Texas State Technical College Waco
Course Syllabus

Course Rubric & Number: NANO 2407 (2-7-4)

CIP Code: 15.0304

Course Title: Nano Measurements

Course Description: This course examines a variety of measurements and techniques essential for controlling micro and nano fabrication processes for repeatability and reproducibility. Monitoring techniques such as residual gas analysis, optical emission spectroscopy and end point detection are discussed. Measurement tools such as Scanning Electron Microscopy (SEM), x-ray spectroscopy, Atomic Probe Microscopy (APM), Transmission Electron Microscopy (TEM), Advanced Optical Microscopy (AOM), laser microscopy, Fourier Transform Infrared Spectroscopy (FTIR), optical thin film measurements, ellipsometry, profilometry, and resistively/conductivity measurements are tied to process control. These include breakdown measurements, junction testing, and capacitance-voltage and current voltage measurements. In addition, the measurements of some simple chip structures and Micro-Electrical Mechanical Systems (MEMS) devices are obtained and discussed.

Prerequisites: LOTT 1372, SMFT 2450

Co-Requisites: NANO 2405

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Building & Office Room Number: Electrical/Electronic Offices, Laser Offices

Department Chair: Tommy Harper *Date:* _____

Approved by CIP Committee: *Date:* _____

WECM Learning Outcomes:

1. Identify measurements systems (tools) used for nano technology.
2. Operate and maintain TEM and SEM Microscopes.
3. Operate and maintain Advanced Optical Microscopes.
4. Operate and maintain Scanning Probe Microscopes and Atomic Force Microscopes (AFM and others).
5. Operate and maintain semiconductor manufacturing equipment.
6. Operate and maintain thin-film measurement equipment (Profilometers and Ellipsometers) applied to the nano scale.
7. Operate and maintain Spectrophotometers.
8. Operate and maintain laser interferometers
9. Operate and maintain X-ray (Fluorescent and diffraction) equipment.
10. Record data in a *real time lab notebook* for analysis.
11. Use reference handbooks.
12. Identify principles of operation for various nano technology instruments.
13. Describe the principles of operation for nano positioning devices and their appropriate uses.
14. Associate appropriate processes and materials to produce a specific outcome.
15. Identify and use the appropriate technique and instruments to measure nanotechnology properties.
16. Use the appropriate instruments and techniques to measure nanotechnology morphology.
17. Repair equipment used in support of nanotechnology.
18. Explain the interaction between various measurement systems used for nano technology architectures.
19. Use computer software (word processing, spreadsheets, databases, presentation, email, etc.) to disseminate data.
20. Incorporate appropriate measurement techniques and handling procedures for SEM, TEM, AFM, Step Profilometer, and Ellipsometers.
21. Develop operating procedures for SEM, TEM, AFM, Step Profilometer, and Ellipsometers.

Resources:

Textbook

- *Encyclopedia of Materials Characterization Tools/Equipment*, Brundle, Evans Jr. Watson, Manning Publishing, 1992.

Tools & Materials Students Purchase

Quantity	Item Description
1	64MB Jump Drive
1	Scientific Calculator (TI-36X or equivalent)
1	Spiral Notebook Paper (Class Room use only)
1	Spiral Notebook Clean Room
1	15Cm Steel Scale Metric
2	Pen Clean Room
2	Pens Blue
1	Safety Glasses (Industrial grade, clear lenses side shields)
3	Latex/Nitral Gloves Box = 200

TSTC Grading Policy:

(Grades for all Major courses must be C or better)

Grade	Percent	Description	Grade Points
A	90-100	Excellent/Superior Performance Level	4
B	80-89	Above Required Performance Level	3
C	70-79	Minimum Required Performance Level	2
D	60-69	Below Required Performance Level	1
F	Below 60	Failure to meet Performance Requirements	0
IP	--	In Progress	
W	--	Withdrawal	0
CR	--	Credit	0
AUD	--	Audit of Course	0
See College Catalog for complete descriptions.			

Department's Participation Policy:

A student absent for more than 15% of the lecture periods or 15% of the lab periods, regardless of grades earned on assignments, will have to repeat the course.

