FLX-2320 - S
Thin Film Stress Measurement

User Manual

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TRADEMARKS

TOHO Technology® is a registered trademark of TOHO Technology

PATENTS

This instrument is protected under the following patents: 5134303 and 524889.

AN IMPORTANT MESSAGE

Thank you for selecting the TOHO Technology FLX-2320-S and welcome to our growing world-wide family. Please read this manual carefully to familiarize yourself with the FLX-2320-S. The TOHO Technology applications staff or the TOHO Technology Service Department will be happy to assist you with any questions you have about your instrument.

OPERATING SAFETY

LASER

The TOHO Technology FLX-2320 contains two solid-state lasers: a Class IIIa laser with 4 milliwatts (mW) power and 670 nanometers (nm) wavelength and a Class IIIb laser with 4 mW power and 780 nm wavelength. The lasers comply with Title 21 of the United States Code of Federal Regulations (CFR), Chapter 1, Subchapter J, Sections 1040.10 and 1040.11, as applicable.

Pursuant to the Regulations for the Administration and Enforcement of the Radiation Control for Health and Safety Act of 1968 (pertinent to laser products), a document describing this product has been filed with the Consumer Industrial Products Branch (HFZ-312) of the Division of Radiological Products of the National Center for Devices and Radiological Health (CDRH).

The CDRH requires that all laser products be maintained to keep them in compliance with CDRH's regulations. To maintain compliance with CDRH regulations, verify the operation of the Beam Attenuator (turns the laser beam off when the instrument door is open) annually or whenever the product has been subjected to adverse environmental conditions (mechanical shock, spilled solvents, and fire).

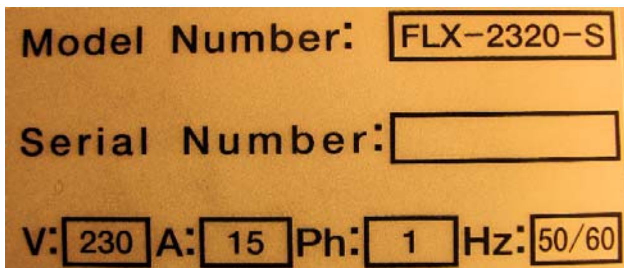
WARNING: **Do not defeat the electrical or mechanical interlocks. When the interlocks are defeated, laser beams of Class IIIb medium power could be present. These beams are a safety hazard. Also avoid direct exposure to the laser beam.**

When operating the FLX-2320-S, comply with safety precautions described in this section; you can consult OSHA, ACGIH, and ANSI standards for additional guidance.

During instrument installation, instrument maintenance, or laser service, avoid unnecessary exposure to laser or collateral radiation exceeding the acceptable emission limits listed in the section titled "Performance Standards for Laser Products," in the CFR, Section 1040.10(d).

Sample Certification and Identification and Interlock labels are displayed on the following page.

Sample identification label:



Sample certification labels:

Sample interlock labels:

VOLTAGE

The system contains components requiring electrical voltages of 115 V or 230 V.

HIGH TEMPERATURES

The hot plate and measurement platform are very hot (up to 500° C) when the heater is operating.

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1 INTRODUCTION

1.1 ABOUT THIS MANUAL

This manual is divided into the following chapters:

- Chapter 1, "Introduction," provides information on the manual organization, conventions, and terminology.
- Chapter 2, "Instrument Overview and Installation," provides information on instrument features, installing the instrument, and installing and upgrading software.
- Chapter 3, "Using WINFLX," provides information on using User Files, Process Programs, the Materials Database, Verifying Calibration, installing and Upgrading Software.
- Chapter 4, "Performing Measurements," covers the measurement modes of first stress, single stress, stress-time, stress-temperature and 3-D Scans.
- Chapter 5, "Managing Data Files," covers the Data Editor window, and the various functions that can be done within the window.
- Chapter 6, "Creating and Displaying Graphs," covers creating and displaying 3-D graphs, trend plots and graphs.
- Chapter 7, "Data Analysis," covers the various calculations, record comparisons, and analysis of data files.
- Chapter 8, "Maintenance," provides information on basic instrument maintenance, troubleshooting, calibration, and diagnostics.
- Chapter 9, "Theory of Operation," provides a brief overview of the theory of operation of the instrument.
- Appendixes describe the instrument specifications, and constants and conversions used in calculations, and the cooling stage option.
- A glossary and an index are also provided at the end of this manual.

1.2 HOW TO USE THIS MANUAL

To get the most out of this manual, you should work sequentially from Chapter 3, “Using WINFLX” through Chapter 7, “Data Analysis.” Chapter 8, “Maintenance,” should be used by the key person responsible for maintaining the instrument.

CAUTION:	**We also strongly recommend that you read the section on Operating Safety on page vii before operating the instrument.**

1.2.1 TERMINOLOGY

Before continuing, you need to familiarize yourself with several terms used throughout this publication.

User

The operator of the instrument and the software.

Arrow Keys

The four arrow keys on the computer keyboard. Each arrow key points in a specific direction. To move the selection bar in menus, press [↓] to move the bar downward and [↑] to move the bar upward. To activate the menu item, press ALT, and then use the arrow keys to select any menu. Press [→] to select menus left to right and [←] to select menus right to left.

Command

The action associated with one of the options appearing on a menu and activities performed when keys are pressed on the keyboard.

Cursor

Small blinking dash appearing in the alphanumeric fields. The cursor serves as a pointer marking the location where characters appear when you type.

Directory

Computer files are stored on the computer’s hard disk in directories. The directory name identifies the location where the files are stored.

Field

Reserved area provided on many windows for typing data, displaying data, or selecting options associated with the field. Three types of fields can appear on windows—data entry fields, option fields, and display-only fields. Data entry fields are reserved for typing numeric values or alphanumeric data. Option fields have predefined values. Display-only fields are used by the instrument to display the current status of hardware.

Highlight

A field that has a different background from the other fields indicating that the highlighted field is to be replaced.

Menu

A list of actions. For example, the File menu contains file related actions. Inactive items in the menus are dimmed.

Process Program

A Process Program is a set of parameters specifying information such as the number of scan points, elastic modulus, substrate thickness, and wafer diameter for the measurement.

Scan

Action performed when the TOHO Technology FLX-2320-S optical system and measurement stage are used to inspect wafers.

2 INSTRUMENT OVERVIEW AND INSTALLATION

This chapter provides information on the following:

- Instrument features
- Operating environment and site requirements
- Procedures for installing the instrument and software
- Procedures for installing upgrades to the software

2.1 INSTRUMENT OVERVIEW

2.1.1 FEATURES

The FLX-2320-S is a thin-film stress measurement instrument. It accurately measures the changes in the radius of curvature of the substrate caused by the deposition of a stressed thin film on the substrate. Some of the features include

- Laser scanning technology to accurately measure stress on all reflecting films. Stress can also be measured as a function of time or temperature (standard temperature range from room temperature to 500° C; optional temperature range -65° C to 500° C). The software displays regular and time-dependent stress measurements in graph form automatically.
- An optional inert atmosphere capability that allows measurements to be made in a controlled atmosphere of nitrogen or argon.
- Only one moving element in the optical components ensures low vibration and high accuracy.
- Ability to customize parameters such as number of scan points, elastic modulus, substrate thickness, and wafer diameter in the Process Programs. Heating and cooling cycles can be specified in recipes for stress-temperature measurements.
- Ability to edit data records, plot graphs, and trend charts. Stress can be calculated for a saved data file by changing the elastic modulus, wafer thickness, or film thickness.
- Comprehensive data analysis capabilities that include calculating the biaxial modulus of elasticity and linear expansion coefficient, displaying thermal stress superimposed on stress-temperature measurement data, stress uniformity, file subtraction, trend plotting for statistical process control (SPC), calculating the water diffusion coefficient in dielectric films, and displaying a 3-D map of the deflection over the wafer.

2.1.2 SYSTEM COMPONENTS

The FLX-2320-S system consists of a desktop computer, keyboard, monitor, mouse and measurement unit. Figure 2-1 shows the measurement unit with its door closed.

Source Power LED, Temperature Display, Heater Switch, Fan Switch, Laser Keyswitch, and the Main On/Off Switch are located along the top front of the cabinet (Figure 2.2)

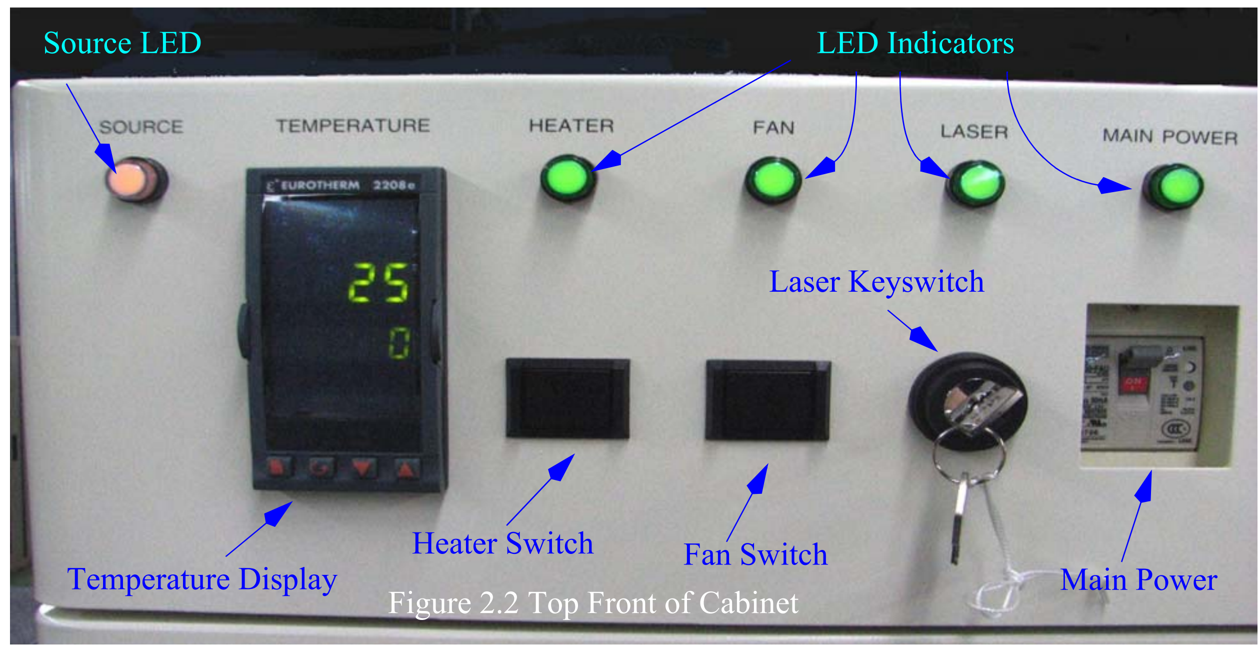


Figure 2.2 Top Front of Cabinet

2.2 OPERATING ENVIRONMENT

The instrument must be installed on a reasonably flat, rigid foundation.

Facility Specification

Temperature	18–22° C (64–72° F)
Air Quality	The FLX 2320-S is a clean tool. It is designed to operate in a class 100 Clean Room.
Gas Connections (Standard instrument)	Inert gas flow rate: 2–10 CFH(3L/min=6.4CFH); Cooling gas (typically CDA or N2) flow rate: Up to 500 CFH (236L/min=500CFH); pressure not to exceed 40 PSI. (.3 MPa= 43.5psi).
System Power	15 amp. at 230 V, 50/60 Hz

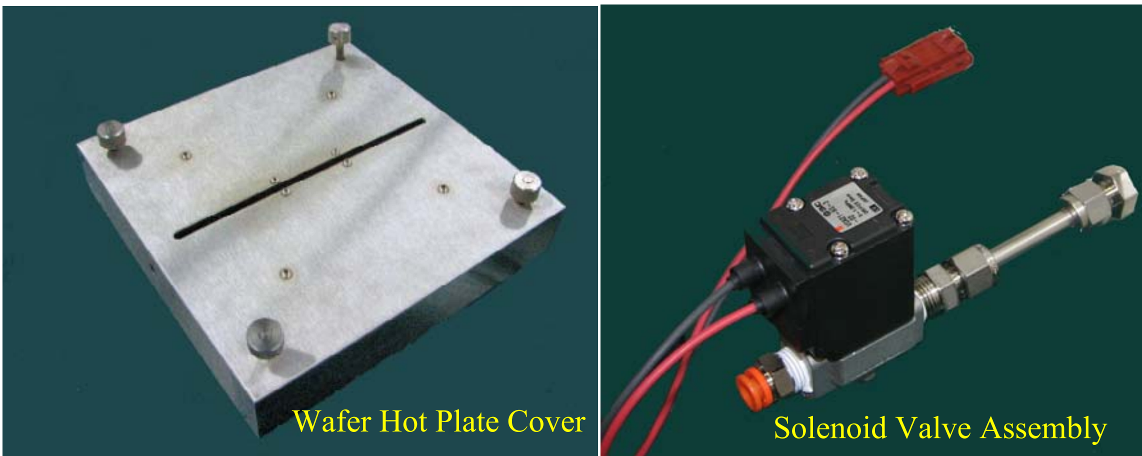
CAUTION: Avoid operating the FLX-2320-S near strong electrical and magnetic fields, emitters of radio frequency interference, sources of mechanical vibration, or contaminating or corrosive vapors.

