Flexus 2320 Stress Measurement System

The Flexus 2320 Stress Measurement Tool is used to measure stress in thin films. Silicon wafers are used as substrates for thin films. These films can be deposited by a variety of chemical vapor deposition, thermal or electron beam evaporation, sputtering or furnace growth. By optically measuring the change in the radius of curvature of the silicon substrate, both tensile and compressive stresses in thin films can be accurately determined.

This tool uses a laser. DO NOT LOOK DIRECTLY INTO THE LASER BEAM OR TRY TO DEFEAT ANY SAFETY INTERLOCKS. Do not attempt to change any calibration settings or laser alignment. Notify any FabLab staff member for help.
Operating Instructions

CHAPTER 1. INTRODUCTION

1.1 Principle of Operation.

FLEXUS Thin Film Stress Measuring Apparatus (TFSMA) measures the changes in the radius of curvature of a substrate created by deposition of a stressed thin film on its surface. The stress in the thin film is calculated from the substrate radius of curvature using the following equation:

\[ \sigma = \frac{Eh^2}{(1-\nu)6Rt} \] ............................................ (1)

where,

E/(1-\nu) - The biaxial elastic modulus of the substrate (\(1.805E11\) Pa for 100 silicon wafers).

h - Substrate thickness (m).

t - Film thickness (m).

R - Substrate radius of curvature (m).

\( \sigma \) - The average film stress (Pa).

Figure 1 shows schematically a substrate deformed to radius R by a film deposited on it. In this case the film is under compression deforming the substrate in the manner shown.

![Diagram of substrate deformation](image)

Figure 1. A substrate of thickness h, deformed to radius R by the film deposited on it.
As an example suppose that a (100) silicon wafer, 525 um thick, originally flat, was deformed to a radius of 30m by a surface film whose thickness is 7500A. Since the biaxial elastic modulus of 100 silicon is 1.802x10\(^{11}\) Pa, the stress is according to equation (1):

\[
\sigma = 1.805 \times 10^{11} \times (525 \times 10^{-6})^2 / (6 \times 30 \times 7500 \times 10^{-10}) = \\
= 3.69 \times 10^8 \text{ Pa} = 369 \text{ MPa} \quad \ldots \quad (2)
\]

The average radius \( R_1 \) of the bare substrate is obtained by measuring \( \theta \) as a function of \( x \) and performing a linear regression. \( 1/R_1 \) equals to half the slope obtained from the linear regression. After film deposition the substrate will deform to a new radius \( R_2 \). Since the stress is proportional to \( 1/R \) it follows that:

\[
1/R = 1/R_2 - 1/R_1 \quad \text{or,} \\
R = 1/(1/R_2 - 1/R_1) = (R_1 R_2)/(R_1 - R_2) \quad \ldots \quad (3)
\]

The thin film stress is now determined by using the effective radius \( R \) in equation (3). The stress measurements require therefore measuring the substrate radius BEFORE and AFTER film deposition.

Single wavelength machines can run into destructive interference from transparent films such as silicon nitride. The Dual Wavelength* system solves this problem by choosing automatically between two lasers and using the stronger reflection for measurement.

* Patent pending.

1.2 TFSMA system overview.

The TFSMA system consists of a computer (controller), a measuring platform and a hot plate. The substrate initial radius is measured by placing the substrate on a table and choosing option 1, FIRST MEASUREMENT (see section 4.1.1).

The wafer curvature is measured, if the laser selection in the defaults screen is AUTOMATIC (see figure 23), the stronger laser is selected. Otherwise the desired laser wavelength is used. The wafer deflection as well as the measured radius is displayed and stored.

After film deposition, the second measurement is made by selecting 2 on the main menu, SINGLE STRESS MEASUREMENT (see chapter 4.1.2) and at this time the stress is calculated using equations (1) and (3). The stress is both displayed and stored.

The TFSMA can also measure stress as a function of time, and as a function of temperature. Time dependent, as well
as, Time-Temperature measurements are automatically displayed in graphical form during data acquisition.

1.3 Schematic diagram.

Figure 2 shows a schematic diagram of the TFSMA. The samples are placed in a well on top of the hot plate (2). Measurements are carried out with the aid of the computer as described in chapter 4. The TFSMA contains a door to block the laser beam, when closed it actuates the beam attenuator which blocks the laser beams.

