Processing of Thin Film Devices

1984

Ramzi Delpak

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PROCESSING OF THIN FILM DEVICES

BY
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THESIS
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1984
ABSTRACT

The ability to do thin film processing has been established at UCF. This paper describes the facilities available.

RF and DC sputtering was used for material deposition. The parameters for both were established experimentally, and the results are presented.

Resistor and capacitor test patterns were used to test the accuracy of the system. The devices were fabricated and tested; experimental results are discussed.
ACKNOWLEDGEMENTS

I would like to thank Dr. Donald Malocha for his suggestions, assistance and friendship in preparation of this thesis. I would also like to thank Samuel Richie and Benjamin Abbot for the use of their mask generation software. Special thanks to Carlton Bishop, Raymond Yap, and Russell Case for their friendship and help in the laboratory.

Finally, I would like to thank my parents, Jalal and Sorore, for their patience, support, encouragement, and love.
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CHAPTER I
BACKGROUND OF PREVIOUS WORK

Sputtering Fundamentals

Sputtering was one of the first techniques used in vacuum thin film deposition since it can be used in a relatively low vacuum. Sputtering involves the ionization of the gas molecules that are present in the vacuum chamber by applying a potential difference across two electrodes located within the chamber, Figure 1. The ionized gas molecules, which are positively charged, will then collide with the cathode material under the acceleration of the electric field and strip the cathode molecules. Cathode molecules or source molecules, at this point, will be free to attach themselves to any surface within the chamber. Sometimes, to capture a higher number of ions within the plasma a magnet is placed under the source electrode, hence magnetron sputtering.

There are two types of sputtering, DC and RF [1]. DC sputtering is used when the source is metallic. RF sputtering is used when the source is nonmetallic.
Introduction to Sputtering Parameters

As with any other technology, sputtering has its own parameters [2]. Chamber pressure, substrate to source distance, power delivered to the gun, source material, source temperature, physical properties of the sputtering gas, chemical properties of the sputtering gas; are some of sputtering parameters. A brief discussion on the first four parameters, and how they effect the deposition rate is provided here.

Background and Chamber Pressures

Background pressure is the pressure of the chamber before the sputtering gas is introduced. In order to have the best film quality, cleanliness becomes very important. One of the factors that determines cleanliness is the number of unwanted molecules present at the time of sputtering. To minimize this number, the chamber will usually be pumped down to its lowest pressure. After the desired pressure is attained, the impurity gas will be introduced into the chamber by means of a controlled leak.

Before a plasma is established, chamber pressure determines the required potential difference across the gun electrodes for ionization. The higher the pressure, the lower the potential needed to ignite the plasma. Once the plasma is established, sputtering takes place and the amount of gas leak determines the rate of deposition.
The potential difference across the electrodes is only enough to ionize a certain number of gas atoms. Hence, for a constant potential difference, an increase in pressure would only increase the number of neutral molecules and reduce the deposition rate.

**Substrate to Source Distance**

Due to diffusion phenomena, there are more source molecules near the gun than there are a few inches from the gun. Thus, the deposition rate increases as the substrate comes closer to the source. However, in order to have thickness uniformity across the sample, a minimum distance has to be kept between the sample and the source. This distance is a function of source area, substrate area, the degree of uniformity required by the process, and whether or not the substrate is rotating during sputtering.

**Power delivered to the Gun**

Power is defined as the product of current and voltage. Before the plasma is established, there are no ions available to produce a current. Thus, as far as the power supply is concerned, the sputtering gun resembles an open circuit. Any increase in the power supply output would only increase the voltage across the gun’s electrodes.

After plasma is established, the ions within the plasma move, due to the electric field, and the result is a
current flow. Since the gun resembles a finite resistor at this point, the voltage across it falls while the current through it rises. The values of voltage and current are set by chamber pressure. An increase in power at this time would increase the voltage, but since there is a plasma established; the excess voltage ionizes some of the neutral ions. Hence, the number of charge carriers increases which reduces the gun resistance and ultimately the voltage across the gun decreases to its original value. An increase in power would increase the voltage only after all the neutral molecules are ionized; but until that point the current increases linearly with power.

