Preface

The Microelectronics Fabrication Laboratory has now been in operation here at UT for almost fifteen years; even so, it is still a lab course which requires constant updating. This course has a number of objectives, chief among them your exposure to basic silicon device processing. You will be required to make use of information from many areas: solid state physics, chemistry, electrical engineering, and computer science. Regardless of your future intentions, we feel the material covered in lecture, and your experiences in the lab, will be very valuable. The use of integrated circuits is pervasive, and knowledge of how they are made is an important compliment to your knowledge of how they can be used.

This laboratory is a synthesis of the work of a number of people. Similar laboratories at Caltech (under the supervision of Prof. Jim McCaladlin and Prof. David Rutledge) and at the University of Illinois (originally developed by Prof. Ben Streetman) have provided both inspiration and guidance. Industrial support has been provided by Bell Laboratories, Advanced Micro Devices, Motorola, and Texas Instruments. Both TI and Monsanto have provided silicon wafers for our use. The Semiconductor Research Corporation has also provided generous support for the development of our new mask set. The technical staff (under the supervision of Mr. Harold Traxler and Marty Ringuette) has provided invaluable assistance in setting up and maintaining the lab equipment. The help of Philip Cheung, Doug Miller, Jeff Meitz, Stu Wentworth, Carl Kyono, Doug Holberg, and Garrett Neaves in designing the experiments is also gratefully acknowledged.

This lab is quite different from any other of the labs in your ECE curriculum. The processing we do is very complicated, and there will be frequent, and often very subtle, problems associated with it. You must be very patient and methodical at all times. Since we have essentially only one set of equipment, you must also be very careful. Please feel free to make suggestions that you think will help improve the lab.

Updates to this manual are made as necessary; make sure to check the World Wide Web version of the lab manual at:

http://weewave.mer.utexas.edu/DPN_files/courses/FabLab/Fab_Lab_Manual/TOC.html

Dean Neikirk
Fall, 1998
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I. Introduction: Lab Rules

filename: INTRO

A. Laboratory Notebooks and Reports

One important objective of this laboratory is learning how to keep a good lab notebook. You have undoubtedly been told in your other lab courses the importance of keeping an accurate (and comprehensive) account of your work, but I cannot possibly overstate this point. Anyone who works in research and development must keep a complete notebook: many of the companies you may someday work for will in fact require this, and will keep possession of the notebook. Many patent decisions have been based on the worker's lab notebook (or lack of it). Your notebook should be like a diary, recording what you do, and why you did it. Especially in I.C. processing, you should feel free to speculate as to the causes of process failures, of which there will be many. You will frequently learn more from these failures, and your attempts to correct them, than from a process that works perfectly the first time. *It is crucial, however, that your notebook accurately records everything you did.* A good test of your work is the following question: could someone else, versed only in the general processing arts, use your notebook to repeat your work, and obtain the same results? For that matter, could you come back six months later, read your notes, and make sense of them? If you can answer yes to these two questions, you are keeping a good notebook.

To make things easier, you **must** buy a specific lab notebook for this class. This is a duplicate notebook with carbon paper; at the end of each lab you will be required to tear out the duplicate pages and turn them in to the TA for grading. The Co-Op has these notebooks (#3-0207 in Spring 89) Your notebook should be neat, but informal. There is no need to copy information from this lab manual into your notebook, except as it reflects what you do. Put in notes on procedures, why you do things, what you observe, and speculations and conclusions. The following rules apply to your notebook:

1. Everything must be written in INK.
2. **Date** every page as you record your work.
3. All data and notes must go **DIRECTLY INTO THE NOTEBOOK**. The duplicate pages will be collected at the end of each lab period. LOOSE LEAF SHEETS OR SCRAP PAPER SHOULD NEVER BE USED, AND WILL NOT BE ACCEPTED.
4. Label all graphs and tables.
5. Write only on one side of each page. All writing should be **LEGIBLE**. Leave room for comments by the TA.
6. Each student must keep her/his own lab notebook.
7. If a particular experiment has pre-lab questions, you **must complete them before the lab period begins**. Record your answers in the lab notebook.
The TA's will deduct 5 points from your score if these rules are not strictly adhered to.

Laboratory Reports

SEE UPDATES IN REPORT SECTION

In addition to your lab notebook, after completion of certain stages in the device processing sequence (this will often take several lab periods) you must submit a Lab Report. The Lab Report should be typed; it is similar to your Senior Lab technical memos, but not as formal. The Lab Report should contain the following:

1) Experiment title, dates performed, and your lab partner's name.
2) Summary of experimental objectives.
3) Experimental processing procedure: DO NOT SIMPLY RECOPY THE CONTENTS OF THIS LAB MANUAL. A very short summary of important points is sufficient, with emphasis on any changes to the process given in the Lab Manual. You should attempt to explain the reasons any process changes were made, as well as any unusual results in the actual processing. Normally this section should not exceed about two pages, and may be shorter in later lab reports.
4) Data: present a summary of the measurements made during the process (originally recorded in your lab notebook) in a concise, tabular form. Make sure you do not give numbers to any more than the proper number of significant digits. Reference the page numbers in your notebook from which you obtained the raw data. Include sample calculations where necessary. Make clear the estimated accuracy of your measurements.
5) Answers to any specific questions and problems given in the lab manual. Specify any graphs or tables from the lab manual or text book used. Write out any equations used in calculations (but not algebraic details).
6) Brief comments on experimental results. Point out any unusual problems or experimental observations, and explain them if you can.