2.3 SHIPPING CONTENTS

The following items are shipped with the unit:

- One FLX-2320-S Instrument
- One Desktop Computer, one Monitor, one Keyboard, one Mouse
- Two FLX-2320-S User Manuals
- One FLX-2320-S software diskette
- Two Laser activation Keys
- User Manual CD Rom

- One Wafer Hot Plate Cover



- One Solenoid Valve Assembly
- One 8.25" Quartz Plate (Very Fragile!)
- One copy of Windows Software
- One Disk with System calibration and configuration Back-Up files

The following items are optionally available:

- Positioning Rings, USA- 3", 4",5",6" Japan- 3",6"
- Gas Panel
- Printer
- Wafer Stress pair; 150mm or 200mm
- Mirror set; Radius 20meter & Flat mirror
- Mirror Positioning Ring
- 3-D Mapping Software
- Lo-Temp option: enables instrument to reach -65 ^{o}C

2.4 INSTRUMENT INSTALLATION

2.4.1 SHIPPING DAMAGE

NOTE:	**The carrier is responsible for damage incurred during shipping and should be contacted immediately if the shipping containers appear damaged (see below). Be sure to retain all damaged containers and documentation for inspection by the carrier.**

Each shipping container has a Shockwatch monitor and a Tiltwatch monitor on the outside of the container. Sample labels are displayed here.

SHOCKWATCH MONITOR

If the shockwatch indicator in the middle of the monitor is red, the crate was not properly handled. Note that normal movements and acute angles during aircraft take-off and landing do not activate the indicator. If the indicator is red, make a notation on the bill of lading and service report and check the instrument for damage. If the instrument is damaged, notify the carrier and the service dispatcher at TOHO Technology.

Also verify that the sticker “FACTORY SEALED, TOHO Technology Inc." is still intact. If the seal is not in place, the instrument could have been mishandled by the carrier. If the seal is missing or not in place, make a note on the Service Report. Check the instrument for damage and notify the carrier and the service dispatcher at TOHO Technology in case of damage.

TILTWATCH MONITOR

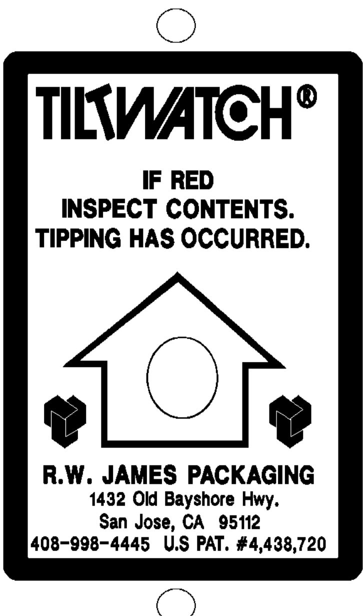


Figure 2-1 Tiltwatch Monitor

If the indicator in the center of the label is red (normal state is white), then the container was tilted on its side or completely upended. Note that normal movements and acute angles during aircraft take-off and landing do not activate the indicator. If the indicator is red, there could be possible damage to the instrument. Make a note on the bill of lading and the Service Report. Check the instrument carefully for damage and notify the carrier and the service dispatcher at TOHO Technology in case of damage.

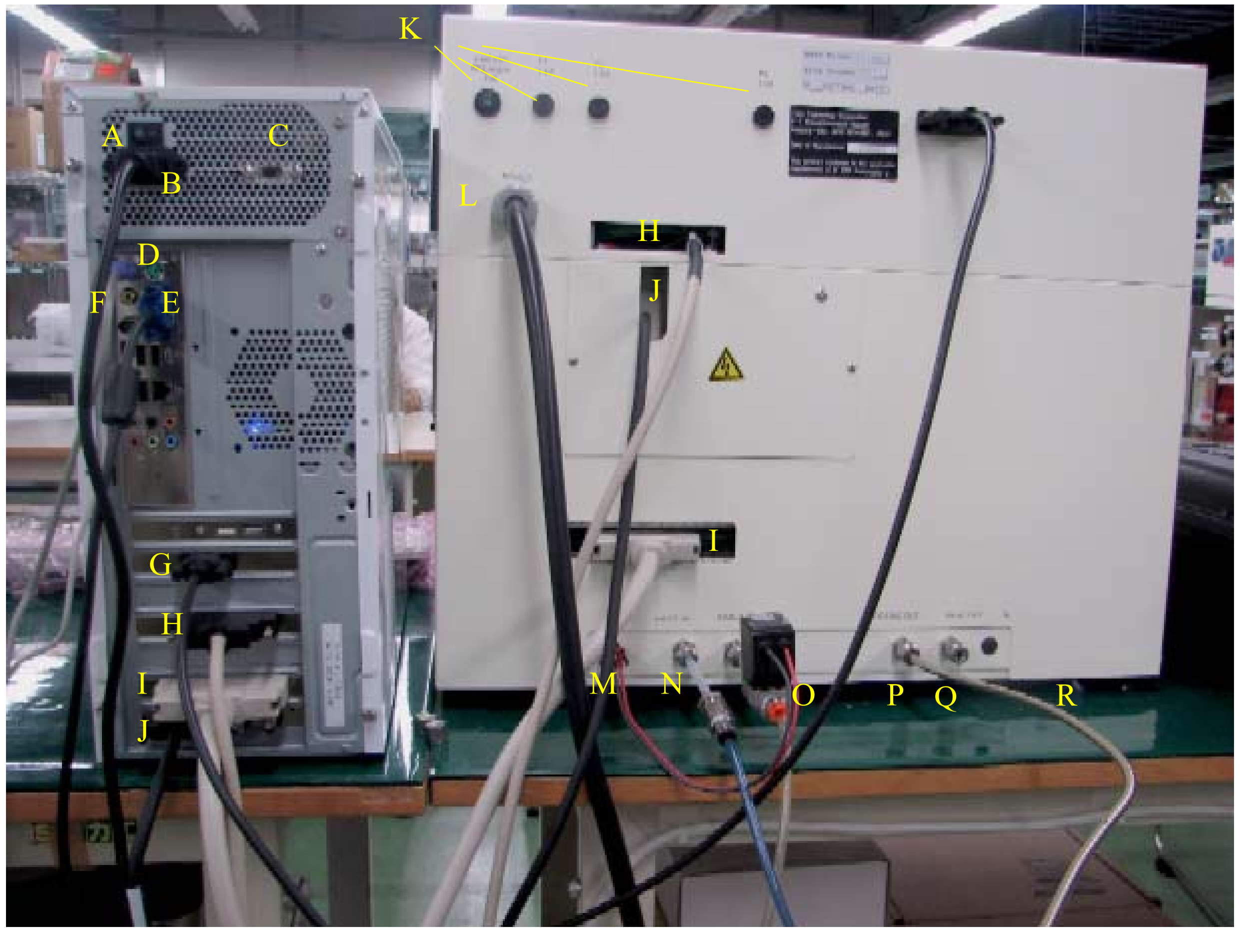
2.4.2 PRE-INSTALL

The FLX 2320-S is a precision instrument. Although calibrated at the factory, upon finding its permanent operating place it will need to be re-calibrated by a qualified Toho technician. Before scheduling an installation date, the user needs to have filled out a pre-install checklist. Before installation, facility has to be equipped with:

- Stable Temperature between 18C & 22C (64F & 72F)
- Instrument Power: Instrument comes with a NEMA L6-30 plug (3 prong 30A) for USA customers. Instrument draws 15A. and runs on single phase 230V, 50/60 Hz.

- Computer Power: requires 1A (0.36 nominal) two 115V outlets (PC & Monitor)
- Inert gas: Unless the Toho Gas Panel was purchased as an option, customer-supplied valves and flow meters are required for all gas connections. Inert gas connection is 1/4" Swagelok.
- Cooling Gas: Cooling gas runs through a closed loop inside the stage. The gas never "sees" the wafer. Typically Compressed Dry Air is used. Some labs will use Nitrogen. Cooling gas should be set at 500 CFH (23.6L/min=50CFH) with a head pressure of 40 psi. (.3 MPa= 43.5psi)

2.4.3 ATTACHMENT

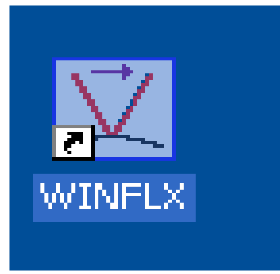


A- PC Power Switch
B- PC Power Cord
C- 115/230 Switch
D- Keyboard Input
E- Monitor Input
F- USB Mouse Input
G- Temperature Cable
H- Motion Cable
I- I/O Cable #1
J- I/O Cable #2
K- Fuses
L- Instrument Power Cord
M- Solenoid Signal Input
N- Inert In
O- Cooling In/ Solenoid Assembly
P- Cooling Out
Q- Inert Out

Only on Lo-Temp option:
R- Additional N2, for N2 blanket

1. Attach Nema L6-30 plug to facility receptacle. Verify "Source Power" is lit on the front of the tool.
2. Attach PC & Monitor Power Cords to standard 115V outlets.
3. Attach Keyboard to keyboard input.
4. Attach Mouse to USB port.
5. Attach Temperature Cable (Black Cable) to the back of tool and to 4th slot from the bottom on the back of the PC.
6. Attach Motion Cable that is hard wired to the Instrument to the 3rd slot from the bottom on the back of the PC.
7. Attach I/O #1 Cable to the back of the Instrument and to the 2nd slot from the bottom on the back of the PC. This is an off-white cable that snaps in place at both ends.
8. Attach I/O #2 Cable that’s hard wired to the tool, to the bottom slot of the PC.
9. Attach Solenoid Assembly to the "Cooling In" port on the rear of the tool. The Swagelok nut will already be on the solenoid assembly. This is a 1/4" Swagelok connection. A 7/16 open wrench will tighten it. Attach 2 wire connectors from the solenoid assembly to the "DC Input". Attach 1/4" tube to the One-Touch quick disconnect on the solenoid valve assembly.
10. Attach Inert gas supply to "Inert In". This is a 1/4" Swagelok connection. A 7/16 open wrench will tighten it.
11. The "Cooling Out" and "Inert Out" ports are available to plumb into the chase. The Cooling will be noisy during a cool down if not exhausted elsewhere. If the inert gas is Nitrogen it is harmless to exhaust into the lab. If it is Argon, be sure to exhaust it properly.

The tool is now ready to be energized. Turn on the PC, turn on the main breaker on the front of the instrument. There will be a shortcut on the desktop that says "WINFLX". Double click to open.



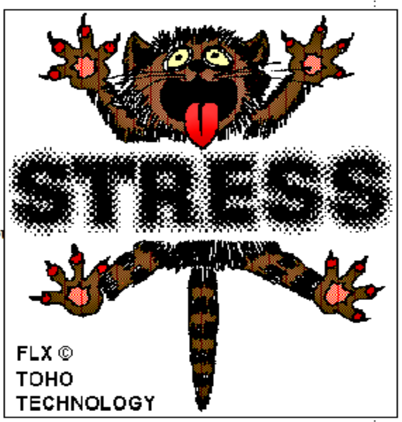
3 USING WINFLX

Once the instrument is connected, the power and facility connections are connected, and the software is opened, the User can begin to perform scans and analyze data. The instrument should be calibrated by a TOHO technician. The FLX 2320-S uses Software called "WINFLX". This chapter covers:

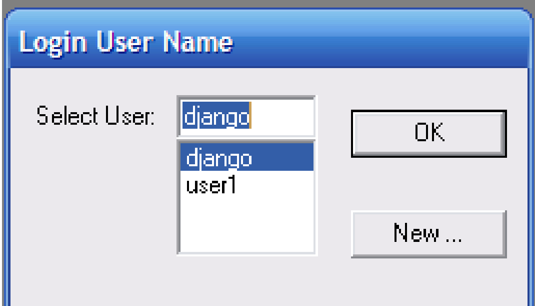
- Logging In and creating User files
- Creating and using Process Programs
- Using the Materials Database
- Verifying the Instrument Calibration
- Installing & Upgrading Software

3.1 Creating a User File

1. After clicking on the WINFLX icon, you will see another "Stress Cat" while the program loads. Do not fear the cat!



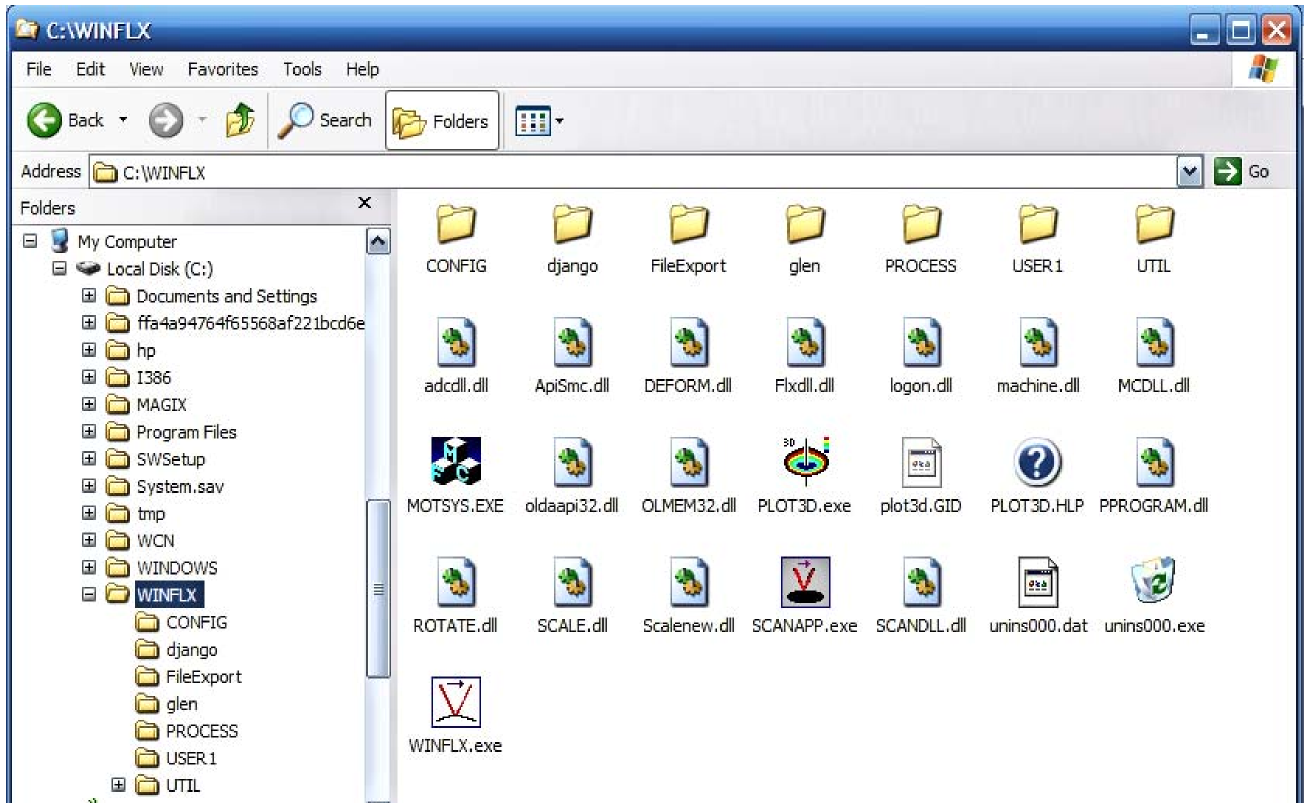
2. A "Login User Name" window appears. Select from the list and press "OK", or to create a New User, click "New..."