Deposition rate always increases as the power increases, provided that the rest of the variables are kept unchanged.

Source Material

Gas ions transfer kinetic energy to the source molecules at the time of collision. The requirement to detach source molecules from the source surface is that the transferred energy be equal or greater than the bonding force within the source molecules. The greater the bonding force, the greater the kinetic energy that is required to break these bonds. Thus for a constant kinetic energy, deposition rate increases as the bonding force decreases.
It is important to note that a material's boiling point is inversely proportional to its bonding force, hence materials with low vapor pressure exhibit a higher deposition rate for all the other parameters held constant [7].

Figure 1. Sputtering phenomena
CHAPTER II
OBJECTIVE OF PROPOSED WORK

The objective of this work is to fabricate resistors and capacitors, on the hybrid level, using the multichamber vacuum system at U.C.F. First, the vacuum system was made operational. Then, system and deposition parameters were established. Finally, masks were generated and a fabrication process was defined that would implement such devices.

After the devices were fabricated, a test was conducted to measure the accuracy of the process. These results are compared to previously published works.
Figure 2. The Multichamber vacuum system. Location of the chambers with respect to each other and the table.
CHAPTER IV
METHODS, PROCEDURES AND EXPERIMENTS

Description of Experimental Set-Up

Multichamber Vacuum System

As shown in Figure 2, this system consists of three vacuum chambers, each designed to accommodate a different process. The roughing line, shown in Figure 3, consists of a brass pipe that is connected to a mechanical pump on one side and passes below all three chambers. Two "tees" located under the first and the second chambers, connect this line to two pressure operated roughing valves. The last chamber uses a 90 degree "elbow" for such connection. The main thermocouple gauge (T.C.G.) is placed between the second and third chamber. This gauge is used to detect the crossover pressure.

![Figure 3. Block diagram of the roughing line](image_url)
The hivac line, shown in Figure 4, is manufactured from stainless steel and connects the cryogenic pump to the three pressure operated hivac valves located below each chamber.

Figure 4. Block diagram of the hivac line

All base plates are aluminum and measure 15" x 15" x 1". There are 6 holes in each base plate, as in Figure 5.
The hivac valve is connected to the 2" hole (dimension on a hole corresponds to its diameter). The roughing valve is connected to the 1.5" hole. All the other holes are 1". They are designed to house the feed-throughs when required.

![Diagram of base plate]

Figure 5. Top view of the base plate

Belljars 1 and 3 are made of aluminum. They are 19" high and 10" in diameter. Bell-jar 2 is made of stainless steel. It is 20" high and 14" in diameter. All the bell-jars are cylindrical. The top plates are all made of 15" x 15" aluminum, 1" thick. They each have five holes (see Figure 6). The 2" hole is used as a view-port. There are two 1" holes. One of them is used to seat the ionization gauge (I.G.). The other is used for venting and the controlled leak. The last two holes are 0.65" in diameter.
These holes house the ferrofluidic feed-throughs that are used to rotate the sample holders and shutters.

The crossover pressure for this system is 20 millitorrs. The mechanical pump, however, can reach 10 millitorrs after pumping for 15 minutes.

The cryo pump is capable of producing 1 microtorr of pressure in any chamber two hours after the crossover.

This system is designed for the use of one chamber at a time. There are four solenoids per chamber. They operate the top plate lifts, venting valves, roughing valves, and hivac valves. The electrical switches for all of the solenoids are located on the control panel.

Figure 6. Top view of the top plate
Overview of Chamber Parameters

Chamber one contains the ION GUN. This gun is capable of ion milling, substrate cleaning, and dry etching.