The main switch (S1) needs always to be left on as well as the laser switch (S2). When the hot plate is used, the fan switch (S3) and the heater switch (S4) have to be turned on as well.

Figure 2. Schematic diagram of the TFSMA, model F2320.

1) Temperature controller. 2) Hot plate. 3) Beam attenuator. 4) Sample. 5) Dial indicator. 6) Adjusting screw. S1) Main on/off switch. S2) Laser key switch. S3) Fan switch. S4) Temperature controller switch.
2.1 Maintenance required to keep this laser product in compliance with the Center for Devices and Radiological Health (CDRH) regulations.

The lasers in this product complies with Title 21 of the United States Code of Federal Regulations, Chapter 1, subchapter J, parts 1040.10 and 1040.11, as applicable. To maintain compliance, verify the operation of all features listed below, either annually or whenever the product has been subjected to adverse environmental conditions (e.g. fire, flood, mechanical shock, spilled solvents etc.) The features are identified on the radiation control drawing (figure 3).

1. Verify that all safety interlocks stop emission of laser or collateral (any electronic product radiation, except laser radiation, emitted by a laser product as a result of, or necessary for the operation of a laser incorporated in that product) radiation when removed.

CAUTION
DO NOT DEFEAT THE ELECTRICAL OR MECHANICAL INTERLOCKS.
When the interlocks are defeated, laser beams of class III-b medium power could be present, these beams are, by definition a safety hazard. The housing should not be opened, it is serviced by the factory only. The laser beam is a safety hazard, avoid direct exposure to the beam.

2.2 Laser controls.
The laser controls are: a) a door (2 in Fig. 2) which completely blocks the laser beam, and a key switch (S2 in Fig. 2) which turns the lasers on and off.

2.3 Labels.
The following is a schematic drawing showing the location of the warning and information labels, and examples of the labels.

Identification and certification label:

FLEXUS INCORPORATED
544 WEDDELL DRIVE, SUITE 7
SUNNYVALE CA 94089.
MODEL F2320. SERIAL# 882501.
THIS LASER PRODUCT COMPLIES WITH 21 CFR CHAPTER 1, SUBCHAPTER J.
Defeatable interlock label:

DANGER - Visible and invisible Laser radiation when open and interlock defeated.
AVOID DIRECT EXPOSURE TO BEAM.

---

Figure 3. Safety Control Drawing.

<table>
<thead>
<tr>
<th>Safety Feature</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission Indicator</td>
<td>1</td>
</tr>
<tr>
<td>Door</td>
<td>2</td>
</tr>
<tr>
<td>Certification and Identification Label</td>
<td>3</td>
</tr>
<tr>
<td>Interlock Warning</td>
<td>4</td>
</tr>
<tr>
<td>Key Switch</td>
<td>5</td>
</tr>
<tr>
<td>Beam Attenuator</td>
<td>6</td>
</tr>
</tbody>
</table>
CAUTION - use of controls and adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

Operating this laser without due regard for these precautions or in a manner that does not comply with recommended procedure may be dangerous. At all times during installation, maintenance or service of your laser, avoid unnecessary exposure to laser or collateral radiation that exceeds the accessible emission limits listed in "Performance Standards for Laser Products". 21 CFR 1040 10(d).

Consult OSHA, ACGIH and ANSI standards for further guidance.

The inside of the measuring platform contains electrical voltages of 110V or 230V. Disconnect all power before opening the instrument cover.

The hot plate, top cover as well as the four thumb screws are HOT when the heater operates - DO NOT TOUCH THE COVER OR SCREWS UNTIL COOL.
CHAPTER 4. OPERATION

4.0 Introduction

The Flexus operating software is menu based and is arranged according to functions. The software itself resides in the directory C:\FLEXUS2 but is operated from the directory C:\DATA by typing FL and hitting ENTER.

Figure 4 shows the menus arrangement. The main menu appears as the computer is turned on and by selecting the desired functions the sub menus appear. Selecting the sub menus is done by either using the up/down arrows followed by hitting ENTER or by typing the menu number.

Finally, by the selecting the sub menu function, a dialog box appears. The ENTER key or arrows are used to move between entries within the dialog box. With few exceptions, to proceed hit ENTER and go back by hitting ESC. At times you will see a large cursor at the right side of the entry, use the DEL key to erase it.

