Lift-off Photoresist Processing

1 General Perspective

This procedure describes the general preparation, exposure, and processing of film stacks consisting of LOR resist beneath Shipley S1805 photoresist, for metal lift-off processing. In a metal lift-off process, a patterned photoresist bilayer stack is prepared on the wafer surface – with the resist removed in areas where metal is to be deposited. Next, via evaporation, the desired metal(s) are deposited over the entire surface of the wafer. The remaining resist is removed in a solvent bath, "lifting off" the metal that was deposited on top of the resist, and leaving metal only in the areas where the photoresist was not. To ensure a good lift-off, the metal on the surface of the wafer must not connect to the metal that is on top of the resist. This, then, is the purpose for the layer of LOR resist under the Shipley resist – it allows for an undercut of the LOR resist, creating a gap between the metal areas (see Figures 1 and 2). In effect, the S1805 resist layer is like a shadow mask, and the LOR layer is a spacer holding the shadow mask off of the wafer surface. Because of the need for the gap between the metal areas, conformal metal deposition methods, such as atomic layer deposition (ALD) or sputtering, are not well-suited to lift-off processes.

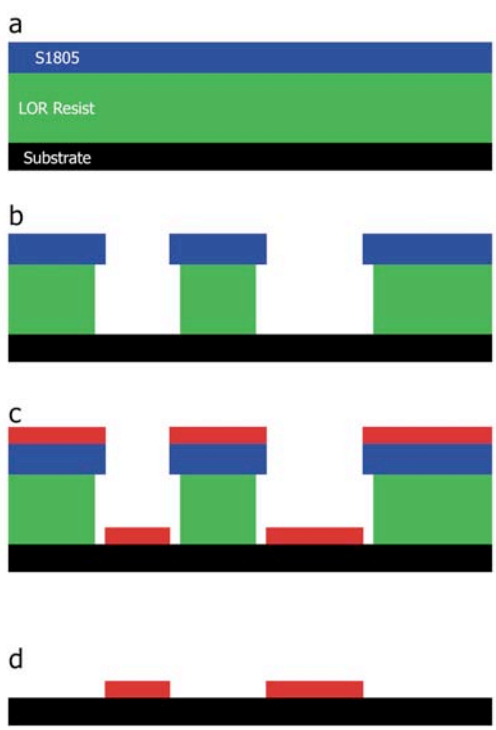

Figure 1: Illustration of the lift-off process. a) Resist bilayer on the substrate; b) After exposure and development; c) After metal deposition (red); d) After resist removal

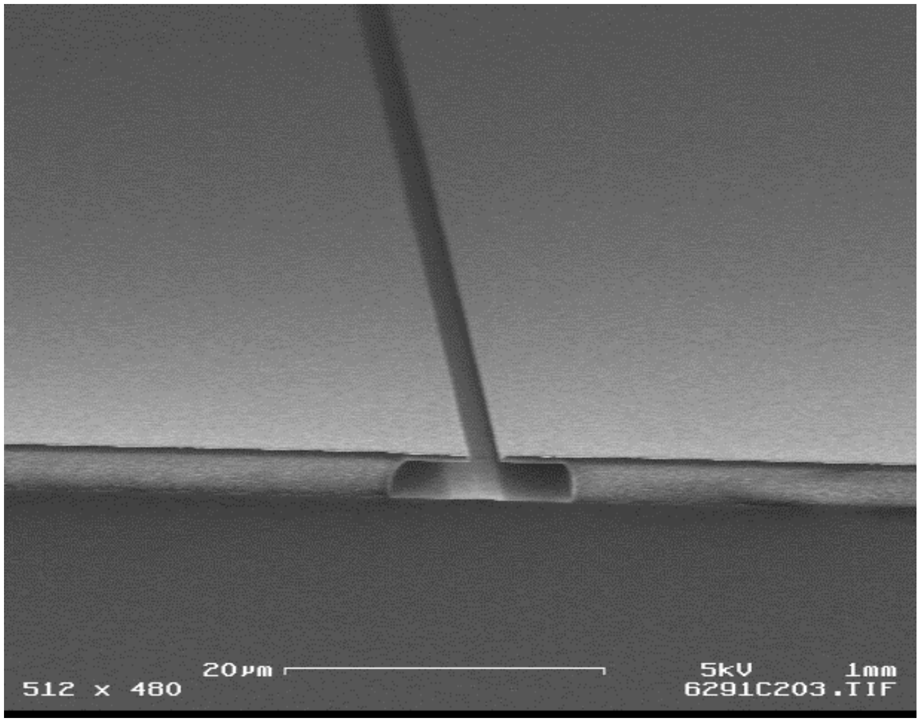

Figure 2: SEM cross-section of Shipley 1805 resist on top of LOR 20B, after development. This degree of undercutting is excessive for normal processing, but illustrates the degree of undercutting possible.

