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The Flexus 2320

Equipment Standard Operating Procedure

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1. **Purpose**
   1.1. The Flexus Thin Film Stress Measuring Apparatus (TFSMA) measures the changes in the radius of curvature of a substrate create by deposition of a stressed thin film on its surface.
   1.2. The Flexus can also measure elastic constant and thermal expansion coefficient of a thin film, if the thickness of the film and the substrate are known.

2. **Reference Documents**
   2.1. Thin Films stress measurement system operation manual, model 2320

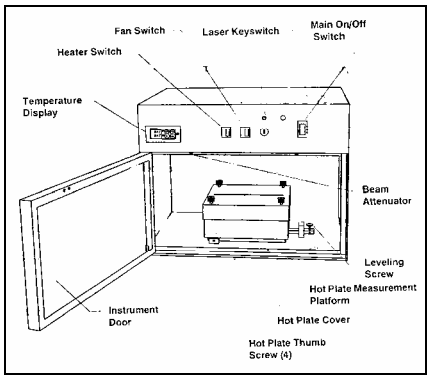
3. **Equipment**
   3.1. Positioning rings
   3.2. Hot plate cover
   3.3. Quartz plate
   3.4. 8-inch wafer stress pair

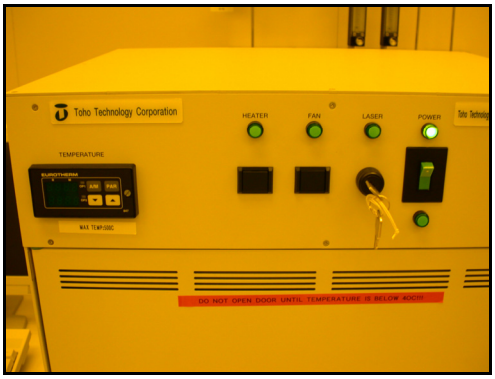
4. **Materials**
   4.1. Nitrogen

5. **Protective Equipment**
   5.1. Eye Protection: safety glasses must be worn at all times.
   5.2. Hand Protection: vinyl or latex gloves.

6. **Engineering and/or Administrative Controls**
   6.1. The Flexus is located in the special projects bay.
   6.2. The tool owner is Kimberly Appel, kappel@eecs.umich.edu
   6.3. The tool check out people is Kimberly Appel and Ning Gularia.

7. **Procedure**
   7.1. You must be an authorized user to operate this tool.





   7.2. You must use the scheduler; failure to do so may revoke your user privileges.
   7.3. Do NOT touch the wafer-leveling knob. This tool is calibrated and an adjustment to wafer leveling should not be needed. If you feel it does, contact the tool owner.
   7.4. Do NOT go into the materials database and make any changes.
      7.4.1. If you have a new material to add to this database, contact the tool owner.
   7.5. Material Restrictions
      7.5.1. This tool can only measure whole wafers: 3 inch, 4 inch, 6 inch and 8 inch.
      7.5.2. Substrate surface must be able to reflect the laser beam.
      7.5.3. Substrate material must be included in the Flexus materials database.
      7.5.4. Do not outgas or melt any materials onto quartz plate.
   7.6. Laser Safety
      7.6.1. The laser beams (2) impinging on the substrate from a class III-a and a Class III-b.
         7.6.1.1.4-mW GaAlAs laser with wavelength 670nm
         7.6.1.2.4-mW GaAlAs laser with wavelength 780nm.
      7.6.2. Do NOT expose the laser beam directly to your eye as it may cause damage.
      7.6.3. Do NOT defeat the interlocks. If caught doing so, your tool privileges will be revoked and disciplinary action could be taken.
   7.7. Types of Stress
      7.7.1. Intrinsic: stress of a film at the deposition temperature.
      7.7.2. Thermal: film stress can change between deposition temperature and measurement temperature. It is caused by the difference of thermal expansion coefficients between the film and the substrate.

7.8. Principle of Operation

7.8.1. The Flexus takes measurements with a laser across one diameter of the wafer.

7.8.1.1. You must measure the wafer before deposition and then after deposition.

7.8.2. The stress in the thin film is calculated from the substrate radius of curvature using the following equation:

$$\sigma = Eh^2/(1-\gamma)6Rt$$

Where as

$E/(1-\gamma)$	The biaxial elastic modulus of the substrate (1.805E11Pa for 100 silicon wafer)
h	Substrate thickness (m)
t	Film thickness (m)
R	Substrate radius of curvature (m)
σ	The average film stress (Pa)