3. A "New User" window will appear. Enter the name of the new user in the field provided. Then click "OK".

4. The new User Name creates a new folder. This folder can be found at:

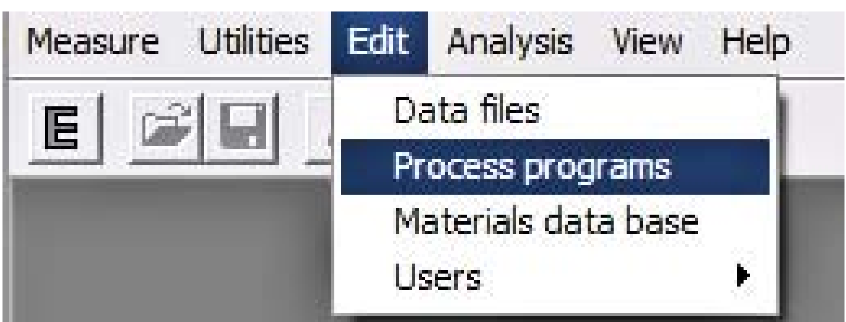
C:\WINFLX\NewUser



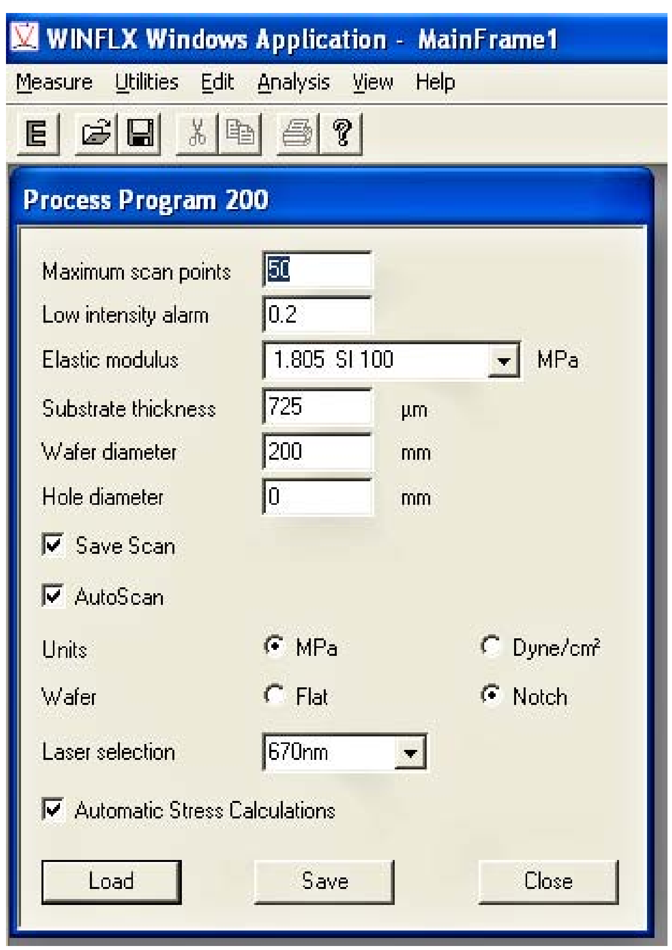
This folder will contain all of the Process Programs, Recipes, and data Scans for this user.

3.2 Process Programs

1. In order to do any scan, you need to set up the correct Process Program. Go to the Edit tab on the top of the main screen. Select "Process Programs."



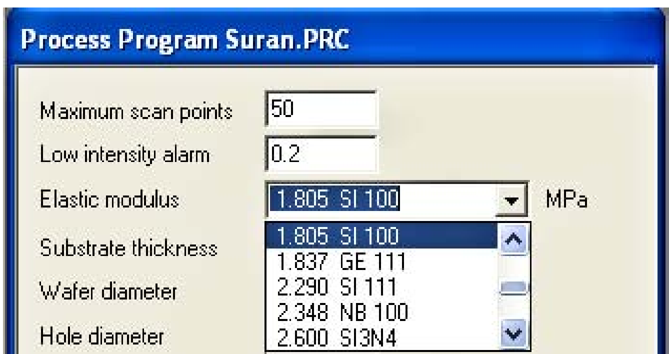
2. The Process Program sets up parameters for different wafers. An incorrect process program may give erroneous results.



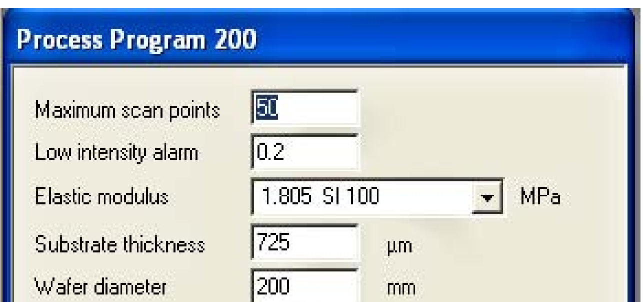
Maximum Scan Points- The default is 50. A single scan may have up to 1250 scan points. However only scans with 50 scan points may be saved.

Low Intensity Alarm- The default is 0.2 (this is amount of light reaching the detector in terms of voltage.) Typically a bare silicon wafer will reflect between 2.0 and 3.0 volts.

Elastic Modulus- This field is controlled by a drop down menu. The default is for silicon. Use the drop down menu to select a different material. If it is not in the menu, then go to the Materials Data Base and enter the new material and its properties.



Substrate Thickness- This is in terms of micrometer (µm). Example below shows an 8 inch wafer that is 725µm thick. Substrate thickness can be adjusted during the "First Scan" or after the measurements in the Editor menu. It's best to be as accurate as possible.

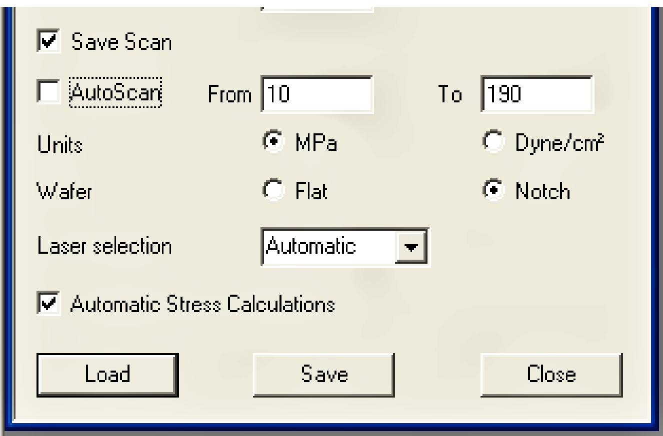


Wafer Diameter- This is in terms of millimeters. 8 inch = 200mm, 6 inch = 150mm, 5 inch = 125mm, 4 inch = 100mm

Hole Diameter- This is also in terms of millimeters. This is used for measuring stress on disk with a hole in the center. This feature may also be used to skip a portion of the center of the wafer when measuring.

Save Scan- When this checkbox is checked, the software will save the data from the scan for future use or review. Save Scan may only be used when there are 50 scan points.

AutoScan - When this checkbox is checked, the software automatically disregards the outer 10%. For example: a 200mm wafer with Auto Scan checked will take points from 20mm to 180mm. The outer 10% typically has noise and is not as important as the inner 90%. With the box unchecked you may enter a beginning and end point in terms of mm (Left to Right from left edge of wafer). Example below shows the box unchecked and a scanning section from 10 mm to 190 mm selected (disregarding the outer 5%).



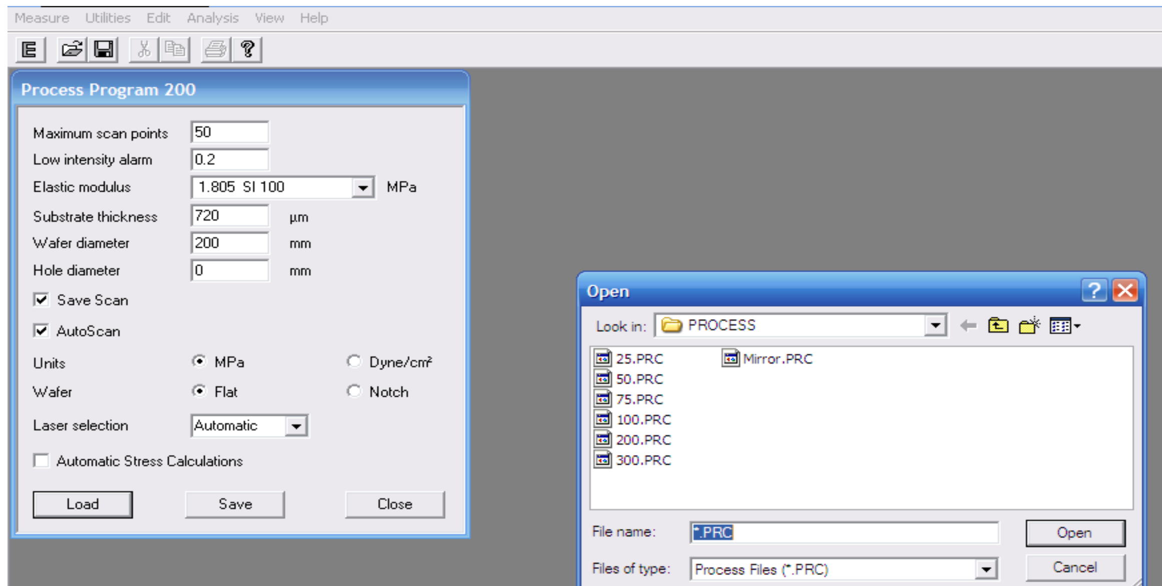
Units-The default is MPa. It is also possible to select Dyne/cm^2.

(1MPa=1 x 10^7 Dyne/cm^2)

Wafer- choices are Flat and Notch. Most wafers have a flat. Typically 8 inch wafers have a notch.

Laser Selection- “670nm” is the Red laser (vertical laser). If you select “670nm” the tool will deliberately use the 670nm laser when doing scans with this Process Program. “780nm” is the infrared, yellow (horizontal laser). When “780nm” is selected, the tool uses only the 780nm for scans. “Both” selects both lasers together for the scans. Most often it is best to select “Automatic”. When on “Automatic”, the tool takes one sample point with each laser and then automatically chooses the laser with the best intensity. Different materials reflect the two wavelengths differently.

Automatic Stress Calculation- This box can only be checked if there are 50 scan points in the Process Program. This feature will calculate stress. If this box is not checked, the tool will only do radius and deflection calculations.

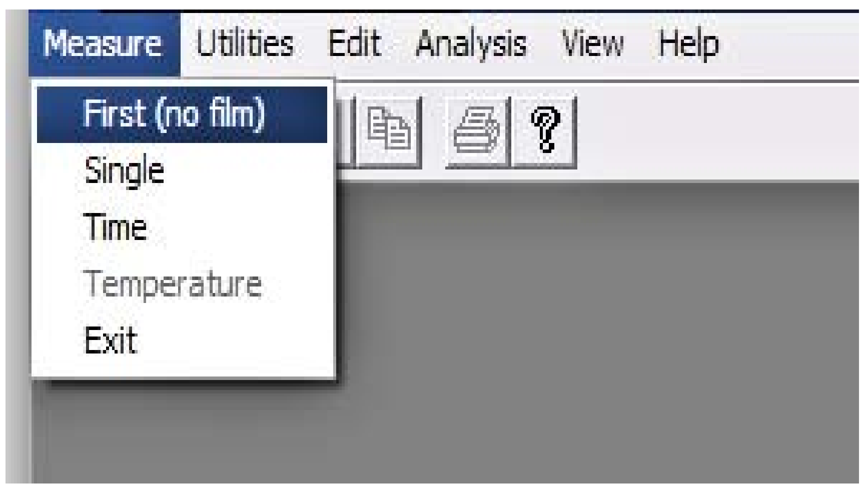


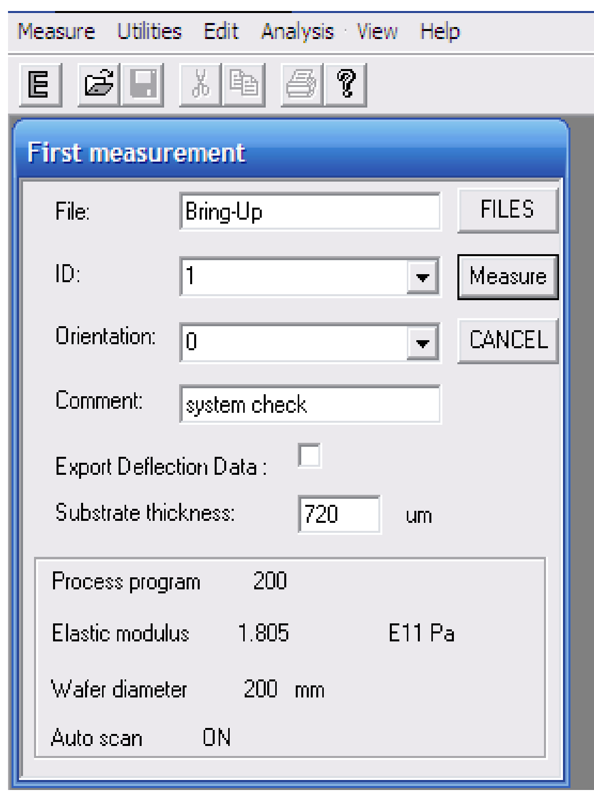
Load- The Load button allows you to recall previously created Process Programs. Process Programs have ".PRC" as extensions. Process Programs are saved in the "PROCESS" folder by default. Any user may access the "PROCESS" folder.