Further information will be discussed in class. SEE LAB REPORT GUIDELINES following the Processing Description, p. Reports - 1.
B. Grading

A significant portion of your course grade is your lab grade. Each lab is worth ten points; each Lab Report is worth another fifty points. Grades will be based on the following:

1) **Be present at each lab ON TIME.** This is VERY important. Tardiness will be penalized. Lab work, even more than lectures or homework, cannot be made up in a last-minute rush. Results in the fabrication lab come slowly, and you will need every minute available to you. Arrangements may be made to make up missed lab periods if you have an EXCELLENT excuse.

2) **Be prepared before you come to lab.** There will be assigned readings from the lab manual for each experiment. You MUST COMPLETE these BEFORE coming to lab, since they explain the operating procedures for the equipment you will be using. We may occasionally give lab quizzes over this material, and it will be fair game for the course exams.

3) Keep a complete lab notebook, and answer any pre-lab questions there may be in the experimental description.

4) Lab Reports are due one lab period after you complete the experiment. Unless you have an excellent excuse, late reports will be derated by ten points per week they are late. See the Lab Schedule for due dates.

The lab TA's will take any equipment problems into account when grading your lab work.

ONE FINAL WARNING: I take this lab very seriously, and will STRICTLY enforce all the rules stated in this manual. Whatever you do, don't tell me you didn't know simply because you failed to read this manual carefully. Woe will indeed be unto you in those circumstances.

**Policy on CHEATING:**

It is expected that you will discuss your experimental procedures and results with each other; you are, however, responsible for doing your own written work. All lab notes and Lab Reports should be your own ORIGINAL WORK. If you transpose data collected by your lab partner you should acknowledge this fact in writing, as if this was a reference.

ANY EVIDENCE OF PLAGIARISM OR CHEATING WILL BE TREATED AS GROUNDS FOR FAILURE OF THE COURSE.
C. Safety

We have done everything we can to make this laboratory as safe as possible; we cannot, however, completely protect you without your cooperation. There are very hot furnaces, powerful acids, and strong solvents which are all used, so you must be careful. If you do not show sufficient regard for safety, you will be told to leave the lab, and your grade will suffer accordingly. This section of the lab manual is intended to give some general guidelines, but the most important item is your COMMON SENSE.

THE UNIVERSITY OF TEXAS AT AUSTIN'S LAB SAFETY MANUAL

YOU SHOULD ALSO REFER TO THE MANUAL FOUND ON LINE AT:
http://www.dcc.utexas.edu/safety/labman/

OTHER UPDATES TO THIS SECTION CAN BE FOUND ON-LINE AT:
http://weewave.mer.utexas.edu/DPN_files/courses/FabLab/Fab_Lab_Manual/SAFETY.html

--Wear glasses whenever you are in the laboratory. If you do not ordinarily wear glasses, get a pair of safety glasses from the apparel cabinet when you put on your lab coat.

--Never wear shorts or open shoes to this lab. You must always wear long pants and regular shoes when you work in this lab to help insure your safety.

--Keep all the chemicals, whether in beakers or bottles, under the hoods at all times. Before beginning any work, make sure the water is running in the sink and leave it running at all times. Whenever working under the hoods you should wear the green acid/solvent resistant gloves over your normal gloves. When you finish, rinse the gloves in running water, then remove them, and finally rinse your normal gloves. If you think any liquid has penetrated the gloves, remove them and thoroughly wash your hands. The large sink in the lithography room is more convenient for rinsing your arms than the fume hood sink.

--Never mix an organic solvent with an acid: the combination may explode. Always rinse chips with high purity water between etching steps and solvent cleaning steps. Acids should be diluted with water in a large beaker, and then poured down the drain very slowly, with the sink water running. Solvents such as ethanol may be poured down the drain with water dilution. Acetone should NOT be poured into the city drains.
HYDROFLUORIC ACID

We use a 10% hydrofluoric (HF) acid mixture for etching SiO$_2$. HF is EXTREMELY DANGEROUS, and we use it ONLY IN THE HF ETCHING HOOD. AT NO TIME IS ANY OTHER PROCESSING TO BE DONE IN THIS HOOD. One major problem with HF is the fact that it does not hurt immediately after exposure. When it does begin to hurt a few hours after exposure, it is too late. It will slowly eat through tissue over the course of several days, until it reaches bone, where it is neutralized by calcium. It is excruciatingly painful.

Although an HF burn is very serious, it is also very easy to prevent. Only when the acid is left in contact with the skin for an extended period is it dangerous. Our procedure is very simple: always wear the green gloves when working at the HF etch station, and rinse them with water frequently. When you finish, rinse thoroughly, and finally rinse your hands and arms. The etch station itself is designed to minimize the chance of exposure, but always be VERY CAREFUL. I have never seen a serious HF accident, but this is only because all the labs I have worked in treat it with healthy paranoia. Please do not break my record.

If an accident does occur, there is both a safety shower and eyewash next to the main door. For any chemical splash onto a person’s face, they should immediately go to the eyewash and activate it. You should put your face into the water stream and rinse for at least several minutes. For whole body splashes, pull down on the safety shower handle, and leave the water on. A non-injured person should use the phone next to the spill kit to call for emergency help if necessary:

DIAL 9911 FOR EMERGENCY HELP.

TELL THE OPERATOR YOU ARE LOCATED AT THE UNIVERSITY OF TEXAS IN ENGINEERING SCIENCES BUILDING ROOM 214

NOTIFY ME AT ONCE IN CASE OF ANY ACCIDENT.

Please see the Materials Safety Data Sheets (MSDS) in Section IV (p. 185) of this Lab Manual for more information.