7.8.3. Since most substrates are not flat prior to film deposition another equation is incorporated.

$$R= 1/(1R_2-1/R_1) = (R_1R_2) / (R_1-R_2)$$

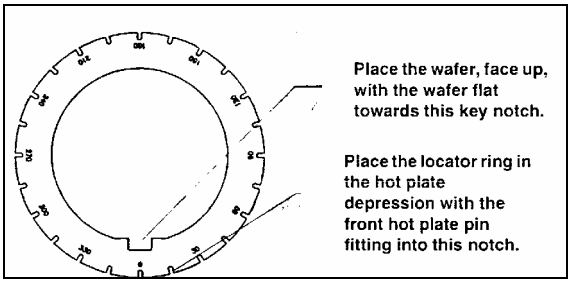
Where as

R_1	Initial radius of curvature
R_2	Film Deposition radius of curvature

7.8.4. It is <u>always necessary</u> to measure the radius before and after film deposition.

7.9. Wafer Locator Rings

7.9.1. A wafer locator ring is used to position the wafer accurately in the measurement chamber.



7.9.2. All positioning rings are located in one of the drawers.

7.9.3. The locator rings come in various sizes: 3-in, 4-in US and 4-in Japan, 6-in US and 6-in Japan.

7.9.3.1. 8 in wafers do not need the locator ring; they are placed directly onto the hot plate depression.

7.9.4. The wafer is placed face up in the depression with the notch or major flat toward the key notch of the locator ring.

7.9.5. The rings are marked in 30° intervals and have a notch at every 15°interval.

7.9.5.1. Rotate the locator with the wafer counterclockwise.

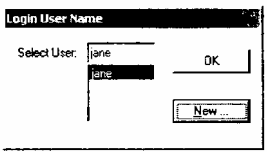
7.9.6. The key notch on the rings face towards the instrument door.

7.10. Overview of Operation

Steps	Tool/Program
1. Measure substrate thickness	Height gauge
2. Determine process program	Process program
3. Pre-Deposition measurement	First measurement (no film) * Decide if plan to use 3D Plotting
4. Deposition	Furnace/Thin Film/PECVD
5. Post Deposition measurement	Choose any program: Single/time/temp * Can only use 3D Plotting if was used for no film measurement
6. Data analysis	View graphs

7.10.1. The substrates initial radius is measured by placing the substrate on the measuring platform and making a first measurement (no films).
7.10.2. The measured radius is stored in the computer by a unique id, and a file extension of .dat
7.10.3. A second measurement is made after film deposition and then the stress is calculated. The calculated stress is displayed as well as stored.
7.10.4. Measurements are taken in a nitrogen-controlled atmosphere.
7.10.5. Measurements options include stress as a function of time or stress as a function of temperature (max 500C).
7.10.6. Data analysis includes calculating biaxial modules of elasticity and linear expansion coefficient, stress uniformity, file subtraction, trend plotting for statistical process control, 3-d mapping, etc.

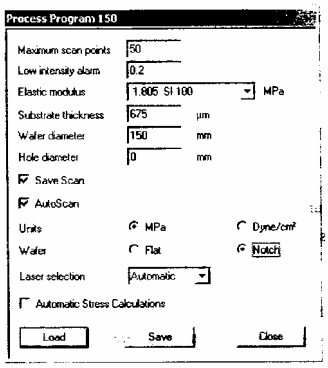
7.11. Start Up
7.11.1. Log usage time on scheduler.
7.11.2. The nitrogen should always be left on.
7.11.3. The machine power should always be on.
7.11.4. Turn key, to turn on laser.
7.11.5. Turn fan on, push button.
7.11.6. The computer should be on, but turn on monitor.
7.11.7. Log into computer. Note the system is password protected.
7.11.8. Click on icon, winflx.
7.11.9. Choose your user login.



7.11.9.1. User name will be given at check out.
7.11.9.2. User name is your folder for data files.

7.12. Performing a Measurement

7.12.1. Set up the process program



7.12.1.1. The process program specifies parameters such as scan points, directory to which data files are saved, elastic modules, substrate thickness and wafer diameter.

7.12.1.1.1. Scan points: 50 points are sufficient for a correct measurement. Maximum number of scan points is 1250, but only 50 will be saved with each scan.

7.12.1.1.2. Low intensity alarm: Do not change this number! An alarm will show if a measurement is taken without a wafer in the chamber, or with a poorly reflective substrate.

7.12.1.1.3. Elastic modules: the biaxial elastic modulus of the substrate to be used in the calculation.

7.12.1.1.3.1. The material database has a multitude of substrates stored for the use in the elastic modules.

7.12.1.1.3.2. DO **NOT** go into the materials database! If the starting substrate material you are working with is not listed, see the tool owner.