Chamber two contains the DC and RF guns. A Crystal Deposition Monitor (C.D.M.) is also located in this chamber [6]. The C.D.M is used to monitor the deposition rate of the DC gun. Chamber three contains the Flash Evaporator. It is capable of evaporating two different materials in one pump down.

The experimental work performed does not require the equipment within chambers one and three; therefore, only a single chamber, chamber two, will be discussed henceforth.

Chamber Two Parameters

As shown in Figure 7, the two holes on the right of the base plate house the feed-throughs for the DC gun and C.D.M. . The RF gun's feed-through is on the left and the fourth hole is sealed.

The DC gun [3], is seated on a 6" Teflon insulator. The electrical power is delivered by the cooling water lines which also supports the gun assembly (see Figure 10).

The feed-through used for the C.D.M. consists of two water lines and a female coax connector. The monitor head is supported by two brass tubes that are silver-soldered to the water feed-through lines.
Electrical power is delivered to the C.D.M. via a vacuum compatible coax cable connecting the feed-through to the monitor head.

The RF gun [4] is seated on a grounded piece of vacuum sealed aluminum tubing. Cooling water and RF power are supplied through this tube to the magnet housing, located below the source or target. Figure 11 shows a cross-sectional view of the RF gun.

Both shutters are connected to the same feed-through and clear 0.5" from the top of the guns, (Figure 8).

The sample holder is connected to the center ferrofluidic feed-through. It is capable of holding one sample and rotating it over both guns.
The sample holder is designed to accept any shape substrate that is up to 2 inches wide.

Figure 8. Cross-sectional view of chamber two

An auxiliary thermocouple gauge (TCG AUX.) is placed on the top plate, as in Figure 9, to monitor the controlled leak. The reading on this gauge is a relative measure of vacuum and is used for consistency within the experimental runs of this chamber only.
Figure 9. Side view of top plate two
Figure 10. Cross-sectional view of the DC gun
Figure 11. Cross-sectional view of the RF gun
Device Configuration for Experiments

Mask Generation

All of the artwork used in these experiments was generated using the UCF SAWCAD facilities. The patterns were then drawn, using the HP 7580B plotter located in EN 331, on Mylar* with India ink. Pen thickness was 0.32 millimeters and patterns were drawn to size.

There were a total of four masks used in these experiments. Resistor mask (RM), and capacitor masks 1 and 3 (CM1 and CM3) were produced on 3" X 1" glass slides, using the artwork. Capacitor mask 2 (CM2) was made of 10 mil thick stainless steel.

RM and CM1 are positive masks. The artworks for these masks were also positive. Thus these two were fabricated using the wet-etch technique that is described in Appendix F. The glass slides were flash evaporated by aluminum.

CM3 is a negative mask, used for lift-off approach. The positive of this mask was implemented much the same as RM and CM1. Then a second glass slide was prepared and CM3 was fabricated on the second glass slide using the lift-off technique, Appendix F. The mask used for the lift-off procedure was CM3 positive, that was fabricated first.

CM2 was prepared by cutting a piece of steel to the desired shape. Then it was cleaned to be vacuum compatible, Appendix E.
Resistors

The single level resistor mask, Figure 12, contains three patterns. Resistors R1 and R2 both have 90 squares. R1 is a straight line [5] resistor. R2 is meander type [5] and has 6 bends. Pattern R3 is another meander type with 214 squares and 8 bends.

R1 extends across the entire glass slide. This is to determine the average film resistivity. R2 and R3 are placed to test the meander versus straight line techniques; and also to check for film thickness uniformity. The procedure would be to determine the sheet resistance using R1. Then to calculate the values for R2 and R3, and to compare that with the measured values.

The 6 contact pads, each one being 25 squares, are not included in the resistor measurements. It was assumed that the contacts do not effect the resistance values.

Minimum line width is 25 mils. Corner squares are 25 X 25 mils.