Additional operating instruction appear on the colored message line.

The main menu consists of seven options:

1) Stress measurement - all measurements are performed in this option.
2) Calibration - this option allows reflected intensity check, calibration (system comes calibrated) as well as laser beam movement.
3) Edit - data editing and graph creation is performed at this option.
4) Data processing - this option consists of seven sub menus shown in figure 1.
5) Setup - this option contains the desired default values for stress measurement.
6) Configuration - this shows the system configuration (not changeable).
7) Exit - exit to DOS.

4.01 Data storage

Measurement data is automatically collected in form of individual RECORDS in files that have a .DAT extension. This data can be reviewed in the Edit mode. It is also possible to save individual scan profiles by setting the Save Scan
Figure 5. First measurement screen.
Figure 6. Typical scan profile.
4.1.2 Single stress measurement

After the deposition you are ready for the actual stress measurement. Place the coated substrate in the system and select sub menu 2 - single stress from the stress measurement menu.

When selected from the sub menu the screen in figure 7 will appear. Again enter the file name (or use F1 as described in 4.1.1), ID and comments (if desired) and film thickness hit ENTER twice to measure. The substrate deflection will appear. By hitting ENTER the light intensity will appear. By hitting ENTER again, the screen in figure 7 will reappear with the measured radius and the stress value. A negative stress indicates compression while positive stress indicates tension.

Stress measurements are difference measurements and they always refer to the last "first measurement" for the entered ID.

The substrate can now be changed and you can continue measuring by repeating the procedure described above.

4.1.3 Stress-time measurement

After the deposition you may want to measure the stress as a function of time, such measurements reveal kinetics such as water absorption in oxides, densification, phase transformations, stress relaxation.

Place the substrate in the system (or furnace, for temperature models) and select sub menu 3 - Stress-time from the stress measurement menu. When selected from the sub menu the screen in figure 5 will appear. Enter the file name (or use F1 as described in 4.1.1), ID, comments (if desired), film thickness, measurement interval and total measurement time. The total number of records in a given file is limited to 1000. The measurements will be collected and displayed such as in figure 9. After completion, the collected data can be made into a graphic file in the editor (section 4.3.5.1) and further processed in the Data processing option.

4.1.4 Stress-temperature measurement (not for F5200)

After the deposition you may want to do measure the stress as a function of temperature, such measurements reveal stress changes upon temperature cycling. Temperature cycling causes stress changes due to thermal expansion.
Figure 7. Single stress measurement screen.
Figure 8. Stress-time measurement screen.
Figure 9. Typical Stress-time measurement.
mismatch, volume changes, plastic deformation etc.

Place the substrate in the system, place the cover, turn on the fan and heater switches. Select sub menu 4 - Stress-temperature from the stress measurement menu. When selected from the sub menu the screen in figure 10 will appear. Again enter the file name (or use F1 as described in 4.1.1), ID, comments (if desired) and film thickness. The desired temperature cycle is determined by creating or selecting an existing recipe. Figure 10 shows a typical example of such recipe. A maximum of 150 recipe lines and a total 1000 points are permissible.

Hitting F2 will start the measurement. The measurements will be collected and continually displayed such as in figure 11.

After completion, the collected data can be made into a graphic file in the editor (section 4.5.1) and further processed in the Data processing option.

4.1.4.1 Recipe creation (not for F5200)

To create a recipe enter "y" in the Create recipe entry in figure 10. A recipe window will appear in which you can program the heating and cooling cycles. To enter a line in the recipe hit ENTER and enter the desired target temperature, time and number of readings. By hitting ENTER twice the ramp will be calculated and displayed. The next recipe line can now be entered. If desired, the time can be skipped and the ramp entered. In this case the time will be automatically calculated. If both time and ramp are entered, the time will take precedence.

Since in some case the furnace cooling may be smaller than the requested ramp (especially at low temperatures) it is advisable to use two lines with the same temperature in the recipe such as lines 2 and 3 in figure 10.

4.2 Calibration

The calibration option includes three sub menus:

1. Intensity check.
2. Calibration procedure.
3. Move laser beam

The system is factory calibrated and does not require re-calibration.
Figure 10. Stress-temperature screen.
Figure 11. Typical stress-temperature measurements.
4.2.1 Intensity check

Occasionally, the reflected light intensity and position may be of interest. In this case select option 2 (Calibration) from the main menu. The laser beam will automatically be centered on the sample. Upon selecting Intensity check both the Intensity and Position values will appear. Use F9 to switch between 670nm, 750nm or Both lasers.