Save- The Save button saves the Process Program in the "PROCESS" folder.

Close- The Close button closes this window. The most recent Process Program brought up will be the Process Program used when going to do a First Scan.

3. Now that your Process Program is set to the desired parameters, close the Process Program window. Select the "Measure" tab on the main screen. Select "First (no film)"





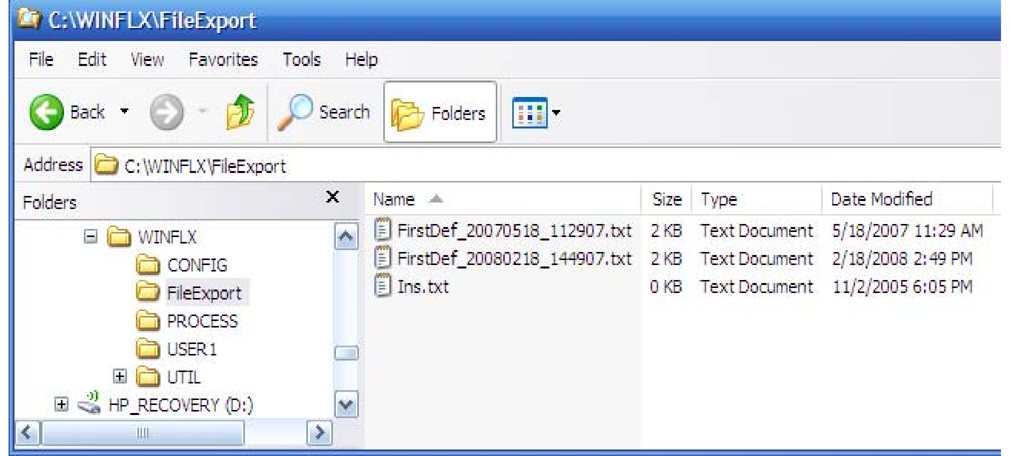
File: you can either create a new File (folder) for the data from this scan to be stored in, or you can recall an existing File by pressing the "Files" button and selecting a file from the selections in the window that pops up. It will be important to know the name of the file that contains the ID for the wafer you're calculating the stress of.

ID: This is the Identity of the wafer. The ID is how the instrument correlates the First Scan (pre-deposition) to subsequent Scans (post-deposition.). Be sure every wafer is given a unique ID.

Orientation: The default is 0. This field enables the user to identify the orientation of the diameter that is being measured. That way the first scan and the single, time, or temperature scans will be over the same diameter of the wafer. This is very important for 3-D mapping.

Comment: The comment field is for the user to easily identify scans when looking in the editor menu. There will be many scans, and the comment has no effect on the scans.

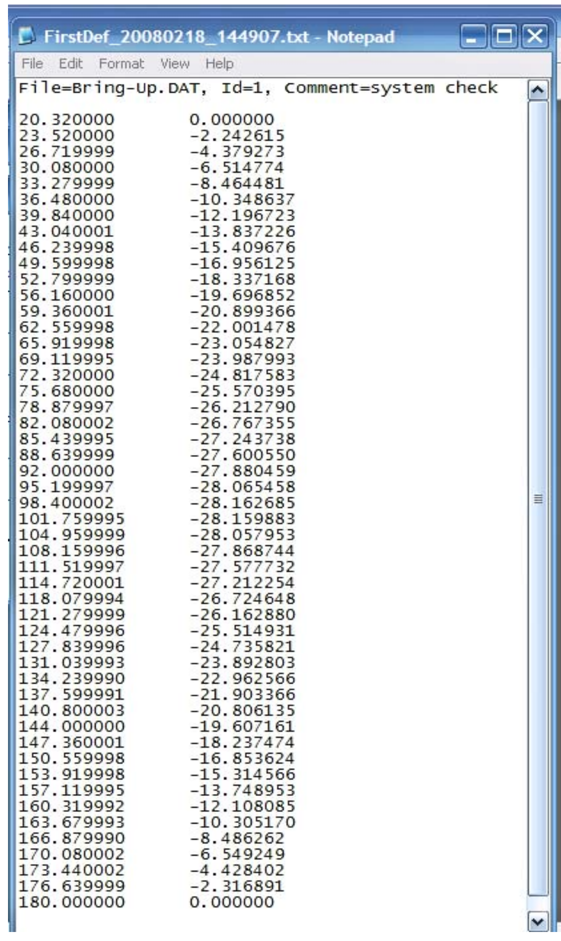
Export Deflection Data: If this box is checked the position on the wafer and the position on the detector will be exported to a file for every one of the 50 points. The file goes to C:\ WINFLX\File Export. It is stored as a ".TXT" file.



The image to the right is an example of the TXT file created when the "Export Deflection Data" box is checked. The first column is the position on the wafer from left to right. Notice the first point at approximately 20mm (indicative of Auto-Scan being selected).

The second column is the deflection. The farthest point from 0 is the "bow". In the example "-28.16" is the bow. This is in terms of micrometers (µm)

The beginning and end point of the scan will always be 0's.



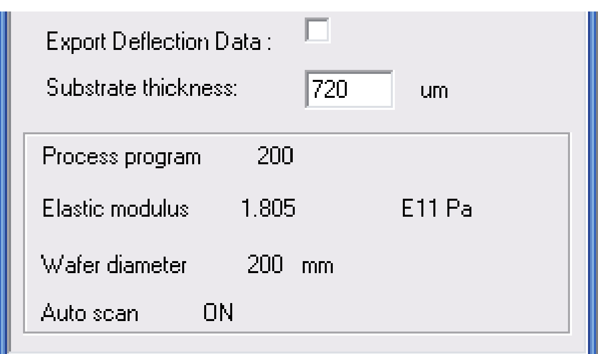
FirstDef_20080218_144907.txt - Notepad

File Edit Format View Help

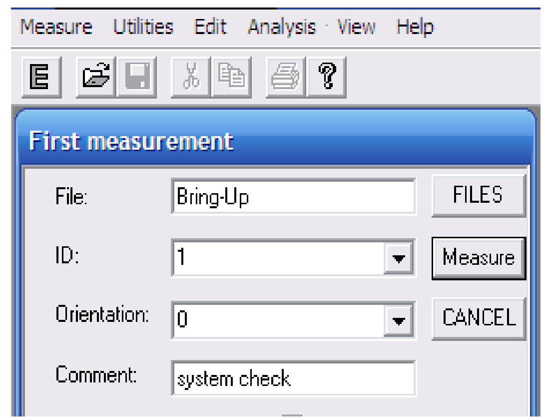
```
File=Bring-Up.DAT, Id=1, Comment=system check

20.320000	0.000000
23.520000	-2.242615
26.719999	-4.379273
30.080000	-6.514774
33.279999	-8.464481
36.480000	-10.348637
39.840000	-12.196723
43.040001	-13.837226
46.239998	-15.409676
49.599998	-16.956125
52.799999	-18.337168
56.160000	-19.696852
59.360001	-20.899366
62.559998	-22.001478
65.919998	-23.054827
69.119995	-23.987993
72.320000	-24.817583
75.680000	-25.570395
78.879997	-26.212790
82.080002	-26.767355
85.439995	-27.243738
88.639999	-27.600550
92.000000	-27.880459
95.199997	-28.065458
98.400002	-28.162685
101.759995	-28.159883
104.959999	-28.057953
108.159996	-27.868744
111.519997	-27.577732
114.720001	-27.212254
118.079994	-26.724648
121.279999	-26.162880
124.479996	-25.514931
127.839996	-24.735821
131.039993	-23.892803
134.239990	-22.962566
137.599991	-21.903366
140.800003	-20.806135
144.000000	-19.607161
147.360001	-18.237474
150.559998	-16.853624
153.919998	-15.314566
157.119995	-13.748953
160.319992	-12.108085
163.679993	-10.305170
166.879990	-8.486262
170.080002	-6.549249
173.440002	-4.428402
176.639999	-2.316891
180.000000	0.000000
```

Substrate Thickness: This field will have a default thickness that was entered in the Process Program. The field is adjustable. Rather than make several Process Programs, you may use the same Process Program for several wafers that share diameter and material attributes, but slightly differ in thickness.



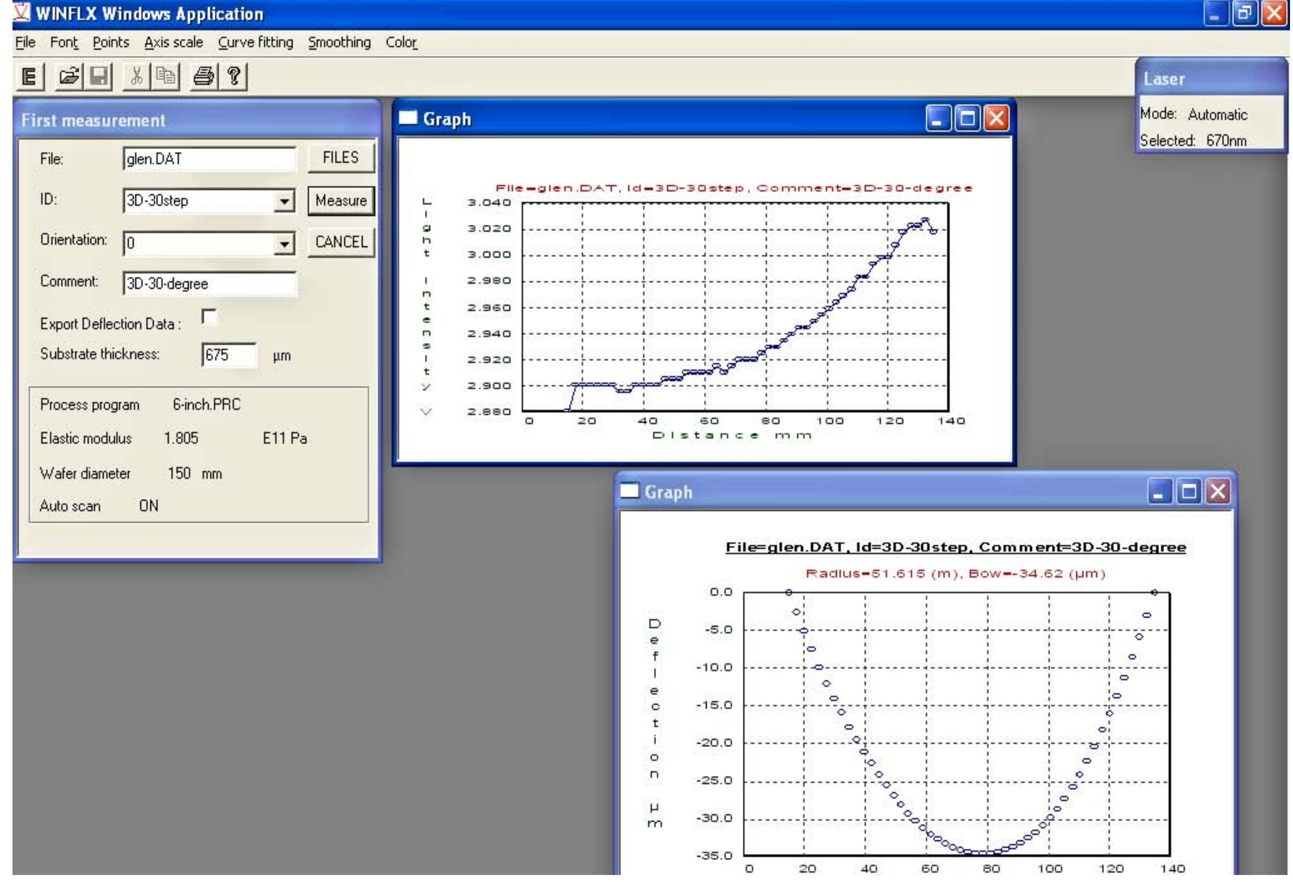
The bottom box of the window reminds you of the name of the Process Program, The Elastic Modulus selected, The Wafer Diameter, and whether Autoscan is ON or OFF.



Measure: The measure button will start the scan. The entire scan will take about 20 seconds. You should hear the linear motor moving the Laser assembly. Measuring requires an ID, a file to send the data to, and a substrate thickness.

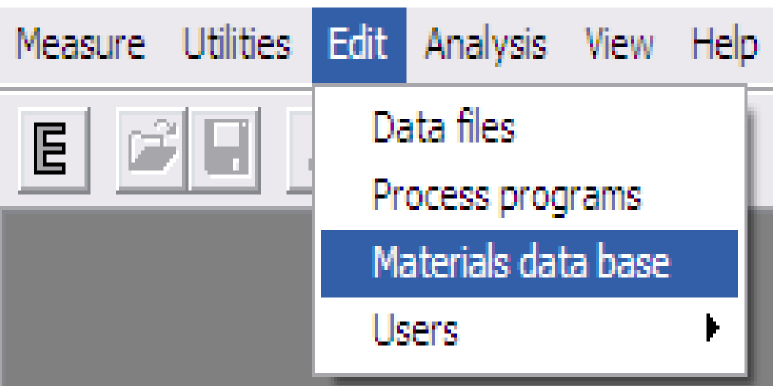
At the beginning of the scan, a window will pop-up in the upper right hand corner telling which laser was selected. At the end of the scan 2 windows will pop-up. There will be a graph of the intensity at each point and a graph of Radius, Bow, and Deflection. These windows will only close by pressing "Cancel" on the "First Measurement" window. To recall these graphs later, you must "save graphs".