1.1 General Safety Precautions

1.1.1 Do not perform any work, or operate any tools, that you have not been specifically trained to do or use.

1.1.2 Keep all wet resist-coated objects, including cups, pipets, wipes, and unbaked substrates inside a solvent bench or other vented enclosure.

1.2 Staff Contacts

For issues or problems with LOR or Shipley S1800 resist processing, contact the following staff members:

Steven Hickman (shickman@cns.fas.harvard.edu) 617 384 5024

JD Deng (jdeng@cns.fas.harvard.edu) 617 495 3396

2 Equipment and Supplies

2.1 Required Equipment

2.1.1 Headway PWM32 photoresist spinner

2.1.2 Suitably sized spinner vacuum chuck

2.1.3 Contact mask aligner

2.1.4 Hotplate

2.1.5 Anatech 106 Barrel Plasma System

2.2 Optional Equipment

2.2.1 Sonication bath

2.3 Required Supplies

2.3.1 Substrate

2.3.2 Plastic pipet

2.3.3 Plastic cup

2.3.4 LOR 3A or 20B resist

2.3.5 Shipley 1805 photoresist

2.3.6 Photomask

2.3.7 Remover-PG photoresist remover

2.4 Optional Supplies

2.4.1 Aluminum foil

2.5 Required CNS Trainings

2.5.1 Wet bench safety training

2.5.2 Headway spinner training

2.5.3 Contact mask aligner training

2.5.4 Anatech 106 training

3 Substrate Cleaning

The degree and type of substrate cleaning needed will vary with the desired level of substrate cleanliness, and prior processing of the substrate. If the deposited metal is to be used to make electrical contact to the underlying substrate, ensuring that the substrate is clean before processing is crucial.

3.1 Dynamic Substrate Solvent Cleaning (optional)

3.1.1 Place substrate into spinner on a suitable chuck. The spinner program is not important.

3.1.2 Obtain spray-bottles of acetone and isopropanol.

3.1.3 Start the substrate spinning.

3.1.4 Once the substrate begins to rotate, spray acetone at the center of rotation for 5 seconds. While continuing to spray with acetone, spray isopropanol at the center of the substrate rotation for 1 second.

3.1.5 Stop the spray of acetone, continue to spray with isopropanol only for 1-2 seconds.

3.1.6 Let the spinner program run to completion, which spin-dries the substrate.

3.1.7 Inspect visually for any remaining debris or contamination on the substrate.

3.2 Static Substrate Solvent Cleaning (optional)

3.2.1 In a solvent bench equipped with a sonication bath, prepare three solvent baths, one each of Trichloroethylene, acetone, and isopropanol.

3.2.2 Place substrate in acetone bath, and sonicate for 5 minutes.

3.2.3 Transfer substrate to methanol bath, and sonicate for 5 minutes.

3.2.4 Transfer substrate to isopropanol bath, and gently agitate.

3.2.5 Remove substrate from isopropanol bath and blow dry with nitrogen gun.

3.3 Photoresist Stripper Chemical Bath

3.3.1 In a solvent bench equipped with a hotplate, prepare a bath of either Remover-PG or AZ 400T.

3.3.2 Place solvent bath on hotplate, heating to 80 C.

3.3.3 Soak substrate for 30 minutes.

3.3.4 Rinse with either DI water or isopropanol

3.3.5 Blow substrate dry with nitrogen gun.

3.4 Oxygen Plasma Cleaning (optional)

3.4.1 Not recommended for removing >1 micrometer thick resist films.

3.4.2 Effective at removing thin organic contamination layers.

3.4.3 The Anatech 106 is suitable for this process.

3.5 RCA Acid/Base cleaning process

3.5.1 Effective at removing both organic and metal contaminants.

3.5.2 Offered as a weekly training, called “RCA Clean”

4 Microchem LOR Resist Film Preparation

4.1 HMDS surface priming NOT required nor recommended

4.2 Dehydration Bake: Immediately prior to applying resist, remove adsorbed water from the substrate by baking at >150 ºC for at least one minute.

4.3 Resist spinning

4.3.1 Resist type selection

4.3.1.1 LOR is supplied in two different forms, 3A and 20B. Each has a different thickness range, and a different dissolution rate in photoresist developer.

4.3.2 Resist thickness determination

4.3.2.1 The LOR thickness must be greater than the thickness of the metal to be lifted off. A good rule of thumb is to make the LOR layer 1.5X thicker than the intended metal thickness.