For blank, flat silicon wafers, the light intensity should measure between 2 and 4. The position should be between -0.05 and 0.05. If the position is outside these limits, please use the leveling thumb screw for adjustment. (not required for F5200, or top position in F2400).

4.2.2 Calibration procedure

The system is factory calibrated and does not require re-calibration. In certain cases, such as detector replacement, calibration will be necessary. In that event, select the Calibration option in the sub menu.

The calibration is done by adjusting the furnace angle and reading the machine response for each dial indicator value. The dial indicator face has two hands. The short hand reads 0 to 25 and each division equals 10 mils (0.010"). The long hand reads 0 to 100 and each division is 0.1 mil (0.0001"). One complete turn of the long hand is therefore 10 mils (0.100"). For example, if you are instructed to set the dial indicator to 100 mils, set the short dial on 10 and the long one on 0. For 120 mils turn the long dial twice clockwise to set the short hand on 12.

Follow the instructions on the screen to complete the calibration. At the end of the calibration, the calibration curve will be displayed. A good calibration is essentially a straight line through all the data points. If satisfactory, save the calibration.

4.2.3 Move laser beam

The laser beam can be moved when selecting Move laser beam from the calibration menu. Three movements are possible:

1. Jog the laser.
2. Set at center.
3. Move desired distance.
Selecting the jogging option allows moving the laser beam left and right at increments of 0.5mm by using the left and right arrows.

Selecting the second option will move the laser to the center of the sample.

Selecting the third option allows moving the laser a certain distance from its present location.

4.3 Edit

The collected data can be reviewed and edited when this option is selected. After recalling a file the data will be displayed as shown in figures 12 and 13. The record structure is reviewed by hitting Home and End to see figures 12 and 13 respectively.

Each line represents one record and all the pertinent inputted and measured data is displayed in figures 12 and 13.

Stress measurements records can be edited individually or in blocks. The parameters that can be edited are: Id, Comment, Film and substrate thicknesses and the elastic modulus.

Files can be moved, saved and merged. New files with selected Id can be created.

ASCII files can be created, graphic files made and stored and trend charts can be displayed.

4.3.1 Single record editing

To edit a single record move the cursor with the up/down arrows to the desired record#, hit ENTER to highlight this line. Change the desired values and hit ENTER to complete the editing. The stress value will be recalculated automatically.