Cancel: Pressing the "Cancel" button will close all of the pop-up windows and exit you from the "first measurement" mode. Although the graphs will not be saved unless you deliberately save them, the data from the scan is automatically stored. Scan information can be reviewed in the editor menu.

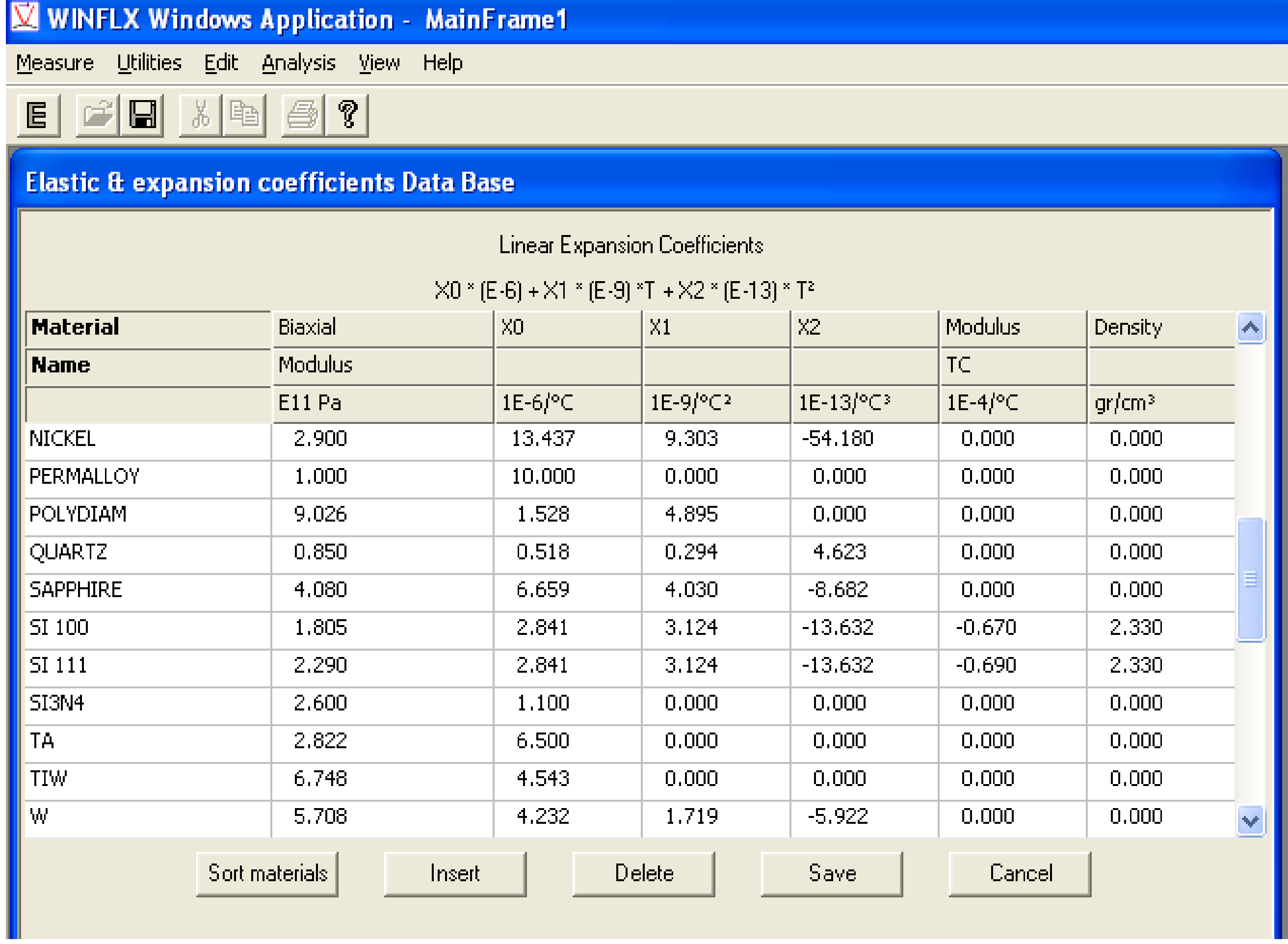


3.3 Materials Database

New materials can be added to the Materials Database. TOHO provides several choices for the substrate material in the Process Program drop down menu. If the elastic modulus properties of a material is known, it can easily be added to the Materials Database.

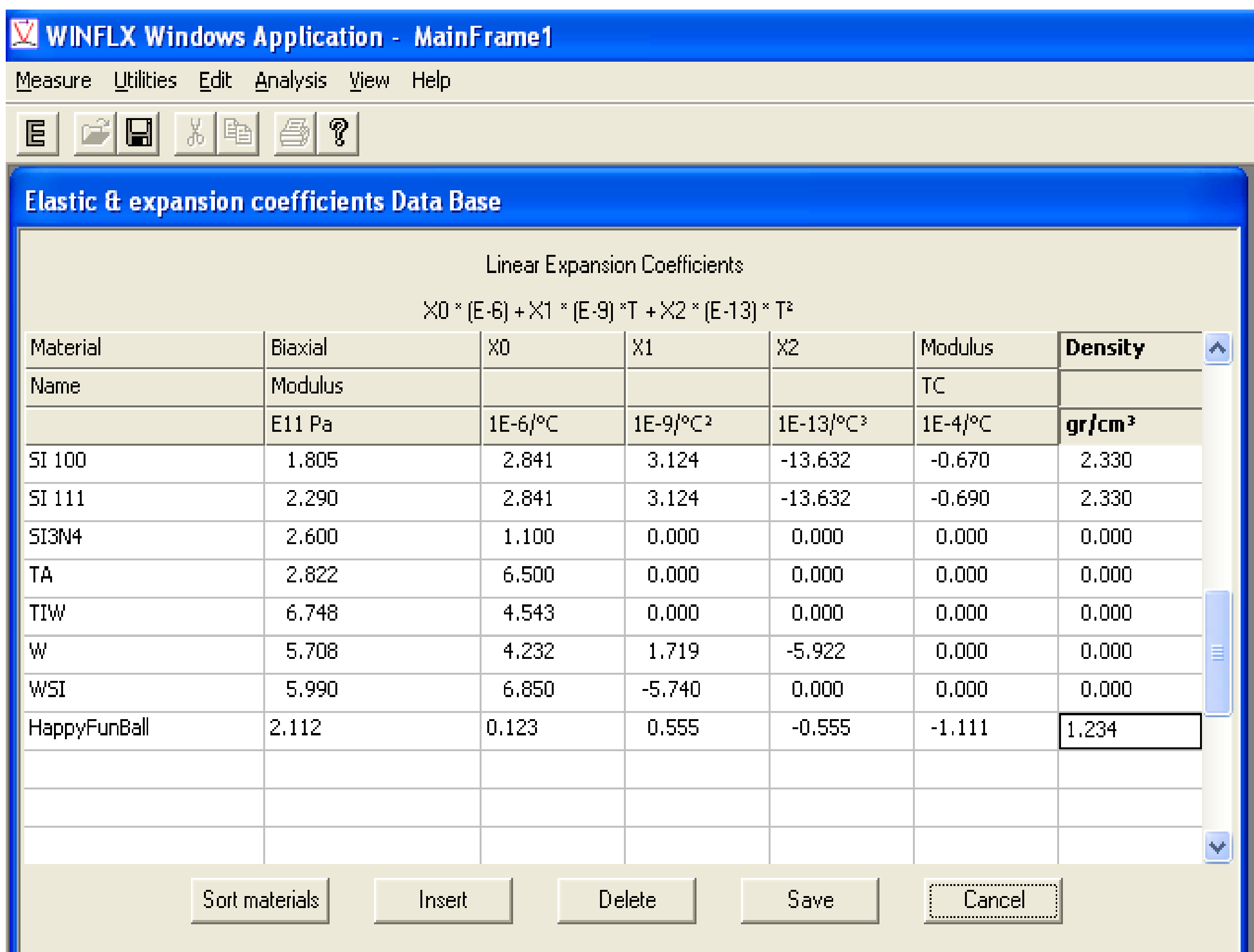


1. Select "Materials data base" from the "Edit" tab.
2. The materials are sorted alphabetically by name.

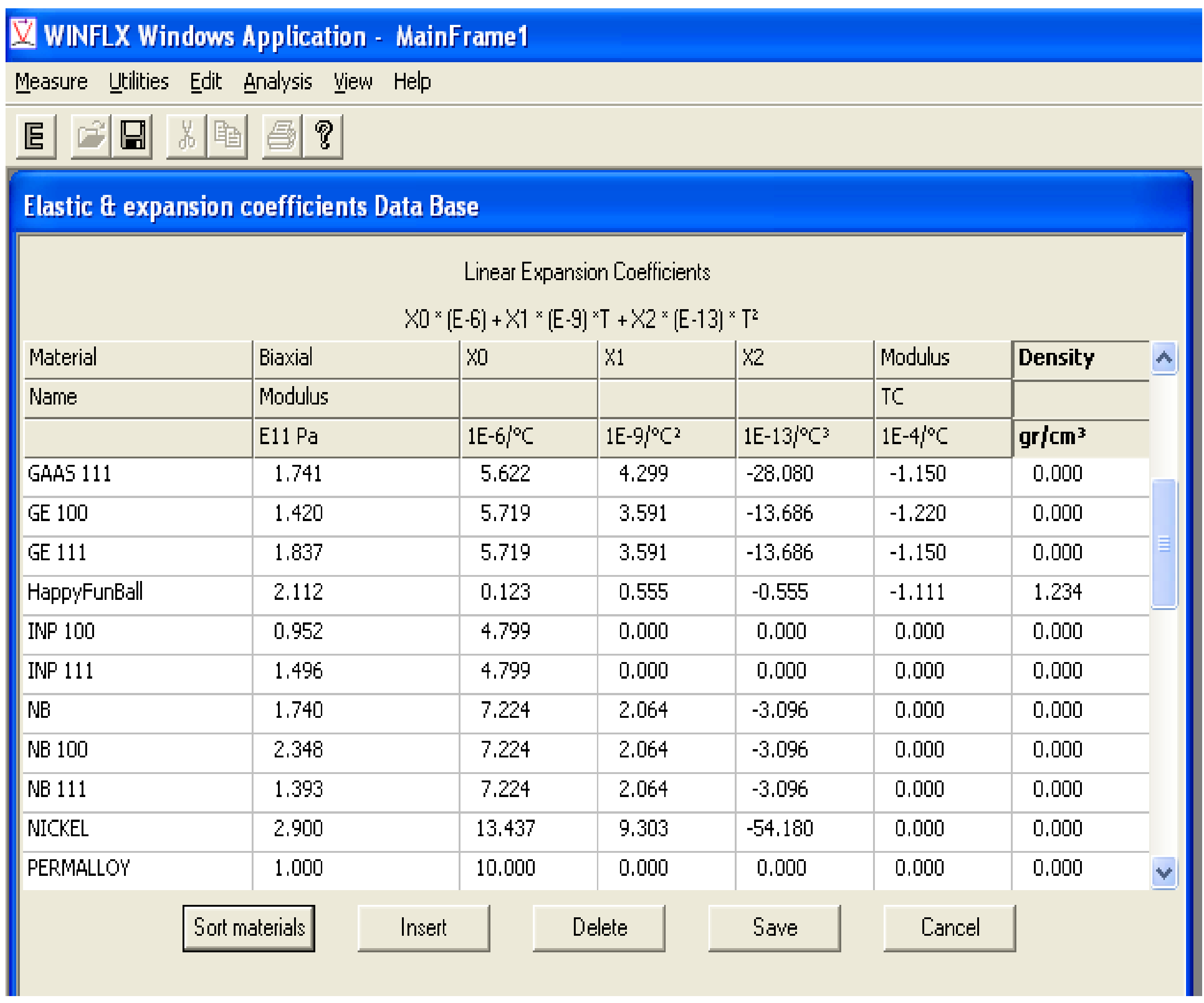


Material Name	Biaxial Modulus E11 Pa	X0 1E-6/°C	X1 1E-9/°C²	X2 1E-13/°C³	Modulus TC 1E-4/°C	Density gr/cm³
NICKEL	2.900	13.437	9.303	-54.180	0.000	0.000
PERMALLOY	1.000	10.000	0.000	0.000	0.000	0.000
POLYDIAM	9.026	1.528	4.895	0.000	0.000	0.000
QUARTZ	0.850	0.518	0.294	4.623	0.000	0.000
SAPPHIRE	4.080	6.659	4.030	-8.682	0.000	0.000
SI 100	1.805	2.841	3.124	-13.632	-0.670	2.330
SI 111	2.290	2.841	3.124	-13.632	-0.690	2.330
SI3N4	2.600	1.100	0.000	0.000	0.000	0.000
TA	2.822	6.500	0.000	0.000	0.000	0.000
TIW	6.748	4.543	0.000	0.000	0.000	0.000
W	5.708	4.232	1.719	-5.922	0.000	0.000

3. **To edit an existing coefficient**:
   - Use TAB to move the cursor to the coefficient line and click once to highlight the first field for editing.
   - After editing each field, press TAB to move to the next field. To erase the entry in a field, use the backspace key. To exit a field without editing it, press TAB. When you press TAB in the last field of the line, the cursor moves to the next line.
2. **To add a new coefficient on a blank line:**
   - Enter the name of the material in the first field, the biaxial modulus (in Pa) in the second field, and the linear expansion coefficients in the next three columns. After entering a value in a field, press TAB to move to the next field. To erase the entry in a field, use the backspace key. When you TAB in the last field of the line, the cursor moves to the next line.



