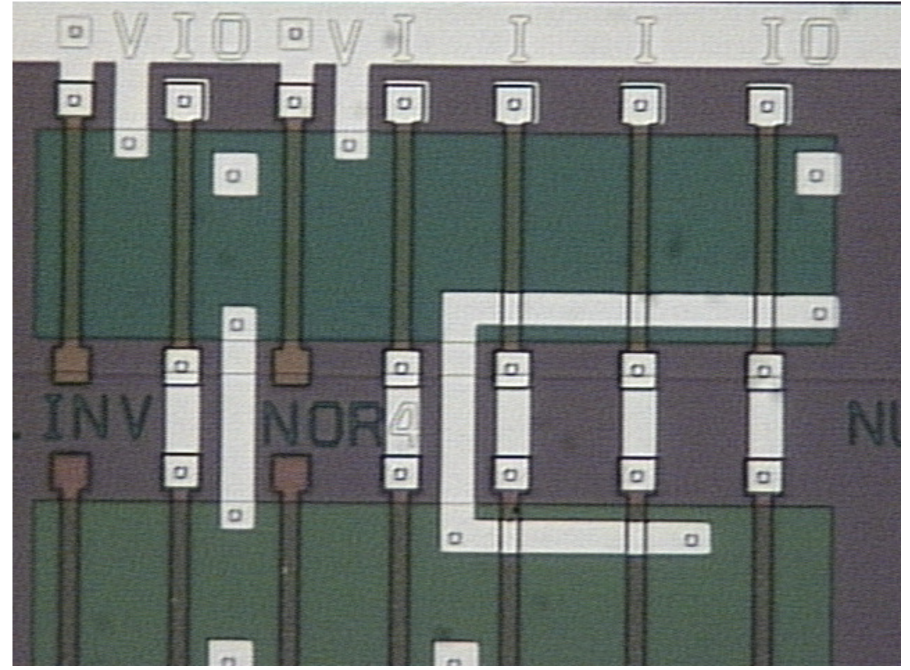
Single Layer nLOF Image Reversal Resist Lift-off Technique
Evaporated Ti/Ni Film

Ultrasonic Acetone Bath, Magnet to Capture Flakes, DI Water Rinse

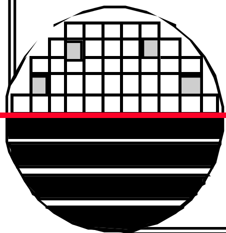


PICTURE OF ALUMINUM LIFT-OFF RESULTS





Using nLOF Image Reversal Resist Technique for Lift-off of Evaporated ~5000Å Aluminum