Course Schedule:

Learning Activities	Student Objectives	References
1	1. Identify measurement systems and their uses in nanotechnology.	Lab Report Requirements Explained Read: Lab Equipment Handout
Scanning Electron Microscope		
2	2. Identify the sub-systems of a scanning electron microscope (SEM). 3. Describe the operation and function of each SEM sub-system. 4. Prepare a sample for imaging on a SEM. 5. Load a sample in the SEM. 6. Observe the capture of images on an SEM and contrast the macro to micro characteristics of the images.	*Topcon, DS-130 SEM user Manual* Textbook: Unit 3, pgs. 6-12 Unit 4, pgs. 13-22 Unit 5, pgs. 23-69 Unit 2, pgs. 4-5
3	7. Describe the basic imaging parameters for successful SEM imaging including focus/working distance and stigmation. 8. Contrast how differences in working distance affects SEM imaging resolution. 9. Using an SEM, obtain an image at long working distance. 10. Using an SEM, obtain an image at short working distance.	*Topcon, DS-130 SEM User Manual* Textbook: Unit 6, pgs. 73-75
4 & 5	11. Describe the effects of varying the imaging parameters of beam current and accelerating voltage on SEM imaging. 12. Using an SEM, obtain an image at the following settings:	

	a. High-voltage and high-current b. High-voltage and low-current c. Medium-voltage and high-current d. Low-voltage and high-current. e. Low-voltage and low-current. 13. Contrast how differences in voltage and beam current affect SEM imaging resolution.	
Atomic Force Microscope		
6	14. Identify the sub-systems of an Atomic Force Microscope (AFM). 15. Describe the operation and function of each AFM sub-system. 16. Prepare and load a sample for imaging on the AFM. 17. With the AFM in contact mode, obtain AFM data and an AFM image.	*Topcon, User Manual* Chapter 1, pgs. 8-12 Chapter 2, pgs. 17-22 User Guide Chapter 1.13 to 1.19 & 2.16
7	18. On the AFM, align the laser to the cantilever and align the laser spot to the photo-detector. 19. Describe how the alignment of the laser on an AFM affects instrument performance. 20. On the AFM, acquire a force-curve. 21. Compare the force-curves at the various laser spots.	*Topcon, User Manual* Chapter 2.16 & 2.5
8	22. Using the force-curve, contact, retraction points and tip for a sample, select a set point on an AFM that falls safely within the contact regime. 23. Using an AFM, perform a line scan and adjust feedback controls for constant deflection mode. 24. Using an AFM, set the instrument into imaging mode and acquire images at varying sizes, scan speeds. 25. Using an AFM, perform a line scan and adjust feedback controls for constant height mode. 26. Compare the AFM images captured at deflection mode and height mode.	*Topcon, User Manual* Chapter 3.13 & 3.19
9	27. On an AFM, load the tapping mode cantilever, adjust the laser and set the AFM to trapping mode. 28. On an AFM, acquire: a. frequency curve for the cantilever. b. acquire force curve. c. acquire a line scan. d. acquire an image. 29. Discuss the imaging resolution capabilities on an AFM.	*Topcon, User Manual* Chapter 4.10
10	30. Identify all of the modes available on the AFM.	*Topcon, User Manual* Chapter 1.3

	31. Prepare the AFM to acquire an image in each of the modes.	
Scanning Tunneling Microscope		
11	32. Compare the functions and controls on a scanning tunneling microscope (STM) to the Atomic Force Microscope (AFM). 33. With the STM in tracking (constant current mode), prepare the STM to acquire images 34. Using a STM, acquire images at different sizes and speeds. 35. With the STM in constant height mode (varying current), prepare the STM to acquire images. 36. Using the STM, acquire images at different sizes. 37. Compare the images taken with the STM in tracking mode with the images taken in constant height mode. 38. Compare the images taken with an AFM with the images taken with a STM.	*Topcon, User Manual* Chapter 2.3 – 2.5
Nanomanipulator		
12	39. Identify the sub-systems of a nanomanipulator. 40. Prepare a Nanomanipulator to be loaded into a microscope. 41. Load a Nanomanipulator into a microscope. 42. Using a Nanomanipulator, manipulate objects.	*Zyvex, S-100 User Manual* Chapter 1 Chapter 2 Chapter 3 Chapter 4, pgs. 7-18 Chapter 6, pgs. 34-35
13	43. Perform a two-probe and a four-probe electrical measurement on a nanostructure. 44. Compare the two-probe and the four-probe I-V curves.	*Zyvex, S-100 User Manual* Chapter 8, pgs. 43-51 Chapter 9, as per application
Transmission Electron Microscope		
14	45. Identify the components and sub-systems of the Transmission Electron Microscope (TEM). 46. Discuss the imaging modes of the TEM. 47. Prepare the TEM to acquire bright field images at low magnification and at high magnification. 48. Acquire images using a TEM.	*Zeiss, EM 109 User Manual* Chapter 2, Operation Chapter 4, Modes
15	49. Using a TEM, load samples into the sample rod, load rod into TEM and acquire a TEM image. 50. Using a TEM, acquire images at various magnifications.	*Zeiss, EM 109 User Manual* Chapter 5, Tests Methods
Film Measurement Tools		
16	51. Operate a thin film measurement tool such as ellipsometers, profilometers and film meters	*Dektak II Operating Instructions*