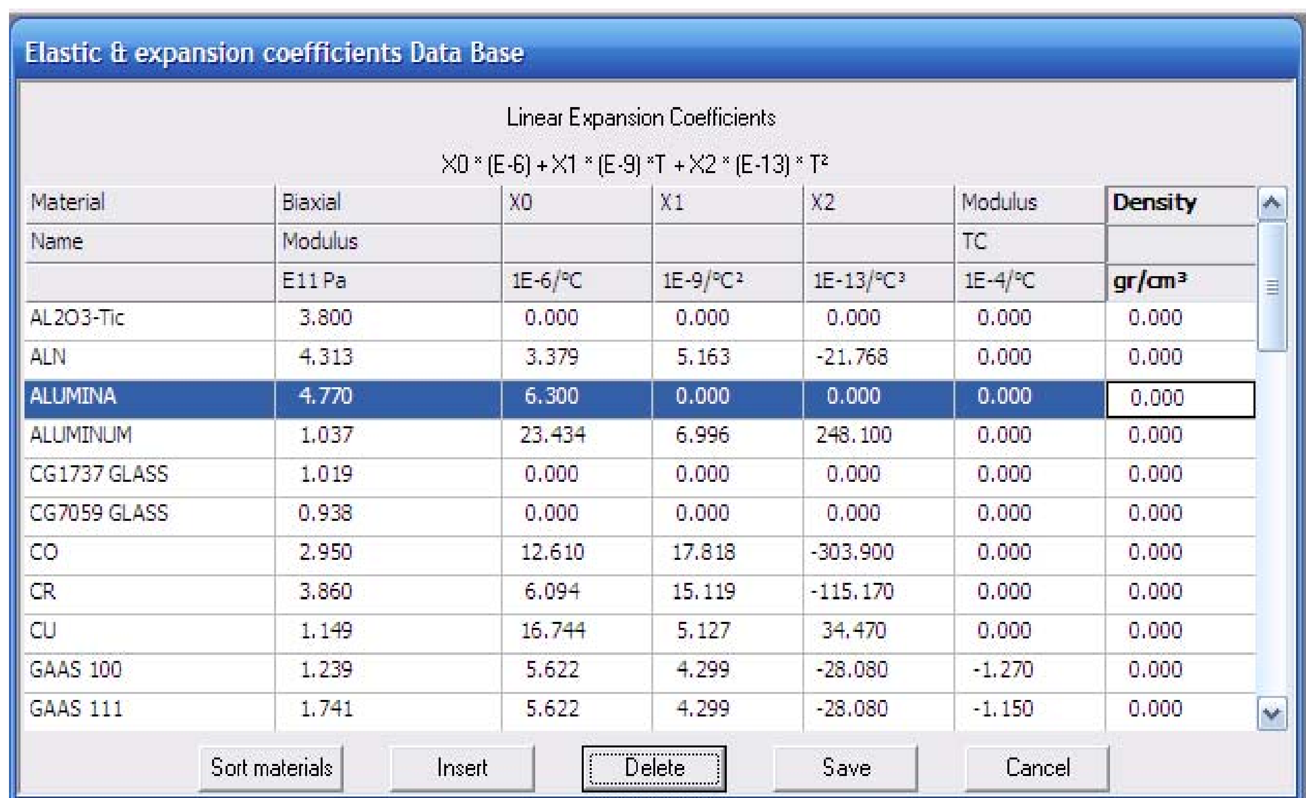
4. Once the properties of the material have been entered, Click the “Save” button to save the material in the Materials Database.
5. Clicking the “Sort materials” button will alphabetize the materials.



Material Name	Biaxial Modulus E11 Pa	X0 1E-6/°C	X1 1E-9/°C²	X2 1E-13/°C³	Modulus TC 1E-4/°C	Density gr/cm³
GAAS 111	1.741	5.622	4.299	-28.080	-1.150	0.000
GE 100	1.420	5.719	3.591	-13.686	-1.220	0.000
GE 111	1.837	5.719	3.591	-13.686	-1.150	0.000
HappyFunBall	2.112	0.123	0.555	-0.555	-1.111	1.234
INP 100	0.952	4.799	0.000	0.000	0.000	0.000
INP 111	1.496	4.799	0.000	0.000	0.000	0.000
NB	1.740	7.224	2.064	-3.096	0.000	0.000
NB 100	2.348	7.224	2.064	-3.096	0.000	0.000
NB 111	1.393	7.224	2.064	-3.096	0.000	0.000
NICKEL	2.900	13.437	9.303	-54.180	0.000	0.000
PERMALLOY	1.000	10.000	0.000	0.000	0.000	0.000

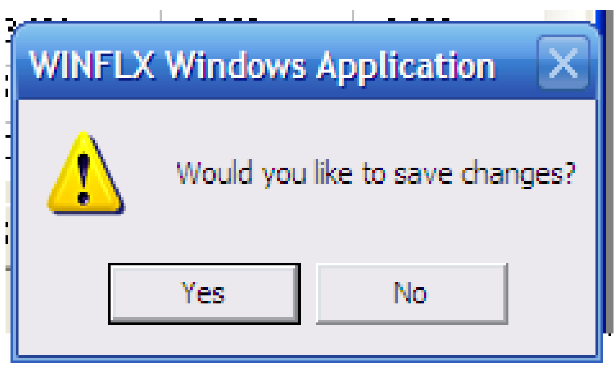
6. **Deleting a Material from the Materials Database**,

- Select a cell. Then hold the “shift” key and select the right-most cell of the row. The row should highlight.
- Then press the “Delete” button.



Material Name	Biaxial Modulus E11 Pa	X0 1E-6/°C	X1 1E-9/°C²	X2 1E-13/°C³	Modulus TC 1E-4/°C	Density gr/cm³
AL2O3-Tic	3.800	0.000	0.000	0.000	0.000	0.000
ALN	4.313	3.379	5.163	-21.768	0.000	0.000
ALUMINA	4.770	6.300	0.000	0.000	0.000	0.000
ALUMINUM	1.037	23.434	6.996	248.100	0.000	0.000
CG1737 GLASS	1.019	0.000	0.000	0.000	0.000	0.000
CG7059 GLASS	0.938	0.000	0.000	0.000	0.000	0.000
CO	2.950	12.610	17.818	-303.900	0.000	0.000
CR	3.860	6.094	15.119	-115.170	0.000	0.000
CU	1.149	16.744	5.127	34.470	0.000	0.000
GAAS 100	1.239	5.622	4.299	-28.080	-1.270	0.000
GAAS 111	1.741	5.622	4.299	-28.080	-1.150	0.000

7. If changes have been made to the Materials Database, (deleting materials, adding materials, changing properties, etc....) then a prompt window will appear upon exiting.



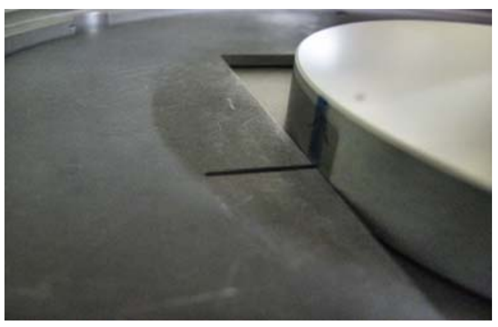
8. Click “Yes” to save the changes to the Materials Database.

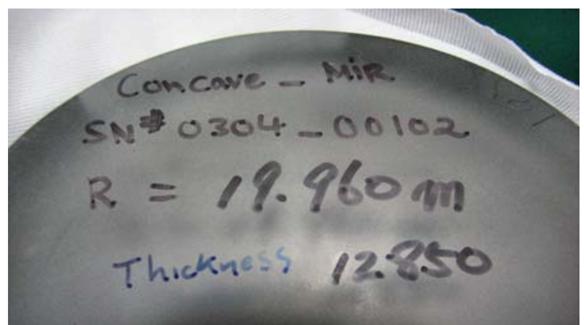
3.4 Verifying the Instrument is in Calibration

3.4.1 Calibrated Mirror Verification:

If the user has purchased the optional mirror set, they can set the appropriate Process Programs and measure the mirrors. The mirror set should come with a Certification. The 20 meter (approximately 20 meters, spec sheet should specify exact radius - e.g. 19.96m) should measure within 5% of the nominal value.

1. Set up a Process Program for the mirrors; they are typically 100mm in diameter and 12,700 mm thick (substrate thickness). The picture below to the right is the bottom of a radius 20 meter mirror. The actual radius is 19.960m. The actual substrate thickness is 12,850mm. The serial number is also on the Certification Record. It's recommended practice to write this information on the bottom of the mirrors.



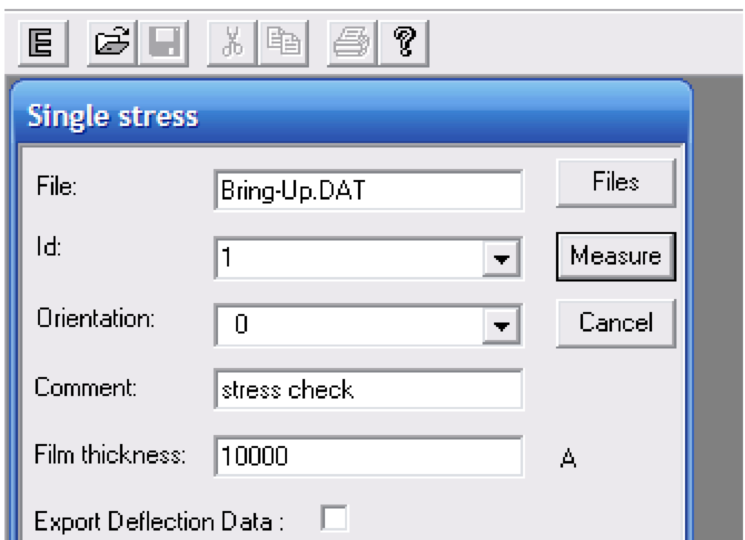


2. Place the Mirror Positioning Ring on the stage. The Mirror Positioning Ring has a square cut out. There is a hash mark that should face up. The hash mark will be to the left. This will line up with a hash mark on the side of the mirrors. This is to ensure that the same diameter is always measured. Locate the mirror in the corner of the square that is far and to the left of the user.

3.4.2 Calibrated Wafer Set

If the user has purchased the optional calibrated wafer set, they can set the appropriate Process Programs and measure the calibrated Stress. The mock Stress should read within 5% of the Certified Stress

1. Set the Process Program up for your Wafer set. Be sure to use the thickness and diameter from the Certification.
2. Use Wafer A for the first scan. Perform the scan and then close (cancel) the First Scan Window.
3. Exchange Wafer A for Wafer B. Select “Single Scan” from the “Measure” tab. Select the ID from the drop down menu that is the same ID that was used for the first scan for wafer A.



Enter the film thickness specified on the Certification. Typically it is 10,000 angstroms. (10,000 A)

The resulting Stress should be within 5% of the Certified Stress if the tool is in calibration.

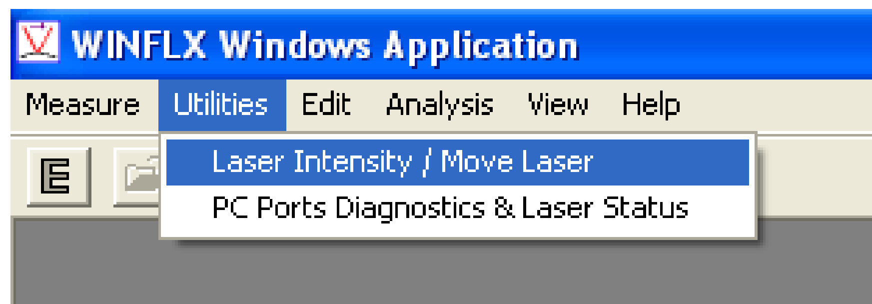
Take note that the flat or notch oriented to the right is considered 0 degrees. (Like the origin in Geometry). The flat away from the user is considered 90 degrees (rotating counter clock wise).