4.3.2 Block record editing

Block editing can only be done after a single record editing. Select the first record of the block and edit it. Then hit F7 to mark the block first record. With the arrows or page up/down move the cursor to the last record in the block, hit F8 to select the block.
<table>
<thead>
<tr>
<th>No.</th>
<th>Temp</th>
<th>Date</th>
<th>Radius</th>
<th>Stress</th>
<th>Thickness</th>
<th>Elast.</th>
</tr>
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<td>24</td>
<td>82.101</td>
<td>No Film</td>
<td>No Film</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>10/05/91</td>
<td>24</td>
<td>81.883</td>
<td>0.3</td>
<td>10000</td>
</tr>
<tr>
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<td>24</td>
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<td>0.0</td>
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<td>10000</td>
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</tr>
<tr>
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<td>28</td>
<td>10/05/91</td>
<td>24</td>
<td>81.905</td>
<td>0.2</td>
<td>10000</td>
</tr>
<tr>
<td>10</td>
<td>29</td>
<td>10/05/91</td>
<td>24</td>
<td>81.945</td>
<td>0.2</td>
<td>10000</td>
</tr>
<tr>
<td>11</td>
<td>30</td>
<td>10/05/91</td>
<td>24</td>
<td>81.773</td>
<td>0.4</td>
<td>10000</td>
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Figure 12. Editor screen 1.
<table>
<thead>
<tr>
<th>Time</th>
<th>Left</th>
<th>Left Diff</th>
<th>Left Sum</th>
<th>Right</th>
<th>Right Diff</th>
<th>Right Sum</th>
<th>Start</th>
<th>End</th>
<th>How</th>
<th>Laser</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:40:44</td>
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<td>-11.24</td>
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<td>-11.20</td>
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<td></td>
<td></td>
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<tr>
<td>00:53:42</td>
<td>0.2542</td>
<td>1.0000</td>
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<td>N/A</td>
<td>18.00</td>
<td>90.00</td>
<td>-11.29</td>
<td>Auto</td>
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<td></td>
</tr>
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<td>90.00</td>
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<td></td>
<td></td>
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<td>00:51:42</td>
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<td>1.0009</td>
<td>N/A</td>
<td>N/A</td>
<td>18.00</td>
<td>90.00</td>
<td>-11.27</td>
<td>Auto</td>
<td></td>
<td></td>
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<tr>
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<td>0.2544</td>
<td>1.0009</td>
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<td>N/A</td>
<td>18.00</td>
<td>90.00</td>
<td>-11.30</td>
<td>Auto</td>
<td></td>
<td></td>
</tr>
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<td>1.0000</td>
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<td>N/A</td>
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<td>90.00</td>
<td>-11.29</td>
<td>Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>01:03:42</td>
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<td>1.0004</td>
<td>N/A</td>
<td>N/A</td>
<td>18.00</td>
<td>90.00</td>
<td>-11.28</td>
<td>Auto</td>
<td></td>
<td></td>
</tr>
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<td>01:07:42</td>
<td>0.2541</td>
<td>1.0002</td>
<td>N/A</td>
<td>N/A</td>
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<td></td>
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<td>01:11:42</td>
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<td>1.0002</td>
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<td>18.00</td>
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<td>01:29:42</td>
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<td>1.0000</td>
<td>N/A</td>
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<td>90.00</td>
<td>-11.28</td>
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<td>01:33:42</td>
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<td>1.0000</td>
<td>N/A</td>
<td>N/A</td>
<td>18.00</td>
<td>90.00</td>
<td>-11.28</td>
<td>Auto</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Use ↑ ↑ +↑,PgUp,PgDn,〈Enter〉 to edit,Home/End to switch screen,〈Alt〉 menu

Figure 13. Editor screen 2.
Use the Alt key and arrows to select the Edit option from the top menu (File Edit Export ...) and hit 7 to recalculate the stress.

To unmark a block use F9.

Additional block operations include moving blocks, copy blocks or deleting blocks are available in this menu. When moving or copying blocks, the blocks will move or be copied starting at the position of the cursors.

4.3.3 File handling.

File manipulation is handled in the File option. This option allows loading other files, saving the file under its current name or saving as a different name. Block saving into a second file is also allowed.

Merge file allows bringing in the data from a second file and merge it with the current file.

Printing a file or a block is done from this option (when a printer is available).

Finally, the Select record option allows creating a new file containing only the records of a specific selected Id.

4.3.4 File export.

This option allows an ASCII file creation from the record data. Each record will now appear as 12 consecutive rows as follows:

row#1: Film thickness (A).
row#2: Sample identification.
row#3: Date.
row#4: Time.
row#5: Left position.
row#6: Left intensity.
row#7: Bow (um).
row#8: Reserve.
row#9: Radius (m).
row#10: Stress (Pa).
row#11: Temperature (°C).
row#12: Substrate thickness (um).

An ASCII file with an extension .TXT will be formed with a record structure above. This file can now be read by you into other data handling software.
4.3.5 Graph creation.

This section allows creation of graphic files from the raw data. The graphs can be created from the whole file (default) or from a preselected selected block. The graph axes can be Time, Temperature, Stress, Light intensity, Record number or Bow.

A second option is viewing a trend chart of the entire file or a preselected block.

4.3.5.1 Create graph.

Hit Alt, select the Graph option and hit ENTER. The screen in figure 11 will appear. Type the name of the graphic file which you want to create and select the X and Y axes. Type in the graph label and hit ENTER.

There are various options for the graph format; connecting the points, drawing the points and autoscaling the X and Y axes. The default values of these options can be changed by hitting F4 after you completed all the data field entries. Hitting ENTER will display and store the graph.

4.3.5.2 Trend Plot.

Hit Alt, select the Graph option and hit ENTER. A screen similar to the one in figure 14 will appear. Type the name of the graphic file which you want to create and select the X axis as a Record number, Date or Julian calendar days. Type in the graph label and hit ENTER.

There are various options for the graph format; connecting the points, drawing the points and autoscaling the X and Y axes. The default values of these options can be changed by hitting F4 after you completed all the data field entries. Hitting ENTER the trend plot will be displayed.