---

Figure 12. Resistor mask
Capacitors

There are three masks used to fabricate the capacitors. All masks are of the in-contact type. MC1 is the pattern of the bottom electrode which is common to all five capacitors, Figure 13.a. MC2 is a shield that is placed on the sample during silicon dioxide deposition, Figure 13.b. MC3 is the negative of top electrode pattern, Figure 13.c; MC3 positive is shown in Figure 13.d.

To prevent dielectric punch through while testing, the top contact points do not overlap the bottom electrode.

All of the capacitors C1, C2, C3, C4, and C5 have different areas. The areas are 325, 225, 50, 100, and 200 squares respectively.

C1 and C2 are used to calculate the sheet capacitance; so they have large areas, to minimize the alignment errors, and are placed on the left and right boundaries of the bottom electrode. The sample sheet capacitance Cs, is calculated by taking the average of values for Cs1 and Cs2; then, the theoretical values for C3, C4, and C5 are calculated, using Cs, and compared to experimental values.
Figure 13. Capacitor masks, MC1, MC2, MC3 negative and MC3 positive
Deposition Parameters

The DC sputtering parameters are:

- Auxiliary pressure, \( p \) = 500 microns
- Dial value of power supply, \( D \) = 2.5 to 2.2
- Voltage, \( v \) = 400 volts
- Current, \( i \) = 0.51 milliamps
- Source to substrate distance, \( d \) = 4 inches

Deposition time, \( T \), was varied from 8 to 13 minutes with 1 minute increments. There were a total of 12 samples, 2 samples per each minute increment. Source material was 99.99 percent pure aluminum.

The RF sputtering parameters are listed below:

- Auxiliary pressure, \( p \) = 450 microns
- Dial value of power supply, \( D \) = 6.0
- Power, \( P \) = 250 watts
- Reflected power, \( RP \) = 0.0 watts
- Source to substrate distance, \( d \) = 4 inches

Deposition time \( T \), was varied from 15 to 40 minutes with 5 minute increments. There were a total of 12 samples, 2 samples per each minute increment. Source material was 99.99 percent pure silicon dioxide.

Device Tests

The fabricated devices were tested for their performance. Resistance of the resistors were measured using a FLUKE multimeter (UCF # 025380), table 1. Capacitance of the capacitors was measured, table 2, using a B & K Precision capacitance meter (UCF # 040485). Film thickness was measured under the metalurgical microscope, BAUSCH & LOMB (UCF # 037468). Both meters are available in EN 347.
TABLE 1

Results of DC sputtering

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Symbol Definition and Units

\( t \) = Sputtering time (minutes)

\( T \) = Film thickness (angstroms)

\( MF \) = Multiplication factor to change CDM reading into true film thickness reading

\( Rs \) = Sheet resistance (ohms per square)

\( Cs \) = Sheet capacitance (nanofarads per square)

\( R1, R2, \) and \( R3 \) (ohms)

\( C1, C2, C3, C4, \) and \( C5 \) (nanofarads = 1000 picofarads)

The "_" indicates that the value given is the expected value.

1 square is 0.635 X 0.635 milimeters.
TABLE 2

Results of RF sputtering

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<td>0.10</td>
<td>4.2</td>
<td>4.8</td>
<td>-11.7</td>
<td>9.3</td>
<td>9.5</td>
<td>-2.3</td>
<td>21.7</td>
<td>21.4</td>
<td>+1.3</td>
</tr>
</tbody>
</table>
Deposition Process Parameters

After device performance tests, film thicknesses were measured, Appendix D. The results of thickness measurement are presented both in Tables 1 and 2, and in graphs 1 and 2. Tables are used to determine the required film thickness that provides the necessary sheet resistance or sheet capacitance. The graphs are used to determine the sputtering time that yields the specified thickness.