Wafer is at 0 degrees

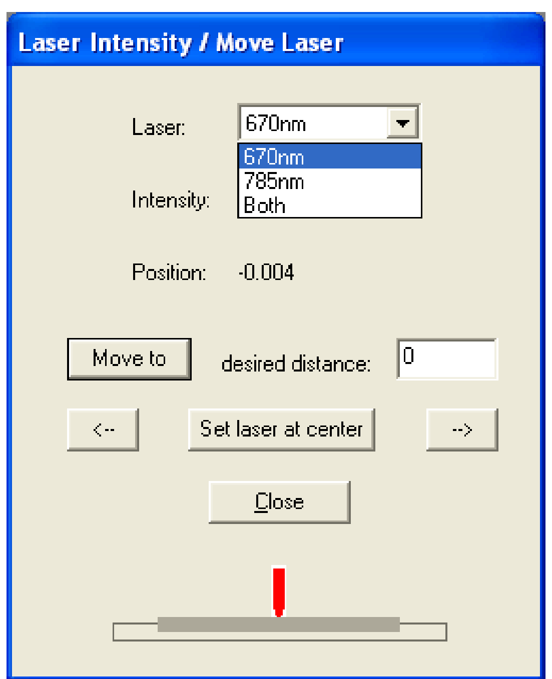
Wafer is at 90 degrees

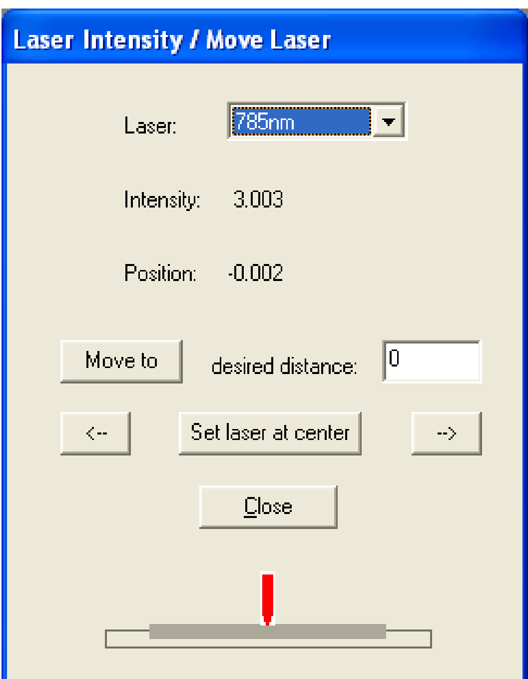
3.4.3 Utilities Menu Checking Position & Intensity:

1. Place a bare silicon wafer on the stage.
2. Click on the "Utilities" Menu from the main screen.



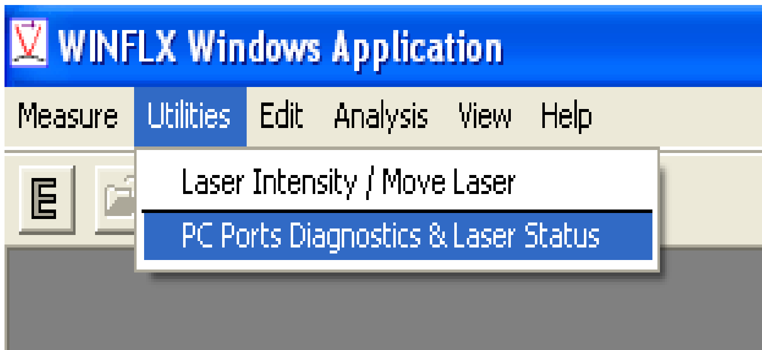
3. Select "Laser Intensity/ Move Laser"



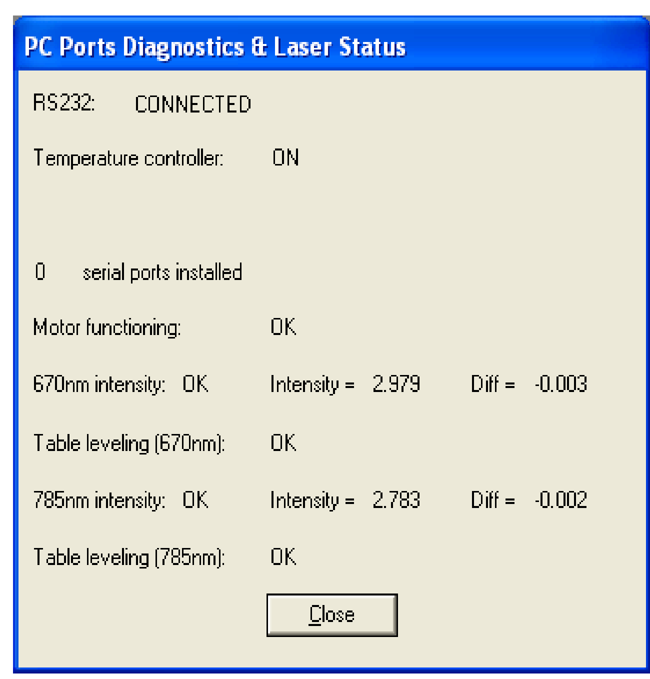


4. You can select 670nm, 780nm, or both lasers.
   - The intensity for the 670nm laser (red or vertical) is nominally 3.08. The spec is from 2.58 to 3.58.
   - The intensity for the 780nm laser (yellow or horizontal) is nominally 2.75. The spec is from 2.25 to 3.25
   - The nominal intensity for both lasers is 3.08 + 2.75 = 5.83

5. **Position**: Position refers to the position on the detector. The nominal position (DIFF) is 0.000. The tool is in spec from -0.100 to + 0.100.
6. **Set Laser at Center**: When this Utility Menu is opened, the tool will automatically move the laser to the center of travel across the wafer. This button is used as a reset in case you've moved the laser.
7. **Move to desired distance**: This field lets you enter a relative distance in terms of millimeters for the laser to move. Negative numbers will move to the left; positive to the right. This is a RELATIVE movement. It is possible to command the laser beyond its stroke and jam the motor. Be very careful to check the laser's position before you give it a command! There is a graphic that will indicate where the software believes the laser is pointing.



8. **PC Ports Diagnostics & Laser Status:**
   - Select the "PC Ports Diagnostics & Laser Status" selection from the Utilities Menu. This will show the DIFF (position on the detector) and the Intensity for both lasers simultaneously.



- **RS232**: Refers to the I/O cable.
- **Temperature Controller:** Refers to the Eurotherm on the front of the tool.
- **0 Serial Ports installed:** Tells you the communications with the PC is OK.
- **Motor functioning:** Tells you the feedback from the motor encoder is OK.
- **Table Leveling:** Refers to the stage. If this Utility Menu says "CW" (clockwise) or "CCW" (counter-clockwise), it is referring to the adjustable thumb screw. Toho recommends NOT adjusting the thumb screw. The leveling was done at the factory and is locked in place. A "CW" or "CCW" reading in this Utility Menu usually means the wafer isn't sitting flat on the 3 ball bearings.

3.4.4 INSTALLING AND UPGRADING SOFTWARE

Toho Technology installs the FLX-2320-S software before the instrument is shipped. However, if a serious software or hardware problem occurs, you might need to reinstall the software. You will also need to install upgrades to the software. Use the instructions in this section to reinstall software. For upgrades, follow the instructions provided with the upgrade diskettes.

To reinstall the software:

1. Insert the FLX-2320-S software CD or diskette into the disk drive.
2. Exit the FLX software.
3. From the Program Manager in windows, choose Run from the File menu.
4. When setup is completed, reboot the system.
5. Type *a:setup* and press OK.
6. Start the FLX software.

4 PERFORMING MEASUREMENTS

4.1 STRESS MEASUREMENTS

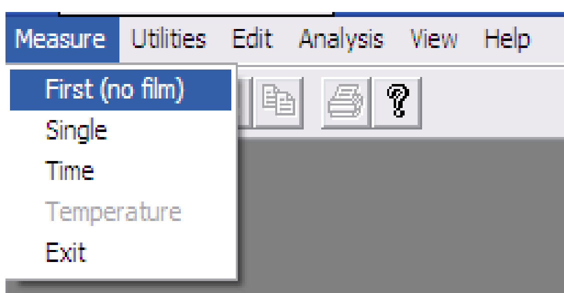
Stress measurements involve setting up a Process Program, taking a measurement of the undeposited wafer, and finally a measurement of the deposited wafer. The Toho FLX-2320 instrument also provides the option of taking stress measurements at specified intervals over a specified length of time and taking stress measurements as a function of temperature. All these measurement options are described in the following sections.

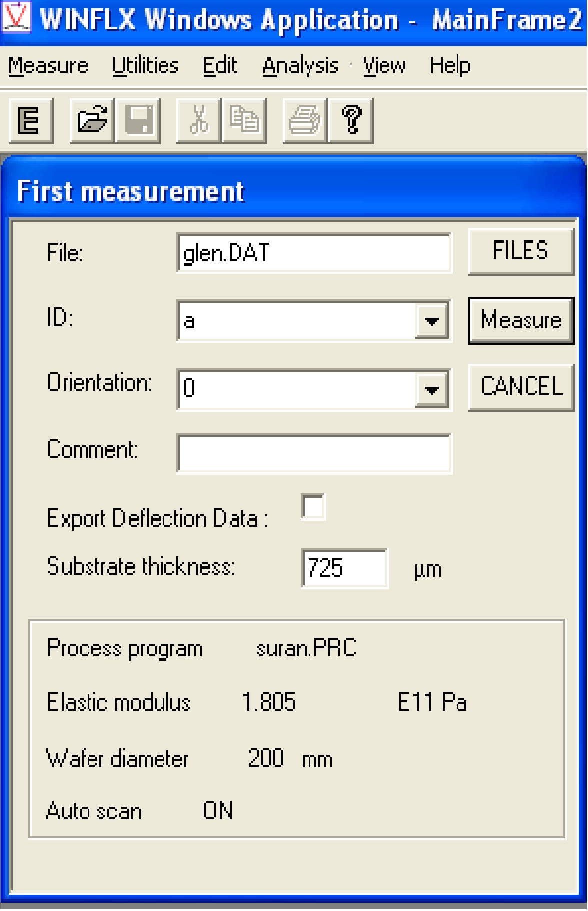
Process Program

Choose or create the correct Process Program for the wafer before you perform the first measurement (no film).

4.1.1 First Measurement (No Film)

1. Place wafer in the instrument. Be sure the correct Process Program is chosen. Be sure the instrument power is on, and the lasers are switched on.

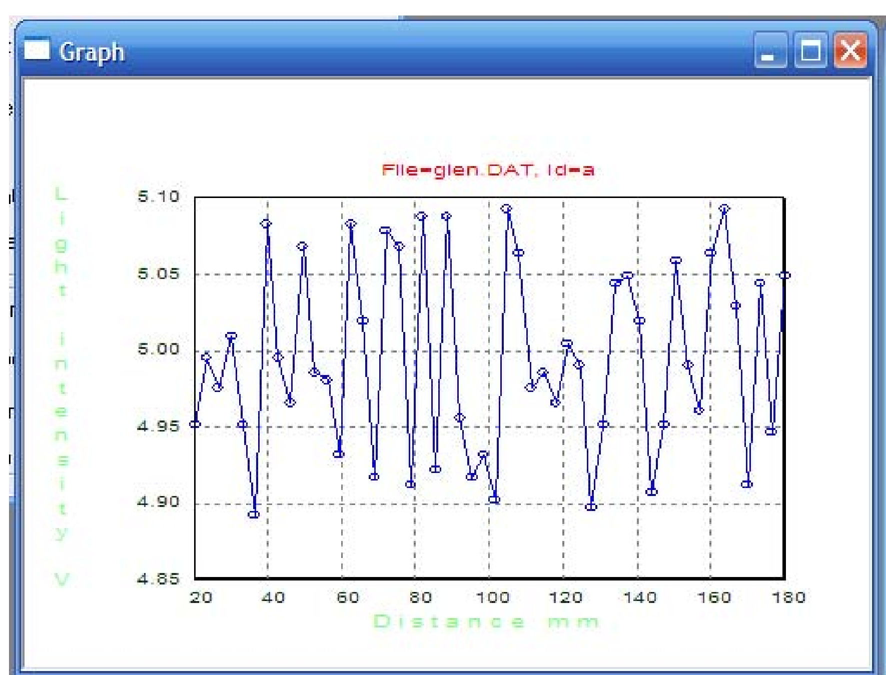




2. Go to measurement tab. Select "First (no film)"
3. Verify the Process Program is the intended Process Program. (e.g. suran.PRC)
4. Verify the substrate thickness is correct, the field allows you to adjust if more accurate thickness is known. (e.g. 725 µm)
5. Be sure to give this wafer a unique "ID" (identity). The ID is what will corollate the wafer's pre-deposition scan to its post deposition scan.
6. When all parameters are set properly, click the "Measure" button.

7. Three windows will pop-up. The first will be the laser selection window. This will be a small window that appears in the top right corner.

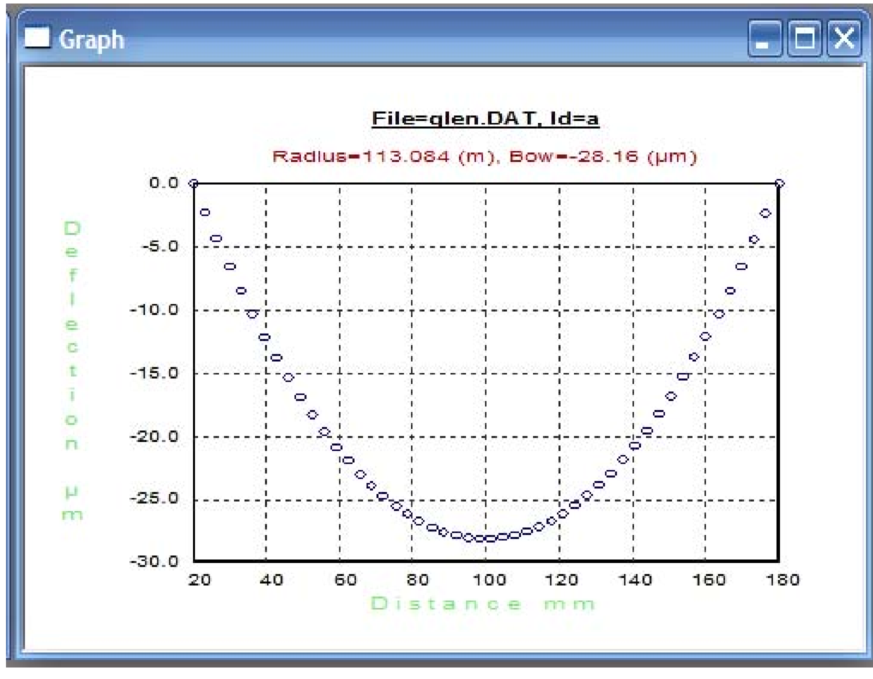
8. The next two graphs will pop-up at the end of the scan. They will be the Light Intensity graph and the Deflection graph.



The Light Intensity graph is a function of the amount of light in terms of voltage (light intensity) over position on the wafer in terms of millimeters.

Each point represents a scan point. (e.g. at 100mm the light intensity was 4.90 volts)

These windows will not close with the conventional windows X box in the upper right hand corner. You need to press “Cancel” on the “First Measurement” window to close these windows.