7.12.1.1.3.3. DO **NOT** make any changes to the information in the materials database section! Only the tool owner may add new substrate materials. If you have a new material you will be required to give all pertinent information to the tool owner.

7.12.1.1.4. Substrate thickness: thickness of the substrate in microns. If you are unsure of the thickness, measure on the height gauge.

7.12.1.1.5. Wafer diameter: diameter of the wafer in millimeters.

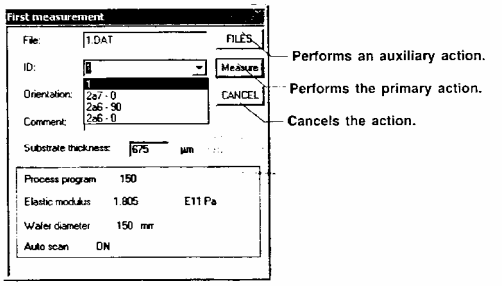
Diameter in Inches	Diameter in millimeters
3	75
4	100
6	150
8	200

7.12.1.1.6. Save scan: ensure yes is checked.

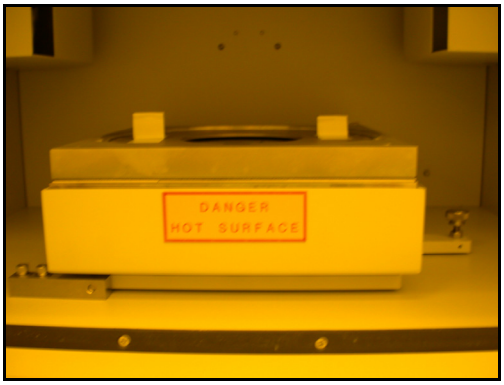
7.12.1.1.7. Auto scan: ensure on is checked to scan from 10% to 90% of the substrate diameter.

7.12.1.1.8. Hole diameter: skip this one. It is used to measure CDs.
7.12.1.1.9. Units: select MPa or dynes/cm^2.
7.12.1.1.10. Laser selection: you can select the laser to be used. Always choose automatic. The tool will then select the proper laser.
7.12.1.2. In edit menu, choose process program.
7.12.1.2.1. A dialog box will be displayed.
7.12.1.2.2. Use the arrow keys to scroll through the list.
7.12.1.2.3. Select the desired process program.
7.12.1.3. In the process program set the desired parameters.
7.12.1.4. Choose save to save changes to process program, cancel to not save changes, or load to load another process program with out making changes to the current values.

7.12.2. First measurement



7.12.2.1. Use this program to measure the stress of the wafer before deposition.
7.12.2.2. Install the correct wafer locator ring in the system. See section on wafer locator ring for correct usage.
7.12.2.3. Place the blank wafer face up in the locator ring. Major flat should face the door.



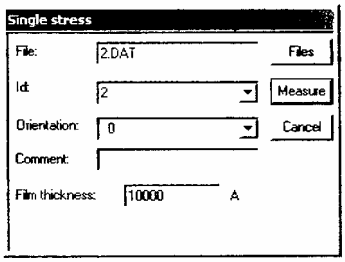
7.12.2.4. Go to the measure menu and choose first (no film).
7.12.2.5. The first measurement dialog box will be displayed.
7.12.2.5.1. All fields except elastic modulus, wafer diameter, and auto scan can be edited.
7.12.2.6. Enter the file field. This will be your user name. You will not need to enter an extension.
7.12.2.7. Enter the ID, this is 16 characters maximum. Remember this id for the after deposition measurement.

7.12.2.8. Enter orientation of the wafer and how many degrees of rotation. This is important if you plan to use 3d plotting. See section on 3d plotting.
7.12.2.9. Comment field can hold up to 12 characters.
7.12.2.10. Enter thickness of substrate in microns. If you are unsure of the thickness, measure on the height gauge.
7.12.2.11. Depress the measure button. Be sure the door to the tool is closed.

7.12.3. View graph

7.12.3.1. After the measurement has been taken two (2) graphs will appear. The substrate deflection graph and the light intensity graph.
7.12.3.2. A negative radius on the deflection graph, indicate a convex surface.
7.12.3.3. A positive radius on the deflection graph indicates a concave surface.
7.12.3.4. To save the graph, choose save as from the file menu.
7.12.3.5. Enter the name of the graph and choose ok.
7.12.3.5.1. If you measure the sample again using the same id, a second record is created and saved without overwriting the first record.
7.12.3.5.2. The most recent record is used as the valid record when measuring stress after deposition.