	to measure a SiO_2 layer silicon substitute.	Chapter 4, pgs. 47-63 *Gaertner, L116* *Operating instructions* *Film Metric*, F20 *Operating instructions*
FTIR Operations		
17	52. Startup and program FTIR for measurement of nanotube sample. 53. Prepare nanotube sample for FTIR. 54. Determine what nanotube is made from using data from FTIR.	*NICOLET Tek Manual* Chapter 1, pgs 1-20
Laser Interferometer Measurements		
18	55. Operate a laser interferometer to measure wave uniformity across materials sample.	*Laser Interferometer Operation instructions* Chapter 4, misc.

Course Assessment:

- Written Assessments (lecture)
    1. Written tests will be distributed at the beginning of each lecture period. The tests will comprise questions from the assigned reading and previous lecture information.
    2. A comprehensive final test will be given at the end of the semester.
    3. The lecture grade for the course will be an average of all the lecture tests and the final.

- Performance Assessments (laboratory)
    1. Lab Reports will be submitted weekly at the beginning of each lab.
    2. A performance-based lab final will be given at the end of the semester.

Grading Scheme:

- Students must average a 70% for all written assessments and a 70% for all performance assessments to successfully pass the course. A final grade of "C" or above is required for course completion. The course must be retaken if a grade lower than a "C" has been earned.

Activity		*Total Points*
29 Lecture Tests	100 points per test	2900
Comprehensive Final	100 points (must pass with at least a 70)	100
Total possible points (must average 70%)		**3000**
13 Lab Reports	100 points per report	1300
Lab Final	100 points (must pass with at least a 70)	100
Total possible points (must average 70%)		**1400**
Total Possible Points for Course		***4400***

A = 3960 min B = 3520 min C = 3080 min D = 2640 min

Course Policies:

- *Safety Procedures:*
  Required attire for labs: Shirt (no tank tops), full-length pants, rubber-sole shoes (no sandals or flops), and **safety glasses**. Remove all jewelry before entering labs.
  Lab behaviors:
  No eating, smoking or drinking in labs.
  No horseplay at any time in this building.
  You are responsible for your safety as well as the others in the lab. Use safety glasses.
  Make sure you stand on a clean rubber mats when using any electronic device.
  Pick up/remove anything unsafe.
  Never probe voltages over 80V.

  I am a safety nut. Think first, move second. Don't break the safety rules.

- *Lab Procedures:*
  Bring your tool box and safety glasses to each lab. If you don't have them, you will not be permitted in the lab – you will go home and get them or be counted absent.

  Leave your lab clean and orderly. A lab attitude grade will be given at the end of each lab. This grade will be based on how you work, what type of work you do, how safely you work, and how clean and orderly you leave the lab.

  If you get equipment out, put it back in the correct place. If the equipment uses batteries, make sure to turn off the device.

  A real-time notebook (RTN) must be kept to record information taken during lab periods. The RTN will be a cleanroom spiral notebook and must contain all the information needed to write a formal lab report.

  Turn off all gasses at the end of the lab!

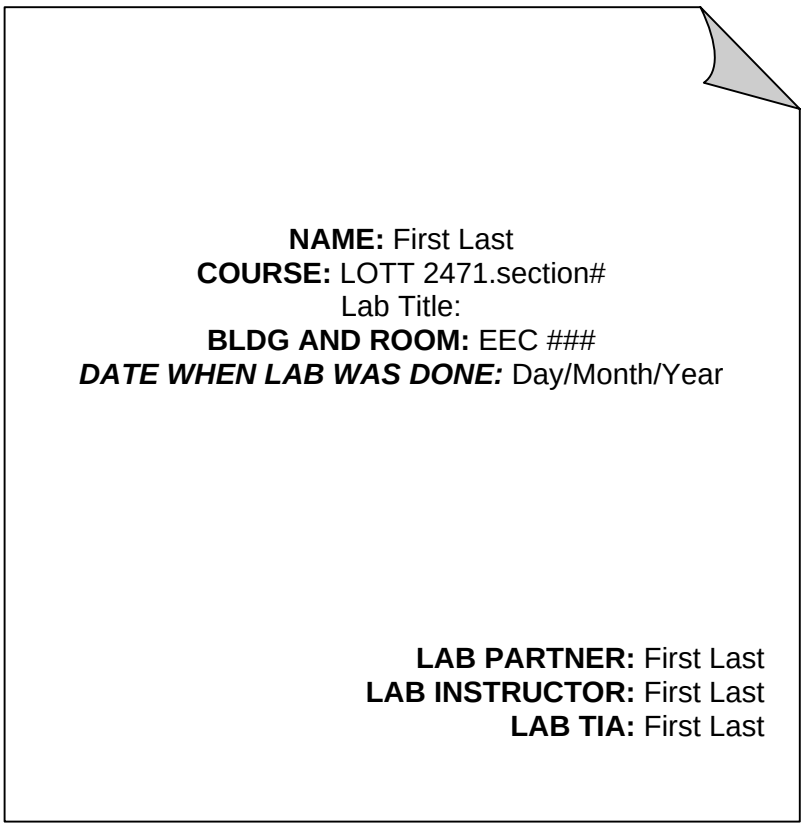
- *Late Work:* No late work will be accepted. All work, including labs, must be completed on time. If you have an excused absence (see Excused Absences below), then the work missed during the absence must be completed and submitted within one week of the return from the excused absence.

