RF COMMUNICATION LABORATORY

EE 409/EE 691; FALL 2004

Experiment 12

Microstrip LPF Fabrication and Measurements

Objective: To introduce the student to RF Printed Circuit Board fabrication and testing.

Equipment:
- PCB Fabrication Facility
- Network Analyzer

Prelab: Read the Printed Circuit Fabrication Procedures handout given to you.

Procedures:
I. Using the photo mask given to you, etch the Microstrip Low-Pass filter circuit on the given copper-clad microwave circuit board, following the procedures for photolithography. Follow all the steps in the fabrication procedures carefully. But before going to the Fab lab, be sure to clean the side of the board to be used with stripping solution using a Q-tip, and keep the surface clean.

Note: Photolithography procedures and precautions to be taken are also posted in the PCB fab lab (2nd Floor, Jobst Hall).

II. Cut the circuit board to the appropriate size, using the paper cutter in RF lab, and solder the coax-microstrip launchers. Before doing this, talk with the lab instructor.

Note1: The procedures for soldering are available in the RF lab.

Note2: Make sure that there is a perfect electrical contact between the body of the launcher and the circuit ground plane, as well as between the coax center conductors and the microstrips.

Note3: Use the thin tin foil pieces provided to pack the space between the connector leads and the ground plane.

III. Check the DC resistance between the microstrip and coax center conductor (should be 0Ω), and between the ground plane and the body of the launcher (should be 0Ω). The resistance between the microstrip and the ground plane (or body of launcher) should be ∞.

IV. Calibrate the Network Analyzer (full two-port calibration) in the frequency range 2-10GHz. Use 51 for the number of points as you calibrate.

V. Measure, record/print the graphs of the following:
   a) Magnitude of S21 and S11 (dB) vs. Frequency (GHz). Obtain the 3-dB bandwidth measurements as well.
b) Phase of $S_{21}$ (Degrees) vs. Frequency (GHz).

VI. Acquire all the four S-Parameter values using the software Agilent-ADS. Use the printed guidelines "Acquiring S-Parameter measurements using ADS" for your measurements. This will be useful in the graphical comparison of measured and simulated results using Agilent-ADS.

Report:
1. Compare and comment on the simulated results in steps II and V of Experiment 5.

2. Plot the simulated and measured S-parameters on the same graph using Agilent-ADS. Follow the instructions in Chapter 8 of the Agilent-ADS Tutorial.

3. Compare and comment on the simulated results in step V of Experiment 5 with respect to the measured results in step V of Experiment 7. Comment on the 3dB bandwidth and both the insertion loss and return loss within the 3dB bandwidth. State possible reasons for any differences between the simulated and measured results.
PRINTED CIRCUIT FABRICATION PROCEDURES

The following are the procedures that must be followed and precautions to be taken in the fabrication of printed circuit boards.

- **Step 1**
  Get the lab ready for fabrication and safety.
  
i) Turn the fan on.
  ii) Wear protective filter mask.
  iii) Wear gloves.
  iv) Wear the protective glasses.
  v) Wear the coat.
  iv) The lab should be maintained neat and chemical stains should be avoided on any instruments at any cost. All the used chemicals should be dumped in the plastic chemical disposing container. Do not throw them in the sink.
  v) Cover the stone top with paper towel.

- **Step 2**
  Get the copper clad circuit board and the photo mask ready for fabrication.
  
i) Inspect the mask for any pinholes or scratches.
  ii) Check to make sure you are using the right board.
  iii) Determine the required size. The size of the board should be 3.7 inch X 3.7 inch.
  iv) Mark the required area on the circuit board with a sharp object (see notes).
  v) Cut the circuit board
     a) If you are using a thin board use the Electrician’s Scissors.
     b) If you are using thick board seek other tools (see your advisor).

**NOTES:**
- The circuit board must be cut to the required size and any plastic lamination on it must be removed after cut.
- Do not handle the boards without gloves.
- Any grease or oxide layer on the board must be removed. Use alcohol and wipes or use soap and water. Do not use cotton buds for cleaning with alcohol. Use the foam brush for cleaning. Dry the board using the hair dryer.
- The photo mask must be inspected for any pinholes and scratches and they be properly closed using a black marker pen. (a pinhole is an unwanted hole in the circuit on the mask)
- Keep the circuit board and the photo mask free of dust as far as possible.

- **Step 3**
  Preparing the developer solution
  
i) Place paper towels on the main table in front of the exhaust fan.
  ii) Fill the water tray with water (about 3/4" to 1") and place it on the table.
  iii) Preparing the developer solution in the developer tray:
a) Use the plastic cup to dilute with 3 parts water to 1 part of developer concentrate. First pour 50ml of the developer solution on the developer tray. Then pour 150 ml of water.
d) Do not leave the uncovered tray for more than 1-2 hours.

Now, on the table, you should have only the water tray and the developer solution tray.