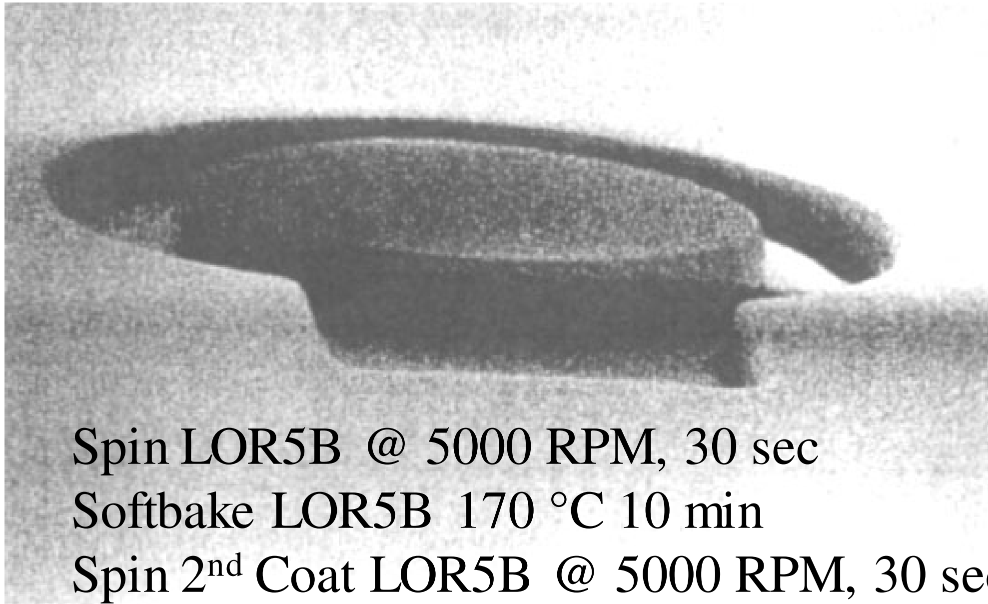


© March 1, 2012 Dr. Lynn Fuller

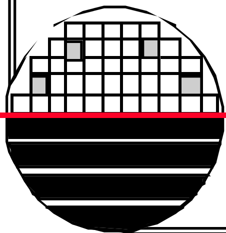
LIFT-OFF USING MICRO-CHEM LOR

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

0.5L Bottle LOR5B $365
4 gal Shipley MIF 319 $185

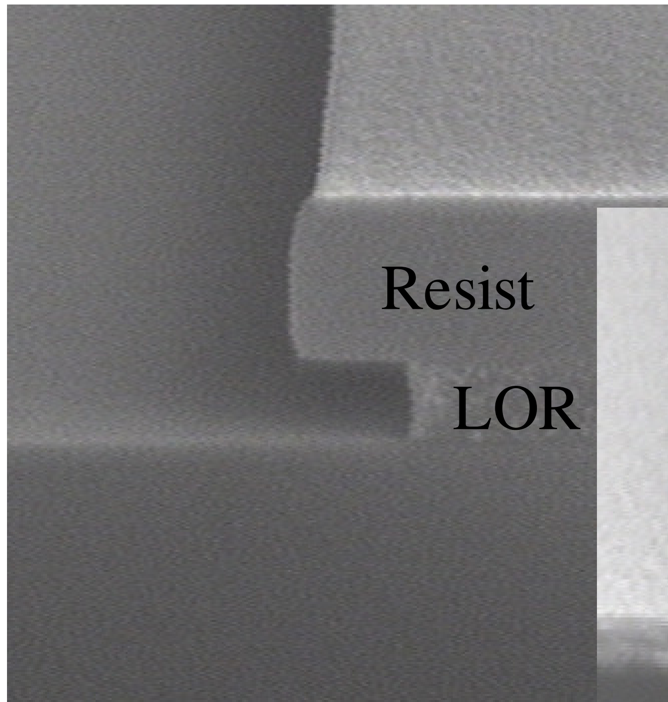


Spin LOR5B @ 5000 RPM, 30 sec
Softbake LOR5B 170 °C 10 min
Spin 2nd Coat LOR5B @ 5000 RPM, 30 sec
Softbake LOR5B 170 °C 10 min
Spin Shipley System 8 Resist @5000 RPM 1 min
Softbake 110 °C, 1 min.
Expose System 8 resist 150 mj/cm2
Develop CD-26, 1 min.
Rinse, Dry

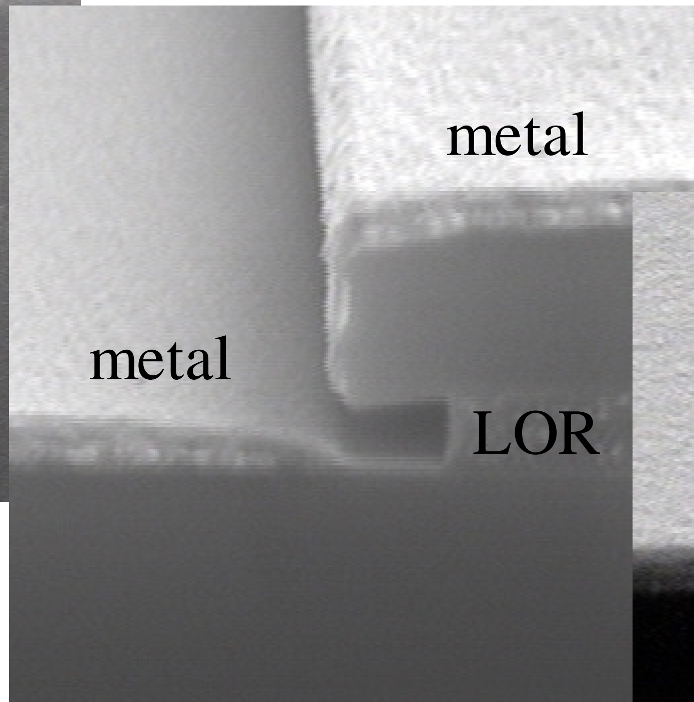


LIFT-OFF USING LOR-5B BILAYER RESIST TECHNIQUE

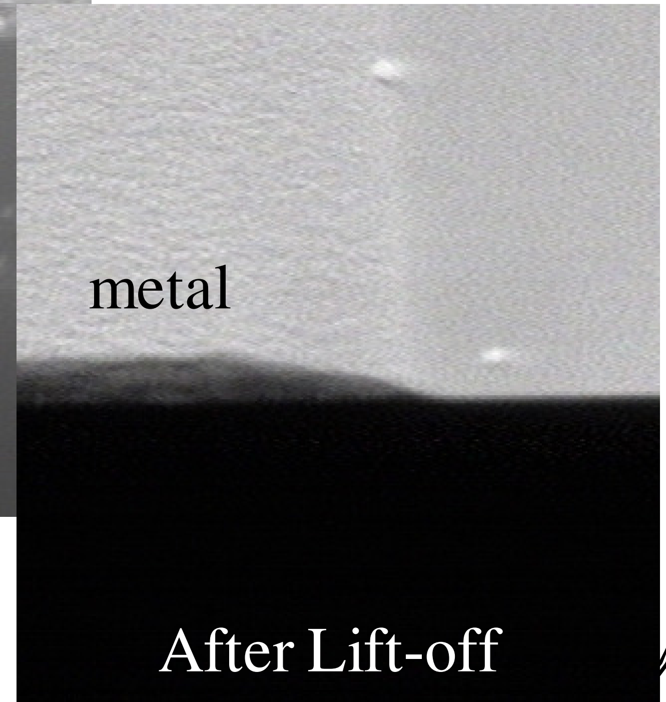
From Dr. Sean Rommel, Dave Pawlik



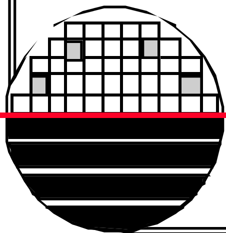
After Develop



After Metal Dep.