Graph 1. Aluminum thickness vs. deposition time
Graph 2. Silicon dioxide thickness vs. deposition time
CHAPTER IV

CONCLUSION AND SUMMARY

The vacuum system was made operational and the system parameters were established. Then some test patterns were designed, the corresponding masks were generated and the test devices, resistors and capacitors, were fabricated from the masks. The deposition parameters were determined from these devices. The DC and RF sputtering rates are 140 and 25 angstroms per minute respectively. The devices were then tested for their performance and the results came within 8 percent of the expected values in most cases.

Possible sources of error are given below:

1. All the substrates have to be at the same position with respect to the guns.

2. All the patterns have to be at the same location on the substrates to assure consistency.

3. The power has to remain constant for all the runs.

4. While outside the chamber, the substrates have to be protected from dust and other contaminants.

5. During the DC sputtering, the output power of the power supply has to be monitored and adjusted to compensate for the rate increase due to temperature rise.

Based on the information gathered, a fabrication process schedule is prepared and provided in Appendix F.
APPENDIX A

Pump Down and Venting Procedure

PUMP DOWN

1. Make sure that the cryo and roughing pumps are up and running, otherwise follow the procedure in [5].

2. Close the nitrogen vent valve if open.

3. Make sure that the top plate is down.

4. Open the roughing valve on the main control unit.

5. Wait until a pressure of 20 microns on the thermocouple gauge is observed.

6. Close the roughing valve; wait 2 seconds.

7. Open the hivac valve which is labeled "CRYO" on the main control unit.

8. Allow 2 minutes for pressure stabilization before operating any of the equipment in the chamber.

9. Turn on the main power switch on the ionization-gauge-controller. Turn on the "DEGAS" switch, and let the ionization tube degas for 3 minutes. Then turn off the "DEGAS" switch and allow the tube to cool-down for 1 minute. Select between auto-range or manual. Turn on the gauge and allow it to stabilize.

VENTING

1. Turn off all equipment associated with the desired chamber; ionization gauge, deposition sources, etc.

2. Allow 3 to 5 minutes for stabilization.

3. Close the chamber's hivac valve, if open.
4. Open the nitrogen vent valve labeled "VENT" on the main control unit.

5. Allow 3-5 minutes for chamber to vent, depending on the flow of nitrogen.

6. Turn off the vent valve after chamber reaches atmospheric pressure. Top plate lift can be engaged now.

STANDBY

1. Close vent valve. Top plate should be down.

2. Rough chamber to 20 microns; then, close roughing valve.

3. Turn off roughing pump and vent it.
DC Gun Deposition Procedure

1. Place the substrate in Chamber 2 sample holder.
2. Pump down Chamber 2.
3. Turn on the water switch after a pressure of 50 microtorr is observed on the ionization gauge. Note that the targets are water cooled.
4. Turn off the ionization gauge and wait 3 minutes.
5. Open the toggle leak valve on the top plate, sputtering gas is argon.
6. Adjust the leak valve until a reading of 500 microns is observed on the auxiliary gauge.
7. Place the shutter between the gun and substrate.
8. Turn on the DC 1000 power supply and the "HV".
9. Increase the voltage until a plasma is established. The required voltage at 500 microns is approximately 1100 volts. After the plasma is established, voltage decreases to 400 volts and the current increases to 5 milliamps.
10. Adjust the voltage and current for the required deposition rate.
11. Allow the gun to sputter for 30 seconds, with shutter closed.
12. Open the shutter and time the sputtering.
13. After the necessary thickness is reached, close the shutter.
14. Slowly reduce the power until all the meters readings indicate zero.
15. Turn off the "HV" and then the main power.
16. Close the toggle valve for sputtering gas (AR).
17. Turn off the water after five minutes.
18. Follow venting procedure as outlined in Appendix A.
APPENDIX C