4.3.3 Spin speed determination.

4.3.3.1 Resist spin curves are printed in the LOR section of the "Photoresist Handbook" kept in the photolithography bay.

4.3.3.2 From these curves, determine the type of LOR and spin speed required to produce your desired resist thickness, rounded to the nearest 500 rpm.

4.3.4 Program Headway spinner for the desired spin speed.

4.3.4.1 Programs 1-7 are for a standard spin program with preset speeds, listed in the table below.

Program	Final Spin Speed
1	2000
2	2500
3	3000
4	3500
5	4000
6	5000
7	6000

All programs consist of an initial 5 second spin at 500 rpm, then ramp at 1000 rpm/sec to the final spin speed. The final spin speed is maintained for 40 seconds, then the spinner ramps down at 1000 rpm/sec.

4.3.4.2 Programs 8 and 9 can be set up in any manner.

4.3.4.3 It is a good idea to check steps 1 and 2 in programs 1-7 to make sure that they are set up properly.

4.3.5 Place substrate into spinner on a suitable chuck.

4.3.6 Pour a small amount of LOR resist into a plastic cup – no more than 10 ml at a time.

4.3.7 Using a pipette, dispense sufficient resist to cover 2/3 of the substrate surface. Do not cover the entire substrate surface with resist, as this causes the resist to flow onto the backside of the substrate.

4.3.8 Start the spinner with the footswitch. It is recommended to press the green footswitch a second time, immediately after the substrate begins rotating, to skip over the 5 second initial spin.

4.3.9 Unload the substrate.

4.3.10 Examine the resist film, inside the hood, for any defects. If the level of defects is unacceptable, the resist film can be removed by soaking in Remover-PG for 15 minutes at 80 ºC. Acetone WILL NOT remove LOR resist.

4.3.11 The bake time and temperature will determine, to a degree, how quickly the LOR resist dissolves in photoresist developer. See the manufacturer information on LOR, found in the "photoresist handbook", for more information. For the process developed for this document, bake the resist film at 180 ºC for 4 minutes.

5 Shipley S1805 Resist Film Preparation

5.1 Program Headway Spinner for recipe #5.

5.2 Use nitrogen gun to blow off any dust from the substrate

5.3 Place substrate on suitable spinner chuck

5.4 Pour a small amount of S1805 resist into a plastic cup – no more than 10 ml at a time.

5.5 Using a pipette, dispense sufficient photoresist to cover 2/3 of the substrate surface. Do not cover the entire substrate surface with resist, as this causes the resist to flow onto the backside of the substrate.

5.6 Start the spinner with the footswitch. It is recommended to press the green footswitch a second time, immediately after the substrate begins rotating, to skip over the 5 second initial spin.

5.7 Unload the substrate

5.8 Examine the film, inside the hood, for any defects in the film. It is likely that there will be at least a few visible, as the double layer resist stack is both more likely to have defects, and it also makes defects more visible. If there is a defect in a critical area of the substrate, the resist film can be removed by soaking in Remover-PG for 15 minutes at 80 ºC. Acetone WILL NOT remove the resist film.

5.9 Bake the substrate at 115 ºC for one minute.

6 Lithographic Exposure

Training is required to use any of the contact mask aligners in the CNS. See relevant SOP documents (017, 028, 041, 057) for operation of the contact aligners. The lithographic exposure only causes a change in the S1805 resist – the LOR layer is unaffected by UV light.

6.1 Exposure dose

6.1.1 For S1805, use an exposure dose of 50 mJ/cm^2 @ 405 nm

6.1.2 From the posted contact aligner intensity data, determine the H-line (405 nm) intensity for the desired contact aligner.

6.1.3 Calculate the exposure time in seconds (1 mJ/cm^2 = 1 sec x 1 mW/cm^2).

6.2 Expose substrate on contact aligner

7 Substrate Development

7.1 Select a container sufficient to accommodate the substrate.

7.2 Carry out developing in the plastic developer hood in the photolithography area.

7.3 Using developer CD-26, pour a sufficient amount into container to submerge the substrate.

7.4 (Optional) Fill a second container with deionized water.

7.5 Soak in developer for 75 seconds.

7.6 Remove substrate from developer, and rinse with water (or place into water bath).

7.7 Blow substrate dry with nitrogen gun.

8 Oxygen Plasma De-scum

8.1 The purpose of the de-scum process is to remove any remnant resist in the exposed regions, so that the deposited metal is in direct contact with the substrate.