7.12.4. Single stress measurement



7.12.4.1. Use this mode to measure stress on wafers after deposition.
7.12.4.2. Install the correct wafer locator ring in the system. See section on wafer locator ring for correct usage.
7.12.4.3. Place the deposited wafer face up in the locator ring. Major flat should face the door.
7.12.4.4. Go to the measure menu and choose single.
7.12.4.4.1. All fields in the single stress dialog box can be edited.
7.12.4.5. Enter file name, this is your user name.
7.12.4.6. Enter same id as first measurement no film for that specific wafer.
7.12.4.7. Enter the orientation of wafer and how many degrees of rotation. This number should be the same as the first measurement. If you did not use numerous orientations for the first measurement you will not be able to use 3d mapping for this measurement.
7.12.4.8. You may enter a comment, but it is not necessary.
7.12.4.9. In the film thickness field, enter thickness of film in angstroms.
7.12.4.9.1. Use the Auto El Eliposometer, the NanoSpec or the Dektak to obtain the correct film thickness.

7.12.4.9.2. If the film was etched rather than deposited, enter the film thickness as a negative number.

7.12.4.10. Choose measure.

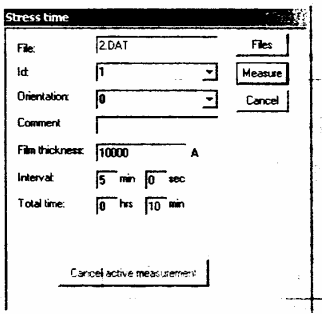
7.12.4.11. After the measurement has been taken two (2) graphs will appear, the substrate deflection and the light intensity graphs.

7.12.4.11.1. The measured radius and stress values are displayed on the graphs.

7.12.4.11.2. A negative value indicates a compressive stress. A negative radius indicates a convex surface.

7.12.4.11.3. A positive value indicates a tensile stress. A positive radius indicates a concave surface.

7.12.5. Stress-Time measurement



7.12.5.1. Will measure stress, over a specified period of time, on a wafer after deposition.

7.12.5.2. Stress-time measurement reveals kinetics such as water absorption in oxides, densification, phase transformation, and stress relaxation.

7.12.5.3. The total number of records in a data file is limited to 1000.

7.12.5.4. Install the correct wafer locator ring in the system. See section on wafer locator ring for correct usage.

7.12.5.5. Place the deposited wafer face up in the locator ring. Major flat should face the door.

7.12.5.6. Go to the measure menu and choose time.

7.12.5.7. The stress time dialog box will appear.

7.12.5.7.1. Enter the file name; this is your user name.

7.12.5.8. Enter same id as first measurement no film for that specific wafer.

7.12.5.9. Enter the orientation of wafer and how many degrees of rotation. This number should be the same as the first measurement. If you did not use numerous orientations for the first measurement you will not be able to use 3d mapping for this measurement.

7.12.5.10. You may enter a comment, but it is not necessary.

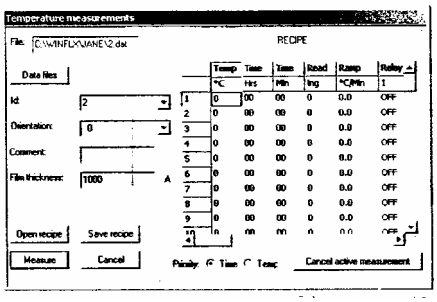
7.12.5.11. In the film thickness field, enter thickness of film in angstroms.

7.12.5.11.1. Use the Auto El Eliposometer, the NanoSpec or the Dektak to obtain the correct film thickness.

7.12.5.11.2. If the film was etched rather than deposited, enter the film thickness as a negative number.

7.12.5.12. In the interval field, enter the time interval the wafer will be measured in minutes and seconds.
7.12.5.13. In the total time field, enter the total time in hours and minutes. This is the time the wafer will stay in the chamber and be measured.
7.12.5.14. Choose measure.
7.12.5.15. After the measurements have been completed a stress-time graph will appear.