RF Gun Deposition Procedure

1. Place the substrate in Chamber 2 sample holder.
2. Pump down Chamber 2 (Appendix A).
3. Turn on the water switch after a pressure of 50 microtorr is observed on the ionization gauge.
4. Turn off the ionization gauge and wait 3 minutes.
5. Open the toggle leak valve on the top plate, sputtering gas is argon.
6. Adjust the leak valve until a reading of 600 microns is observed on the auxiliary gauge.
7. Turn on both the RF 500 MB power convertor and the RF 500 MB power supply. Wait 3 minutes for all of the power supply interlock LEDs to light up.
8. Place the shutter between the gun and substrate.
9. Turn the auto/manual switch on the RF 500 MB Load Match Tuner (L.M.T.) to manual.
10. Set the tuner to 59 units (59 implies that 59% of the variable tuning capacitor is being used).
11. Set the load to 64 units.
12. Turn on the RF power switch on the control unit.
13. Increase the power until a) the reflected power is approximately 35 watts; or b) a plasma is established.
14a. Dip the reflected power by moving the position of the tuning capacitor. Then dip it again using the load capacitor and repeat until the reflected
power is less than 5 watts or the minimum possible reflected power is achieved. If the plasma is established go to (14b); otherwise go to (26).

14b. Increase the power towards the desired limit at small increments. Go to (14a) each time that reflected power increases to 35 watts. Go to (15) when the desired power level is achieved.

15. Reduce the pressure to 450 microns on the auxiliary gauge. Follow (14a) if the reflected power increases drastically, otherwise go to (16).

16. Set the auto/manual switch on the L.M.T. to auto.

17. Allow the gun to sputter for 30 seconds.

18. Open the shutter and time the sputtering.

19. After the necessary thickness is reached, close the shutter.

20. Slowly reduce the power until all the power dials indicate zero watts.

21. Turn off the RF power switch on the control unit.

22. Close the toggle valve for sputtering gas.

23. Allow five minutes for the RF tube to cool down; then turn off both the main power switch on the control unit and the circuit breaker on the power supply.

24. Turn off the water switch.

25. Follow vent procedure as outlined in Appendix A, stop.

26. Go to (13) if the power is less than 100 watts. If the power is greater than 100 watts and a plasma is still not established, go to (27).

27. Reduce the power until the power dial indicates zero watts.

28. Turn off the RF power switch.

29. Follow steps (6) through (9) in Appendix B.
30. Reduce the current on the DC power supply to minimum, without destroying the plasma.
31. Turn on the RF power switch.
32. Turn off the DC 1000 power supply, as in steps (14) through (15) in Appendix B.
33. Go to (14) if the plasma is established, otherwise turn off the RF power and consult the laboratory manager.
APPENDIX D

Thin Film Interferometric Thickness Measurement

PRINCIPALS OF OPERATION:

Monochromatic light reflected through a wedge shaped air film will produce multiple fringes of equal thickness. If a partially reflecting flat is placed on a sample with a thickness discontinuity and viewed under a microscope; the discontinuity will produce a shift of the fringes. Furthermore, the thickness of the discontinuity can be measured using the formula given below [1]:

\[ t = \left( \frac{d}{fs} \right) \times \frac{w}{2} \]

where \( t \) is the thickness; \( d \) is the amount of shifting; \( fs \) is the fringe width; and \( w \) is the wavelength of the monochromatic light.

PROCEDURE:

1. Prepare a sample with the desired film thickness.
2. Generate a pattern on the sample and etch to provide the discontinuity. Note that it is preferred to have a smooth discontinuity. One can accomplish such a task by placing the edge of the film in the etchant at an angle.
3. Coat the sample again with approximately 800 angstroms of aluminum.
4. Use partially reflective the optical flats.
5. Place the coated side of the flat on the sample such that part of the flat rests on the film and the other part rests on the substrate.

6. Place the sample under a microscope and illuminate with monochromatic light.

7. Make the necessary measurements using the Filer eye-piece.

Note that the above procedure is valid for metal and dielectric films.
APPENDIX E

Sample Preparation

1. Turn the tap water on. The water should be on at all times in order to wash all the chemicals from the sink.

2. Put on your lab coat and the PVC gloves.

3. Wash the sample with tap water and detergent to get all contaminants off the surface.

4. Rinse the sample with the tap water.

5. Hold the sample with tweezers such that the tip of the tweezers is at the bottom part of the sample as close to the edge as possible.