8.2 Either the Technics Plasma Stripper or the Anatech Barrel Plasma system can be used for this process; in this document, the Anatech system is used.

8.3 Specific training is <u>required</u> to use either of the oxygen plasma systems

8.4 Anatech Plasma Descum Process

8.4.1 Load the substrate into the chamber

8.4.2 Use 75W RF power, 20 second etch time, 40 SCCM O_2 flow rate.

9 Material deposition

9.1 For a lift-off process, it is best if the metal is deposited in an evaporator – as this affords a highly directional deposition of the metal. More isotropic deposition processes, such as sputtering, atomic layer deposition, and chemical vapor deposition, will not give as good of results.

10 Resist removal / material lift-off

10.1 The lift-off process is conducted in the solvent fume hoods in the wet process bay of the cleanroom.

10.2 Select a glass container sufficient in size to hold the substrate

10.3 Fill container with Remover-PG to a sufficient level to cover the substrate.

10.4 On a hotplate, heat the Remover-PG to 80 ºC.

10.5 Soak the substrate until the resist and deposited metal film have completely lifted-off from the substrate. The time for this to occur depends on the type and thickness of the material deposited, and can range from tens of minutes to a few hours.

10.6 (Optional) The lift-off process can be accelerated by sonicating the substrate after it has been soaking in the remover-PG for a few minutes.

10.7 Remove the substrate from the Remover-PG, and rinse with isopropanol, then blow dry with nitrogen.

11 Example Scanning Electron Micrographs.

11.1 Example SEM images for a 200 nm evaporated silver film, patterned using LOR 20B. A LOR 3A film was also tested, with a 50 nm silver layer, but it was exceedingly difficult to obtain SEM images of that film.

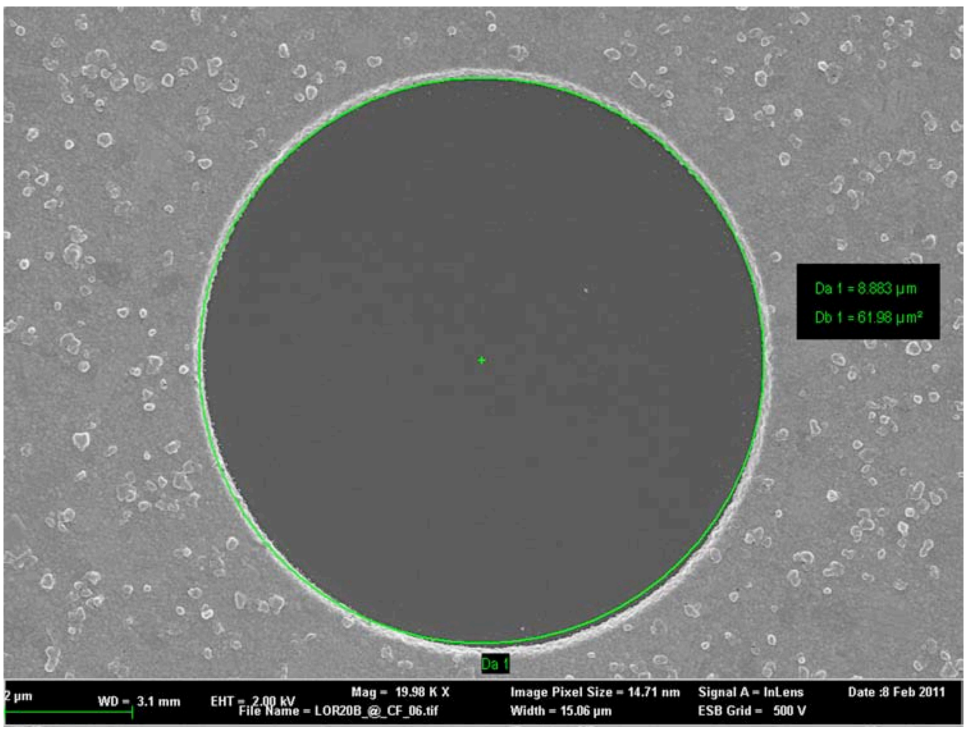

Figure 2: A 9 micron diameter clearfield circle.