• Step 4
  Coating the board with photo resist
  DANGER: Photoresist is Harmful, Extremely Flammable!

Precautions when using the Spin coater:

1. Never open the lid when the chuck is rotating. Open the lid only when the chuck has stopped completely and the message “Remove coated part” comes on the spin coater screen.
2. The chuck in the spin coater will not rotate if either the vacuum pump is not on or if the board sits unevenly on the top of the chuck.

Coating using the spin coater:

Both the sides of the board have to be coated with the photoresist. The ground side of the board will be coated first. Then the board will be dried and the circuit side of the board will be coated next.

1. By default you will see the recipe no. 3 selected on the screen of the spin coater.
2. Turn on the oven. Open the glass door and remove the chuck from the spin coater. Place the board on the top of the chuck in such a way the ground plane comes on the top. Use the screw driver and adjust the screws on the fingers of the chuck, so that the board sits on the chuck real tight. Hold the chuck on the top of the table and be mindful of not losing the screws or washers.
   Hint: For securing the board properly on the chuck, corner the board on two diagonal fingers and then adjust the other two screws of the other fingers of the chuck.
3. Put the chuck back into the spin coater with the board. Close the glass lid.
4. Turn on the red light and turn off the lights of the room. Lock the door of the room.
5. Connect the plug of the vacuum pump to turn it on. Usually it produces a lot of sound which is normal.
6. Make sure the red light is on and the room light is off. Take out the syringe with the photoresist from the syringe box and keep it ready on the table. The syringe should never be exposed to the conventional light.
7. Read the step 8 and understand what should be done after pressing the “start” button. Press the "start" button on the spin coater. The chuck starts to rotate. If you get an error message saying the "err; check vacuum" then press the CLR button to clear the message. Now open the lid and check if the board is placed properly on the chuck. You should make sure that the board is in plane and is inside the fingers of the chuck to avoid
this message. You may have to take out the board and chuck and make sure the board is sitting inside the fingers of the chuck. Close the lid and press start again.

8. Once the chuck starts to rotate, take the syringe and put it inside the hole on the lid so that the needle points to the center of the board. The speed of the chuck is displayed on the screen. When the speed reaches 710 rpm from 250 rpm, drop the photoresist. The photoresist added should be around 15-20 drops. Make a continuous drop until you see the photoresist completely spread on the board. Make sure enough photoresist is added to cover the whole surface area of the board. It is ok to add a little excess photoresist to make sure there are no uncovered regions on the surface to be coated, but please avoid the wastage of photoresist by adding too much on the board surface.

9. Take out the syringe and wait till the chuck completely stops. Once the chuck stops to rotate and the message “remove coated part” appears on the screen, remove the power socket of the vacuum pump to turn it off. Now open the lid and take out the board.

10. Remove the power socket of the vacuum pump to turn it off.

11. Examine if the photoresist has been coated in the area where your ground will be made. If the photoresist is not applied properly over the surface of the board, clean the surface of the board with the developer solution. Use the foam brushes to clean the board with developer solution first and then with water. Blow-dry the board using the hair dryer and start the steps 2 through 11 for coating the board.

12. Once the coating is done place the board in a container in the oven and turn off the oven. (Use a Pyrex dish to keep the board in the oven).

13. Let the board be in the oven for 10 or 15 minutes (while the oven cools down the board dries).

14. Turn the board upside down and repeat steps 2 to 13 to coat the photoresist on the other side of the board.

15. When both the sides of the board are coated secure the syringe in the syringe box.

NOTE:
- Coating becomes light sensitive after coating with the spin coater.
- Dry in dark place.

* Step 4
  UV (Ultra-Violet) exposure

1. Open the UV exposure unit and open the inner plastic layer.

2. Check the photo mask and make sure it does not have any dust particles on it. If there are particles present in the mask clean it by blowing the compressed air.

3. Place the board in the center of the UV exposure unit (after the board has cooled to the room temperature).

4. Place the photo mask on top of the board.

5. Align the mask on the board properly (your circuit should be centered on the board).

6. Close the plastic layer of the exposure unit and lock it.

7. Turn on the vacuum switch and observe the mask being secured with the board.

8. Close the UV unit and switch on the UV bulbs (The switch on the right most corner-Light exposure from top). Be careful not to switch the light which exposes the UV rays from bottom.
9. Turn on the oven. Take out the hair dryer, connect it to the power supply and keep it ready for usage.
10. Once the exposure is done, open the UV unit and turn off the vacuum.

NOTE:
- Even though the light fixture is shielded, avoid looking directly at the diffracted light if any.

11. Unlock the plastic cover, and carefully remove the mask and the board.
12. Hold the board with tweezers from one corner.
13. Place the printed circuit board, image side up, in the developer solution tray.
14. Agitate by rocking the tray until your PC image begins to appear (agitate slowly till the circuit lines are well defined).
   Continue to agitate until all of the background material is dissolved down to the copper board base (the unwanted photo resist is removed).