NOTE: FOR THE REMAINDER OF THIS PROCEDURE, IT IS IMPORTANT THAT THE SOLUTIONS ARE POURED ON THE TOP OF THE SAMPLE AND DRIPPED INTO THE SINK WHERE THE SAMPLE IS HELD BY THE TWEEZERS. AVOID ANY SPILLAGE ON GLOVES OR HANDS. IF ANY SPILLAGE OCCURS, WASH THAT AREA WITH TAP WATER IMMEDIATELY AND NOTIFY THE PERSON IN CHARGE OF THE LAB.

6. Rinse the sample with trichloroethylene to wash the detergent residue.

7. Rinse the sample with acetone to wash the trichloroethylene residue.

8. Rinse the sample with methanol to wash the acetone residue.

9. Rinse the sample with deionized water to wash the methanol residue.

10. Blow dry the sample using the air gun.

11. Place the sample in the pre-heated oven for total dryness.
APPENDIX F

Photoresist Process

1. Prepare sample (Appendix E).

2. Turn on the vacuum pump for the spinner table and close the valve.

3. Adjust the time and speed of rotation by placing a dummy sample on the stage and pressing the foot switch. The rotation is 5000 rpm and the time is 30 seconds for this particular process.

4. Have the photoresist (PR) ready.

5. Place the sample on the stage.

6. Apply the photoresist to the sample. Normally you would want to put the PR in the middle and near the edges of the sample. The important point is that you want the photoresist to cover the entire top surface of the sample after the spinning process is over.

7. Turn on the spinner using the foot switch.

8a. If the sample surface is not fully coated with PR, go to step 1.

8b. Place the sample in the 90 degree oven for 15 minutes.

9. Take the sample out and take it to the COBILT mask aligner.

10. Place the mask on the sample, patterned side down, and expose for 15 seconds.

11. Develop the PR in the 1:1 solution of developer and deionized water for approximately 75 seconds.

12. Wash the sample with deionized water to stop the developing process.
13. Place the sample in the 110 degree oven for 30 minutes.

14a. If the fabrication process is etching, place the sample in the etch solution.

14b. If the fabrication process is lift off, place the sample in the vacuum system for deposition.

15a. Wash with the deionized water after etching is completed.

15b. Follow the procedure for deposition.

16. Wash the sample with acetone. Make sure that all the PR has been removed.

17. Rinse with methanol.

18. Rinse with deionized water.


20. Turn off all the equipment and clean up.
APPENDIX G

The Fabrication Process

RESISTORS

1. determine the required value of resistor.
2. Determine the required number of squares(Table 1).
3. Prepare the mask.
4. Prepare the substrates (Appendix E).
5. Depending on the mask, follow the procedure in Appendix E for wet-etch or lift-off techniques. If the technique is lift-off, go to step 6 for metal deposition.
6. Place the substrate in chamber two of the multichamber vacuum system. Follow Appendix A for pump down procedure; and Appendix B for DC sputtering.
7. Sputter for the required time which can be obtained from Graph 1.
8. Follow the procedure in Appendix A for venting.

CAPACITORS

10. Follow steps 1 through 3, but use Table 2 instead of Table 1.
11. Prepare the substrates.
12. Follow part 5 to fabricate the bottom electrode, minimum film thickness should be 1200 angstroms.
13. Place the sample in Chamber 2 sample holder. Cover the section that contains the bottom electrode contact point with the shield mask.
15. Follow Appendix A for pump down. Then follow Appendix C, and sputter for the required time.

16. Vent chamber two, Appendix A.

17. Follow the procedure in Appendix F, for lift-off.
REFERENCES