7.12.6. Stress-Temperature measurement



7.12.6.1. Measures the stress as a function of temperature on a wafer after deposition.
7.12.6.2. The instrument uses temperature cycling to reveal stress changes.
7.12.6.3. Temperature cycling causes stress changes due to thermal expansion, mismatch, volume changes, and plastic deformations.
7.12.6.4. Maximum temperature is 500C.
7.12.6.5. Do NOT open the chamber door until the temperature is below 40C.
7.12.6.6. The tool is nitrogen cooled.
7.12.6.7. Install the correct wafer locator ring in the system. See section on wafer locator ring for correct usage.
7.12.6.8. Place the deposited wafer face up in the locator ring. Major flat should face the door.
7.12.6.9. Place the quartz plate over top of the substrate and wafer locator ring.
7.12.6.9.1. Do not scratch the quartz plate as this can alter your measurements.
7.12.6.9.2. When removing quartz plate be sure it is cool, so that you do not melt your gloves on the plate.
7.12.6.10. Place the hot plate cover on top of the hot plate. Tighten thumbscrews finger tight.
7.12.6.10.1. The hot plate cover should only fit in 1 direction. The slit on hot plate cover should be horizontal.
7.12.6.10.2. The hot plate cover and quartz plate are located in the second drawer.
7.12.6.11. Go to the measure menu and choose temperature.
7.12.6.12. Enter file name, this is your user name.
7.12.6.13. Enter same id as first measurement no film for that specific wafer.

7.12.6.14. Enter the orientation of wafer and how many degrees of rotation. This number should be the same as the first measurement. If you did not use numerous orientations for the first measurement you will not be able to use 3d mapping for this measurement.
7.12.6.15. You may enter a comment, but it is not necessary.
7.12.6.16. In the film thickness field, enter thickness of film in angstroms.
7.12.6.16.1. Use the Auto El Eliposometer, the NanoSpec or the Dektak to obtain the correct film thickness.
7.12.6.16.2. If the film was etched rather than deposited, enter the film thickness as a negative number.
7.12.6.17. Select a line for entering the heating and cooling cycles.
7.12.6.18. Enter the desired target temperature, time and number of readings.
7.12.6.18.1. You may skip time and use a ramp value.
7.12.6.18.2. If a value is entering in time and ramp, the software will automatically choose time.
7.12.6.19. You may enter a maximum of 150 recipe lines, but the total number of readings should not exceed 1000.
7.12.6.20. Save the recipe. Enter a desired file name and choose ok.
7.12.6.21. Turn on the heater switch.
7.12.6.22. Depress the measure button.
7.12.6.23. As measurements are done and data is collected, a stress-temperature graph is displayed on the monitor.
7.12.6.24. Turn off heater switch.
7.12.6.25. To remove the wafer.
7.12.6.25.1. WAIT for the chamber temperature to be below 40C.
7.12.6.25.2. Remove the hotplate cover and quartz plate. Carefully things still may be warm. Do not melt your glove onto quartz plate.

7.13. Data Files
7.13.1. Read section 5 of the Flexus manual.
7.13.2. The manual should never leave the Flexus table.
7.13.3. Exporting files, see section 5.4 of the Flexus manual.
7.13.3.1. The CD-drive is a CD-RW and there is also a 3.5 in high-density floppy diskette.

7.14. Creating Graphs
7.14.1. Read section 6 of the Flexus manual.
7.14.2. The manual should never leave the Flexus table.

7.15. Data Analysis
7.15.1. Read section 7 of the Flexus manual.
7.15.2. The manual should never leave the Flexus table.
7.15.3. There are several types of data analysis you may use, section 9 of the Flexus manual will show the calculation used in the software.
7.15.3.1. Diffusion coefficient
7.15.3.2. Elastic and expansion coefficient
7.15.3.3. Graph subtraction

7.16. 3D Plotting
- 7.16.1. Read section 7.5.1 of the Flexus manual.
- 7.16.2. The manual should never leave the Flexus table.
- 7.16.3. You will need to measure the substrate at different angles for the before deposition and after deposition measurements.
- 7.16.4. The angles selected must include 0° and 90°. This number will be entered in orientation.
- 7.16.5. Choose 3dplotting from the analysis menu.
- 7.16.6. Choose open from the file menu and select desired file name. Click ok.
- 7.16.7. Select the desired records and click ok.
- 7.16.8. On the deflection map, you could change the viewing angle by depressing the various icons on the tool bar.

7.17. Shut Down
- 7.17.1. Log out of any programs.
- 7.17.2. Turn off the fan switch.
- 7.17.3. Turn off the laser.
- 7.17.4. Shut down the computer.
- 7.17.5. Turn off the monitor.
- 7.17.6. Leave power to the instrument on.
- 7.17.7. Leave the nitrogen on.
- 7.17.8. Clean up the area. Do not leave any clean room wipes around.

8. **Waste Products**

8.1. N/A

- **Report all accidents (injuries, spills, fires) to the SSEL On Call or other SSEL staff. For emergencies during non-business hours, call the SSEL Emergency Response Team at (734) 764-4127 or Department of Public Safety at (734) 763-1131.**