Figure 15 shows such a plot. The sigma and 3 sigma values are automatically displayed on the graph. Points within +/- sigma are plotted as squares, points with +/- 3 sigma but outside the +/- sigma limits are plotted as circles, while points outside the +/- 3 sigma levels are marked with X. By hitting ENTER again, a table of the outlying points (outside +/- 3 sigma) is displayed.
Figure 14. Graph retrieval screen.
Figure 15. Typical trend plot.
4.4 Data processing.

The purpose of this menu is to process graphic or scanning data files. Seven sub menus are available as seen in figure 1.

4.4.1 Graph retrieval.

This option allows retrieving graphic files, linear regression and diffusion coefficient calculations.

Select Data processing from the main menu and Graph retrieval from the sub menu. Type in the retrieval file name and hit ENTER. At this point, the default graph values can be changed by hitting F4, else hit ENTER to view the graph.

To show a linear regression, select Linear regression after hitting F4. Enter the desired limits. For a curve of increasing temperature choose the Tempi (lower limit) as the lower temperature. For the temperature decreasing branch of a curve choose the Tempi as the higher temperature.

Stress-time curves allow diffusion coefficient calculation. Respond with "Y" to Diffusion question and enter the desired time limits for the calculation. The resultant diffusion coefficient will appear on the graph at the end of the iteration cycle. Figure 13 shows such an example.

The diffusion coefficient is calculated by least square fitting to the diffusion equation into a finite film:

\[ \sigma = \sigma_0 + \Delta \sigma \left( 1 - \frac{8}{(2n^2)} \sum \frac{1}{(2n-1)} \right)^2 \exp \left\{ (1-2n)/(2L) \right\} \pi^2 D t \]  \hspace{1cm} (4)

where,
\[ \sigma \] - The stress at time t.
\[ \sigma_0 \] - Initial stress.
\[ \Delta \sigma \] - The total stress change after completion.
\[ n \] - A running index from 1 to infinity.
\[ L \] - Film thickness.
\[ D \] - Diffusion coefficient
\[ t \] - Time.

Note that the least square fit is working by iteration. It may not converge; if this happens the attempts will stop after 20 iterations.

4.4.2 Elastic & expansion coefficient calculation. (not for FS200)

The purpose of this option is to allow the calculation of the film thermal expansion coefficient and the biaxial elastic modulus.
Figure 16. Diffusion coefficient extraction.
Figure 17. Stress-temperature curves of W on silicon and W on GaAs.
Figure 18. W linear thermal expansion coefficient and biaxial modulus.
The stress change with temperature in the elastic range is governed by the following equation:

$$\frac{d\sigma}{dT} = \left(\frac{E}{(1-\gamma)}\right)_f (a_s - a_f) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (5)$$

where,
- $d\sigma/dT$ - The derivative of stress vs. temperature.
- $(E/(1-\gamma))_f$ - Biaxial modulus of the film
- $a_s$ - Substrate thermal expansion coefficient.
- $a_f$ - Film thermal expansion coefficient.

The equation above has two unknowns $a_f$ and $(E/(1-\gamma))_f$. In order to solve for both we need to perform two temperature cycles with two different substrates and solve two simultaneous equations. For best results use slow heating or cooling (<400°C/hour) to minimize the lag of the wafer temperature behind the heating stage.

After acquisition of the two graphs and creation of graphic files (.ORF files) use the current option to calculate both thermal expansion and biaxial modulus of the film.

As an example, figure 17 shows the cooling curves of two substrates (silicon and GaAs) coated with a tungsten film. When hitting ENTER the expansion coefficient will be displayed as shown in figure 18. By hitting ENTER again, will show the average values of the expansion coefficient and biaxial modulus.

4.4.3 Data base

This option allows the review, addition and deletion of material's biaxial modulii, and linear thermal expansion coefficients.

4.4.4 Thermal stress (not for F5200)

This option allows the display of the thermal stress superimposed on the measured graph.

Enter the retrieval file name as well as the film material and hit ENTER. The thermal stress will now be displayed on the graph. Figure 19 shows such an example of W on GaAs. If a file name is not entered, then a thermal stress graph can be displayed by itself within any desired temperature limits.
Figure 19. W on GaAs thermal thermal stress super imposed on stress-temperature measurement data.
4.4.5 File subtraction (not for F5200).