- *Excused Absences:* For Lectures – only the Lecture Instructor can give an excused absence for lectures. Only the Lab Instructor can give an excused absence for labs. To qualify for an excused absence, you must call (254)867-4857 leave a message as to why you will miss class, examples: Jury duty, military recall/duty, sick but not hung over, court summons etc.

Lab Report Format: Content

All lab reports must be a minimum of twelve (12) pages in length unless noted.
Reports must be typed (Arial, 12 point font).
Do not use first person format in formal lab reports (avoid I, me, we, us, my).
All lab reports are use one week after lab has been completed and within the first 10 minutes of the start of the lab.
All lab must be completed and all lab reports submitted to pass the course.
Reports must contain the items listed below.

Page 1: **Cover Page** (5 points)



Page 2: **Abstract** (5 points)

In this section, you provide a condensed version of your report. What you did, how you did it, what you found about what you did and how you did it. Three paragraphs maximum.

Page 3: **Objective** (5 points)

Provide the specific goals of the lab as explained by the instructor.

Page 4: **Experimental Setup** (5 points)

Provide a neat drawing (no free-hand images) or the lab setup including important dimensions such as distances between components. Provide an explanation of how the lab was setup.

Page 5: **Materials List** (5 points)

In a table format, provide a listing of all the materials used in this lab. Headers for your table include quantity, description of item, manufacturer, manufacturer's model number, and manufacturer's serial number. Use "NA" for unknown information.

Page 6: **Procedure** (5 points)

Provide a complete step-by-step description of what you did to perform the lab. List every step separately. This section could be several pages long (numbered 6, 6A, 6B, etc).

Page 7: **Data** (5 points)

In a table format, list the data you gathered during the lab. This will be used to prove what you did in the lab. Do not provide data calculations in this section. Columns in the table might include laser wavelength, SEM magnification.

Page 8: **Formulas** (5 points)

Provide all the formulas you used to gather data for this lab.

Page 9: **Calculations** (10 points)

Using all the formulas listed on page 8, provide the math to prove your data. Every calculation you did should be listed.

Page 10: **Graphs** (5 points)

Using graph paper, provide graphs that prove your data. Graphs can be hand drawn.

Page 11: **Analysis** (40 points)

In this section, you provide an analysis of your data. Analyze how you got the data. Analyze the results of what you did. Provide possible uses.

Page 12: **Conclusion** (5 points)

Provide a summary of the lab. Did it work? What could be done to make the lab better? Complaints? Any issues not covered in the previous pages?

Formal Lab Report: Style

	Presentation	**Sentences & Grammar**	**Logical Flow**
Supervisor (A) Industry Standard	Report bound with plastic cover. Report contains a title page & Table of Contents page. Report contains illustrations & Charts. Margins & footers are consistent. Footers contain title of report & page numbers. Consistent use of fonts.	Proper verb tenses. Smooth transitions between paragraphs. Active writing.	Sections titled. Charts & illustrations are labeled. Graphics, charts & illustrations are legible & understandable.
Senior Technician (B) Industry Standard	Report bound. Footers contain title of report & page numbers. Uses section titles & uses boldface for section titles. Consistent use of fonts.	No comma faults. Proper paragraphing.	Separate sections of paragraphs used for complex ideas.
Entry-level Technician (C) Industry Standard	Report pages are stabled. Paper free of smudges, stains & rips. Consistent use of fonts. Pages are numbered.	Complete sentences. No misspelled words. Proper capitalization.	Use of one paragraph per idea.