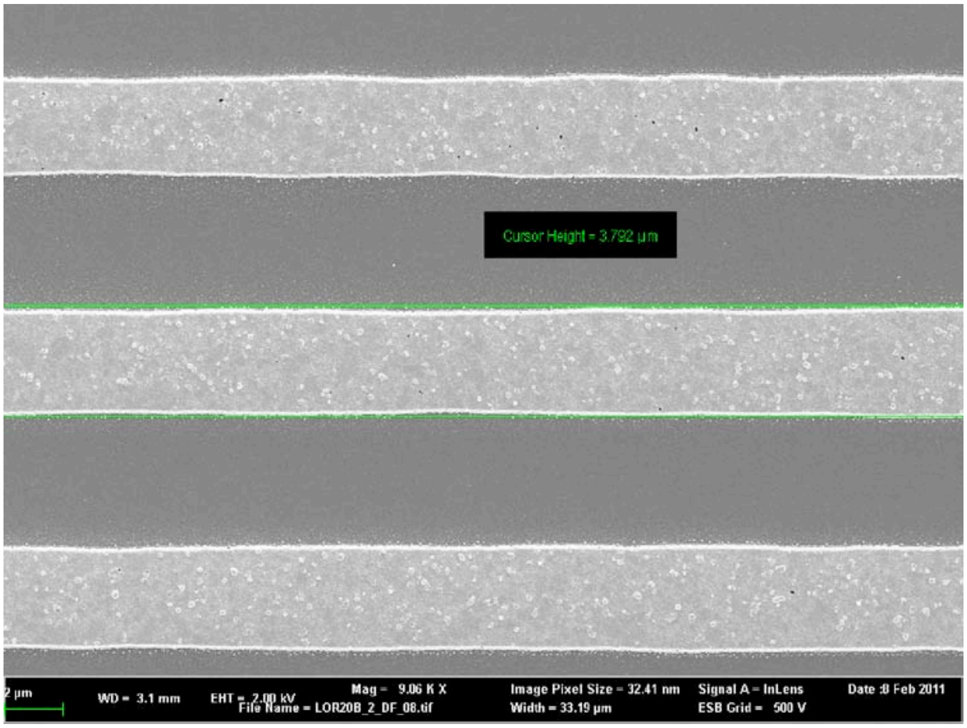

Figure 3: A series of 4 micron darkfield lines, spaced by 4 microns

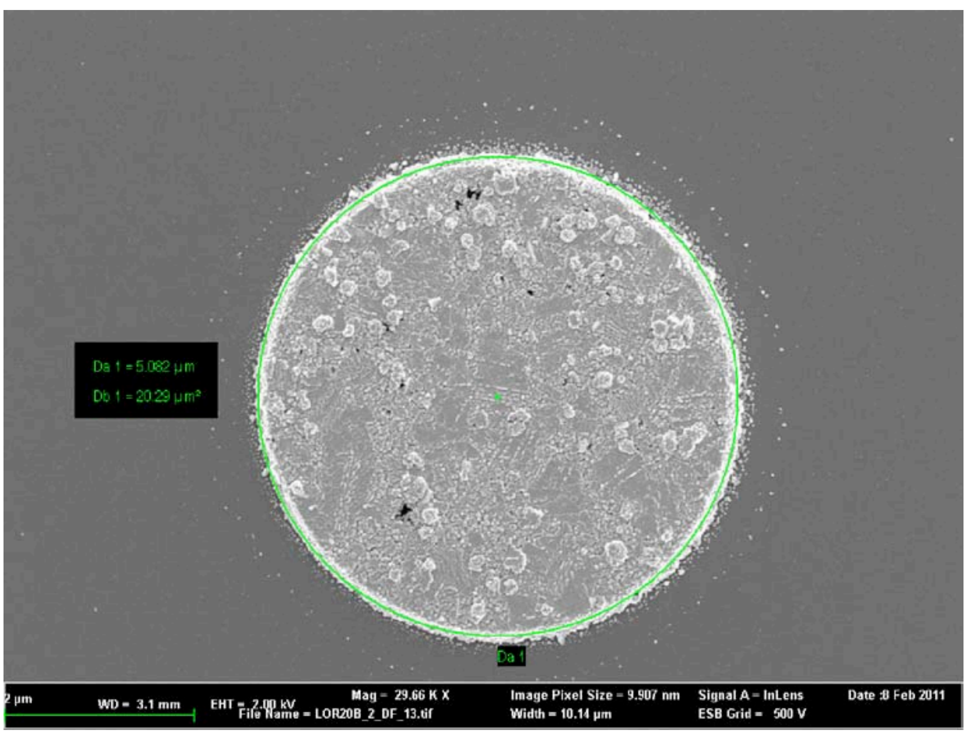

Figure 4: A 5 micron diameter darkfield circle.

12 REVISION HISTORY

Revision #	Date	Author (s)	Changes/Additions
0.1	4/11/11	S. Hickman	Initial issue.
1.0	5/6/11	S. Hickman	Added SEM images
1.1	5/13/11	S. Hickman	Minor spelling corrections, added material to substrate cleaning section