After Lift-off



LIFT-OFF USING MICRO-CHEM LOR

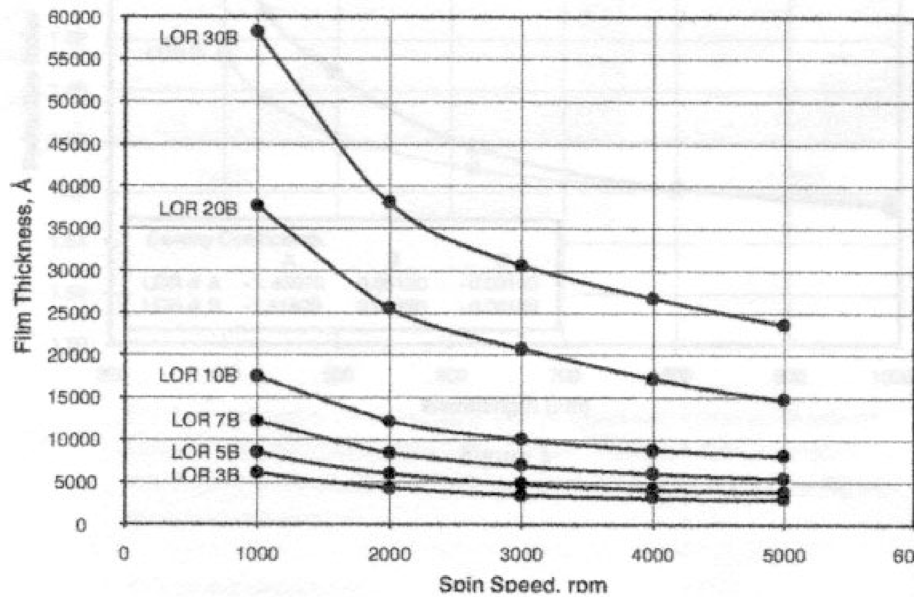


Figure 2

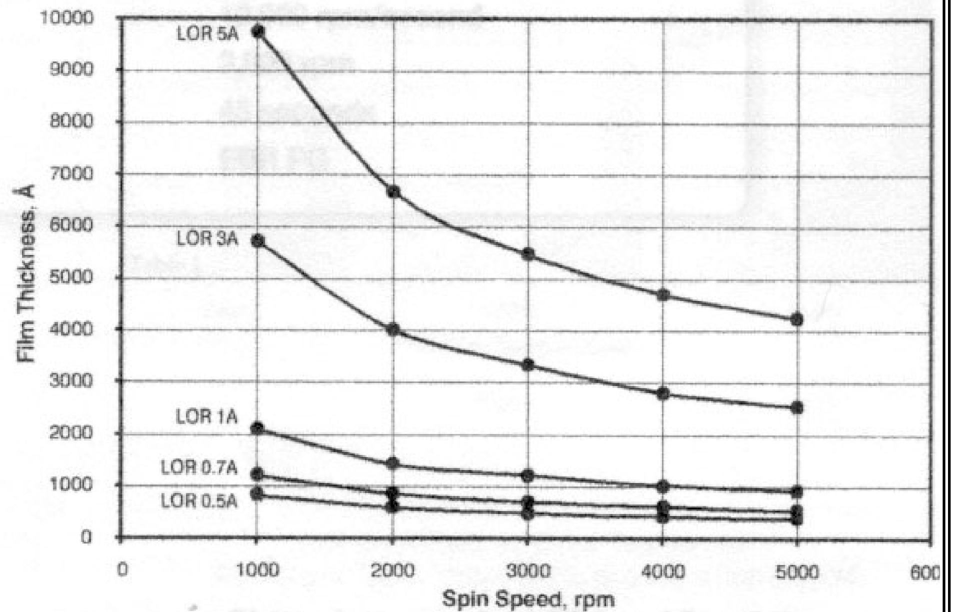
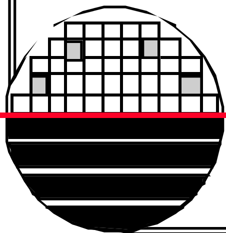
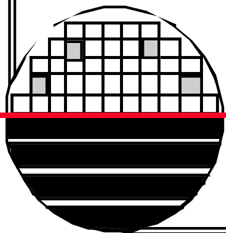


Figure 1



REFERENCES

1. Microchem, 1254 Chestnut Street, Newton, MA 02464, (617)965-5511
2. http://wiki.smfl.rit.edu/index.php/Lift_Off_Process



© March 1, 2012 Dr. Lynn Fuller

HOMEWORK – LIFT-OFF

1. Compare the various techniques for lift-off.
2. What type of mask is needed (clear field or dark field)