   **You must continue the agitation as long as the board is in the developer.**

15. Remove the board from the developer, and at this point immerse it in the water tray, take it out, and immerse it again for 3 to 4 times, then, immediately take the water tray to the sink and rinse the board under running water.
16. Make sure the syringe with the photoresist is kept inside the black syringe box and then turn the room light on.
17. Turn off the red bulb.
18. Check to see if all the circuit lines are well defined.
20. Place the board in the oven for 5 minutes.

NOTES:
- Do not use very cold water, as this may affect the development process.
- Be careful not to develop so long that photo resist is removed from the circuit lines. Approximately, 10 to 20 seconds should be adequate.
- If the circuit is not clearly defined or there are breaks in the microstrip lines, the board must be cleaned and the entire procedures must be repeated.

Cleaning:
- Pour the developing solution in the plastic chemical disposing container.
- Do not throw the developer solution in the sink.
- Clean and dry the developer tray, the water tray, and all other equipment and tools you used with water in the sink. Put them back on the carrier near the sink.
- Place all equipment and materials in respective places in the lab.
- Remove the paper towels from the main table and dispose them.
- Wipe off and clean all areas where the developer solution or water has spilled.
• **Step 6**
Prepare the board for etching operation.

i) Turn the oven off (after being there for 5 minutes).
ii) Take the board out and let it cool.
iii) Check to see if all the circuit lines are well defined.

*If the board is acceptable, go ahead and etch the circuit.*

• **Step 7**
The etching operation

*DANGER: CAUSES SEVERE BURNS, HARMFUL IF SWALLOWED*

i) Place paper towels on the main table in front of the exhaust fan.
ii) Fill the water tray with tap water (about 3/4" to 1" depth) and place it on the table.
iii) Prepare the etching solution tray
   a) Use a large tray.
   b) Place enough solution to cover the board (about 1/4"). Use just enough quantity of etching solution, to cover the board.
   c) Do not leave the etchant in open tray.
iv) Hold the board by a pair of tweezers by the side of the board.
v) Place the printed circuit board, image side up, in the etching solution tray
vi) Agitate by rocking the tray, or hold it using tweezers and move the board around in the etching solution.
vii) Agitate by lifting the tray up and down making the etching solution move back and forth above the board face.
viii) Continue to agitate until all the circuit lines are well defined and background material (the unwanted copper) is removed (maximum 13 -17 minutes, undercutting may occur beyond this period).

*You must continue the agitation as long as the board is in the etching solution.*

ix) Remove the board from the etching solution and at this point immerse it in the water tray, take it out and immerse it again for 3 to 4 times, then,
x) Immediately take the water tray to the sink and rinse the board under running water.
xi) Dry the board on both sides using the hair dryer.
xii) Pour the etching solution in the plastic chemical disposing container.

• **Step 8**
Photoresist removal using stripping solution:

i) Take out and open the lid of the stripping solution.
ii) Wet a foam brush with the stripping solution. Apply the stripping solution on the top of the circuit lines and rub it with the foam brush.
iii) Do the same on the ground plane. This will remove the photoresist remaining on the top of the metal layer. If not removed this may cause circuit etching in a long run.
CAUTION:

*** Avoid contact with eyes, skin and mucous membranes. In case of contact with skin and mucous membranes, flush with water for 15 minutes. For eyes, get medical attention.
*** Handle with care as solution might stain skin or clothing. People with sensitive skin should avoid direct contact or wear rubber gloves.
*** Used solution should be discarded in the plastic chemical disposing container.

NOTES:

- Do not keep the board in the etching solution for too long; undercutting of microstrip lines will result if kept in the etching solution for too long.
- Do not heat the etching solution.
- Keep the water running for a while after you rinse the board.

Cleaning:

- Dispose the etching solution in the plastic chemical disposing container;
- Clean and dry the etching solution tray, the water tray, and all other equipment and tools you used.
- Use the thinner to clean any photoresist spills. Do not use water for cleaning photoresist. The thinner will dry after cleaning.
- Use the wet paper towel to clean developer and etching solution spills.
- Place every thing in their respective places in the lab.
- Remove the paper towels on the main table and dispose them.
- Wipe off and clean every area that the etching solution or water remain on.
- Wipe off the fume exhaust unit out of any chemical spill.

• Step 9
  Prepare to exit the lab.

i) Clean and dry well all the containers, trays, tweezers, Pyrex dishes ... etc.
ii) Place all items in their respective places in the lab.
iii) Close the lids of all chemical containers tightly.
iv) Clean the tables and floor if you have spilled any chemicals by accident.
v) Throw away the gloves and the protective air filter mask.
vi) Clean your hands well with soap and dry them.
vii) Turn off the fan. Turn off the red light. Make sure the oven is off.
viii) Fill in the logbook and turn off all equipment and lights before leaving the room.