This option has a dual purpose:

a) Simple file subtraction for comparison or correction reasons.

b) Multilayer work.

In the first case simply invoke this option by hitting 5 on the Data processing option and enter the two file names in the screen seen in figure 20. The files can simply be subtracted i.e.:

Result = file 1-multiplier x file 2

Pressing ENTER will show the subtracted file. If the smoothing option is invoked than the second file is smoothed before the subtraction. Otherwise the corresponding data points are subtracted one by one. When smoothed file 2 can contain only one heating and cooling cycle.

For multi film use, first measure film 1 (of thickness t1) as a function of temperature, prepare a .GRF graphic file and store it as file 2. Then measure film 1+ film 2 (use film 2 thickness of t2 when measuring) and store the .GRF file as file 1. The stress measured with film 1 + film 2 and using film 2 thickness is:

\[ \sigma = \frac{(\sigma_1 t_1 + \sigma_2 t_2)}{t_2} = \sigma_1 t_1/t_2 + \sigma_2 \ldots \ldots \ldots \ldots (6) \]

Since we measured \( \sigma_1 \) in file 2 we can now obtain \( \sigma_2 \) by subtracting \( \sigma_1 t_1/t_2 \) from file 1. This is done simply by inserting the value of \( t_1/t_2 \) as the multiplier of file 2. Note that the above procedure is valid only if film 1 stress is not affected by film 2.

4.4.6 Record comparison.

The purpose of this editor is to compare the deflection curves of a first and single stress measurements. If you elected to store SCN files in the First measurement and Single stress (along with the normal DAT files) you can compare the scans in this option. Note that stress-time and stress-temperature measurements do not create SCN files.

Select option 6 on the Data processing menu. Enter the file name to be compared and hit ENTER. Tag the two records to be compare by moving the cursor with the up/down arrows.
Figure 20. Record comparison screen.
Figure 21. Comparison between scan profiles before (triangles) and after (crosses) film deposition. The difference (circles) is also plotted.
next to the desired records and hitting T. A letter F (first) will appear next to the first tagged record, the second record tagged will display the letter S. (You can also inspect an individual records by tagging the same record twice.)

By hitting ENTER, a graph such as figure 21 will be displayed. This graph shows a plot of the deflections of the first (triangles) and second measurements (crosses) and the difference between the two (circles).

By hitting ENTER at this point you can select between two options, you may elect to show the stress uniformity plot or do a segment analysis.

In the segment analysis you can compare any scanned segment and find the local radius of curvature and stress. The stress uniformity allows plotting the stress across the wafer. In this case you can allow also for film and substrate non-uniformities. Note that these results are strictly correct for radially symmetrical non-uniformities.

4.4.7 3 D isometric view.

This option allows an isometric display of substrate shape.

Select option 7 from the Data processing. Enter the retrieval file name and the record sequence that you want to display.

The wafer has to be first measured in the First measurement mode at different angles. Place the wafer on the chuck with flat in front and measure. Repeat the measurements by turning the wafer counterclockwise at desired angular increments (for example every 30°). When hitting ENTER you will see an isometric image of a wafer (figure 22).

This image can be:

Tilted back and forth using the up and down arrows. Moved up and down by PgUp/PgDn keys. Change vertical magnification by Up/Down arrows. Expand and shrink by Ctrl PgUp/PgDn.

Hit ENTER or ESC to return to the sub menu.
Figure 22. Isometric view.
4.5 Setup.

The setup screen (option 5) is seen in figure 23. The parameters of interest are the maximum scan points (1250 maximum). 50 to 100 points are more than enough for measurement. When saving the scan profiles, 50 points will always be automatically saved in order not to clutter the computer with many data points. The low intensity alarm helps indicate adverse reflection conditions as well as alarm the user attempting to measure when no sample is present.

The next values are the elastic modulus and the substarte (sample) thickness. H/W (hardware) simulation should remain "n". The units can be toggled between MPa and Dynes/cm² and the laser selection can be automatic, 670nm or 750nm.

4.6 Configuration.

The system configuration screen (option 5) is seen in figure 24. The configuration is for information only and is not changeable through the program.

4.7 Exit

Hitting 7 at the main menu will exit to program DOS.
Figure 23. Setup screen.
Figure 24. Configuration screen.