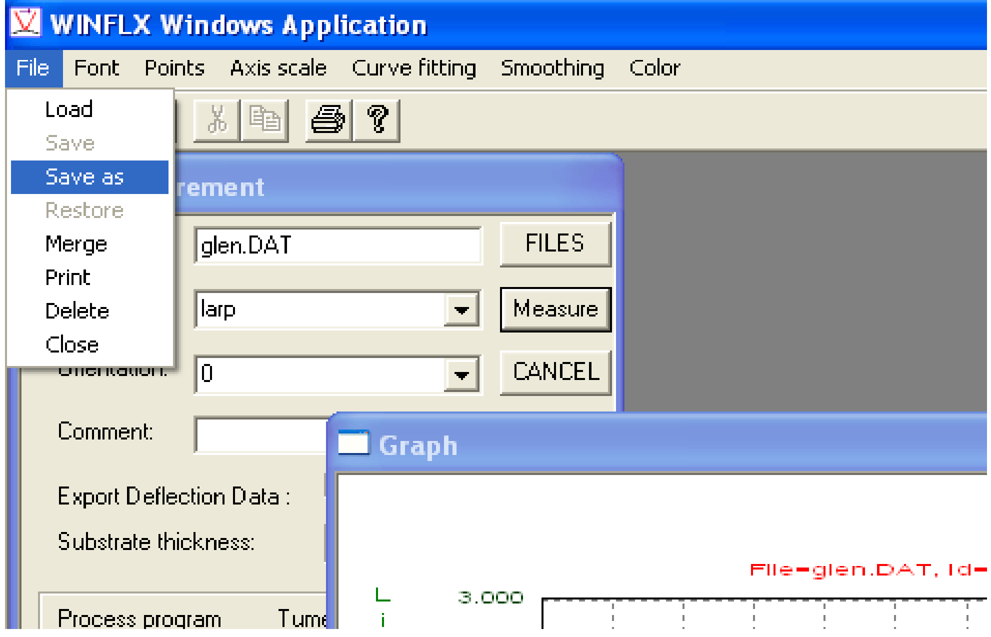
The deflection graph is a function of bow (in microns) over position on the wafer in millimeters.

The tool will always consider the first point of the scan and the last point of the scan to be 0. Points bowing below that line will be considered to have a negative bow, above the line will have a positive bow.

NOTE: The default font is short and fat, be sure not to confuse an equal sign “=” for a negative sign “-”.

(e.g. Bow = -28.16mm)

9. **Saving Graphs -** If you want to save these graphs that pop-up, do not press "Cancel" on the First Measurement window until the graphs have been saved. To save the graphs, go to the "File" tab and select "Save As". These files have to be saved individually. The most forefront window (boldest border) will be the graph saved. Both graphs can be saved, just not at the same time. Graphs are saved as ".GRP" files. These can be recalled and analyzed at a later time.

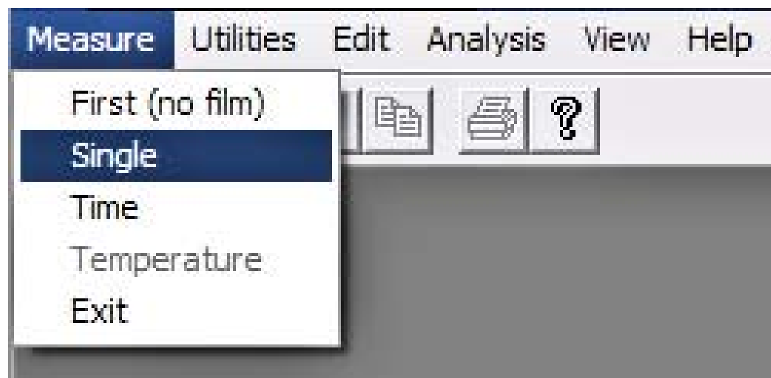


10. Note that if you measure the sample again using the same ID, a second record is created and saved without overwriting the first record. The most recent record is used as the valid record when measuring stress after deposition.

4.1.2 Single Scan

Once the deposition has been made on the wafer, place it back on the stage inside the tool. This measurement will generate a stress measurement.

1. Select "Single" from the Measure tab on the main screen.



2. The “Single Stress” window will appear.

File: The file field will tell you where the data is going to be stored. It also tells you from which file it will seek wafer ID’s. You can write in the file name in the field or press the “files” button to navigate and select a file.

ID: In the Single Scan Mode, ID’s are available in the drop-down menu. Be sure to select the correct ID for the wafer you’re measuring Stress on.

Orientation: This field may only be changed with the use of the drop -down menu. The default is 0. This is primarily used for 3-D scans.

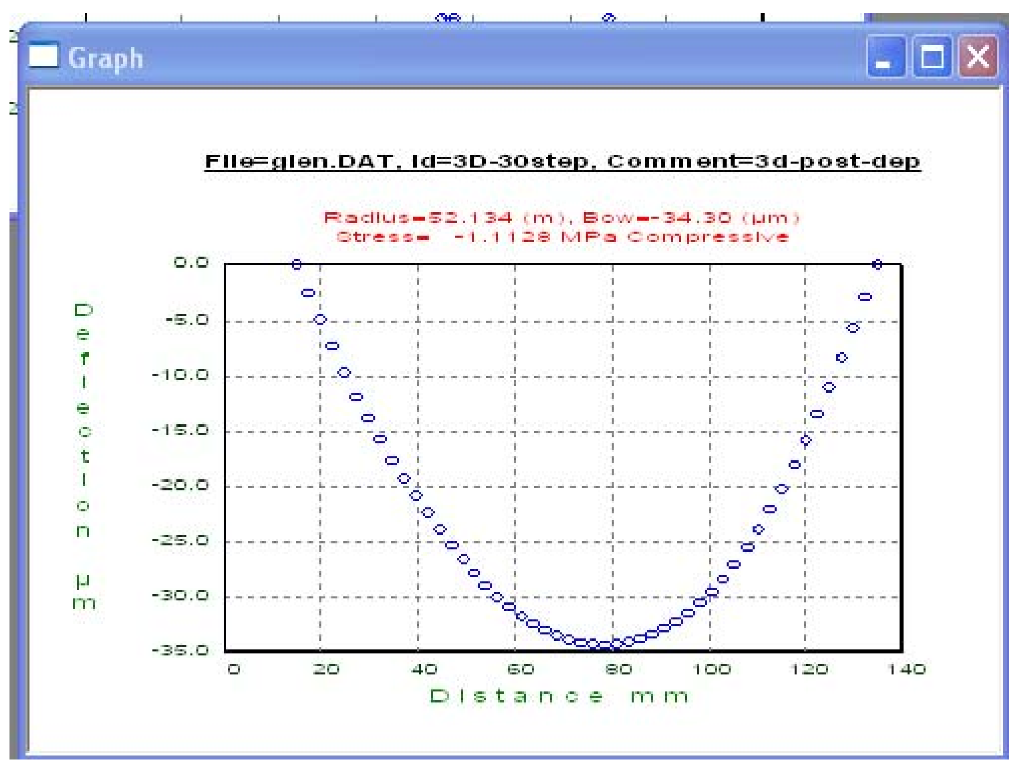
Comment: Just like before, this field is for the user’s benefit when navigating several scans in the Editor menu. This field cannot affect the measurement.

Film Thickness: This is in terms of angstroms. There will be an error message if this field is left at 0.

Export Deflection Data: When this checkbox is checked, the deflection data for each point is exported to a file.

3. Press the “Measure” button. The instrument will perform a scan.
4. Next, the following windows will appear: Laser Selection, Intensity Graph, and Deflection Graph. The Deflection Graph will include the Stress calculation.

5. The Stress reading will appear underneath the Radius and Bow readings above the graph. (e.g. -1.1129 MPa). The instrument will also indicate whether the Stress is Tensile or Compressive.

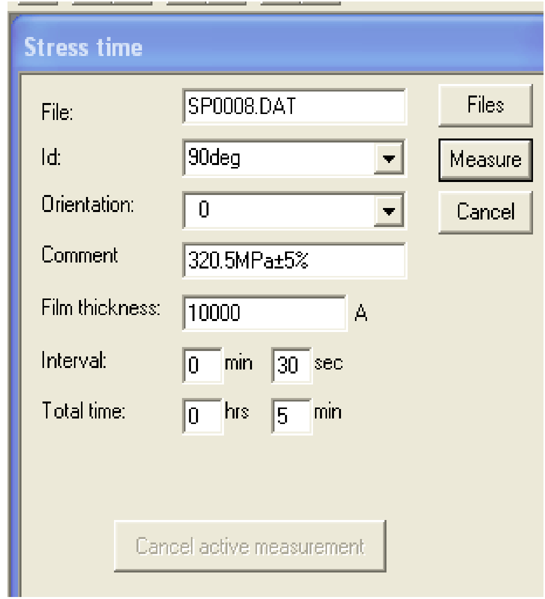


6. To recall this graph later, it must be saved, before cancelling out of these windows.(See 4.1.1 Item #9)

4.1.3 Time Measurement

Time measurements are several scans over an amount of time up to 99 hours and 59 minutes, typically with intervals of 30 seconds. The stress-time measurement reveals kinetics such as water absorption in oxides, densification, phase transformations, and stress relaxation. Note that the total number of records in a data file is limited to 1000. Therefore when doing a 20 hour Time Measurement the minimum interval is 1 minute and 12 seconds (20hrs = 1200minutes= 72000 seconds/1000 = 72 seconds = 1min 12 seconds) This may also be used to determine the repeatability of the instrument on a known and stable stress.

1. Go to the “Measure” tab on the main screen. Select “Time”.



Stress Time measurements require all of the same data inputs as Single Measurements. The only additional information you must provide is the time interval in between scans.

File: Verify the File name that the scans will go to is the desired file for all of the several scans.

ID: Be sure this is the intended Identity of the wafer. The drop down menu will allow choosing from all of the wafer IDs in the selected file.

Orientation: The default will be zero. The drop down menu will give the choices of all the orientations of this particular ID within this particular File. Verify the orientation is the angle to be measured (especially if it was an angle different from the default of Zero).

Comment: This has no effect on the scan. It is for the user's convenience.

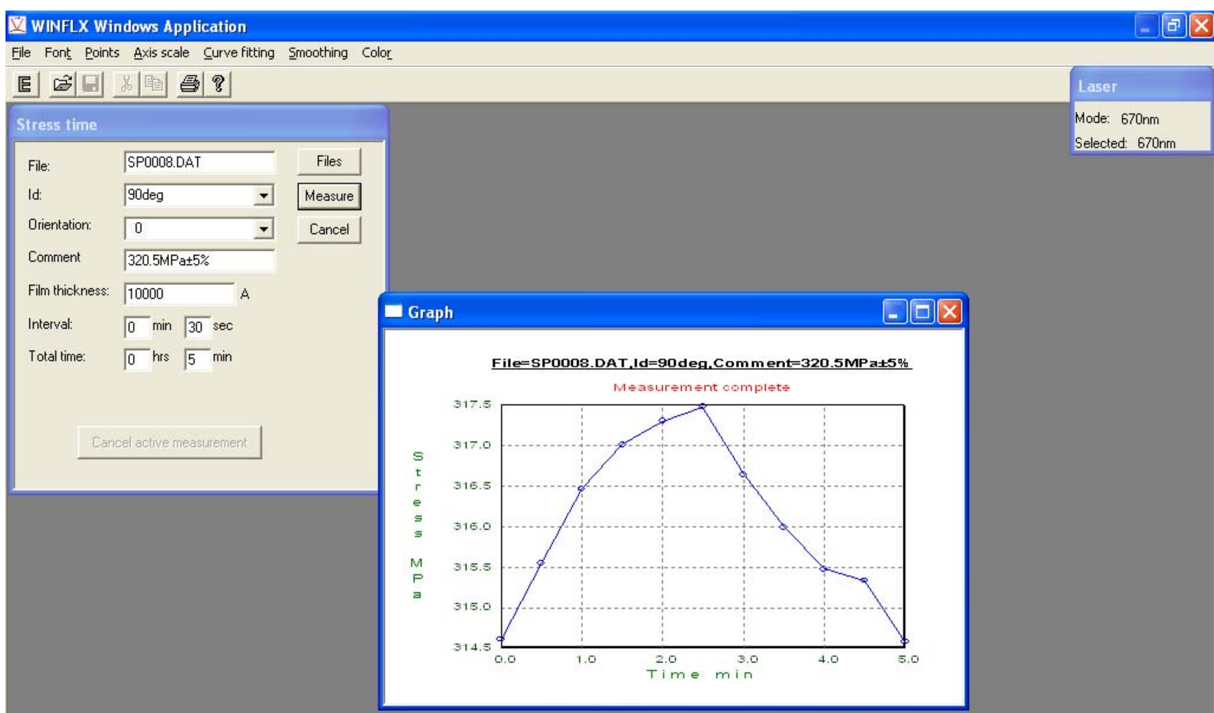
Film Thickness: Must be entered, otherwise an error will pop-up "Cannot have a Thickness of Zero". This is in terms of Angstroms.

Interval: This is the time in between the start of each scan. The quickest interval the instrument can perform is 30 seconds. You may have intervals of up to 99 minutes.

Total Time: This can be up to 99 hours and 59 minutes. Any total time of 8 hours and 20 minutes or less may have intervals of 30 seconds. Any total time that is longer than that may only have intervals that will give a maximum total of 1000 scans.

Cancel Active Measurement: Time measurements might be very long. It is always possible to stop the instrument from completing a test. If the "Cancel Active Measurement" button is pressed, the instrument will complete the current scan (it may seem as though it is performing one last scan). It will then stop. All of the completed scans will still be saved automatically. They can be recalled in the editor menu.

After the first scan of a time measurement, a pop-up window will appear and begin a plotting function. Each scan's stress will be plotted over time. Remember, the graphs will always "scale", so even though the arc of the graph is dramatic, the actual values may be virtually the same. In the example below, notice the range of stress is very small and virtually the same.



Like all the pop-up graphs, this graph must be saved in order to be recalled again. The X-Box in the coorner of the graph window will NOT close the window. The Minimize and Maximize buttons will work. To close the graph window press the "Cancel" button. Each scan's data, however, is automatically saved in the specified file.

4.1.4 Temperature Measurement

Use the Stress-Temperature Measurement mode to measure stress as a function of temperature on a wafer after deposition. The instrument uses temperature cycling to reveal stress changes. Temperature cycling causes stress changes due to thermal expansion, mismatch, volume changes, and plastic deformations.

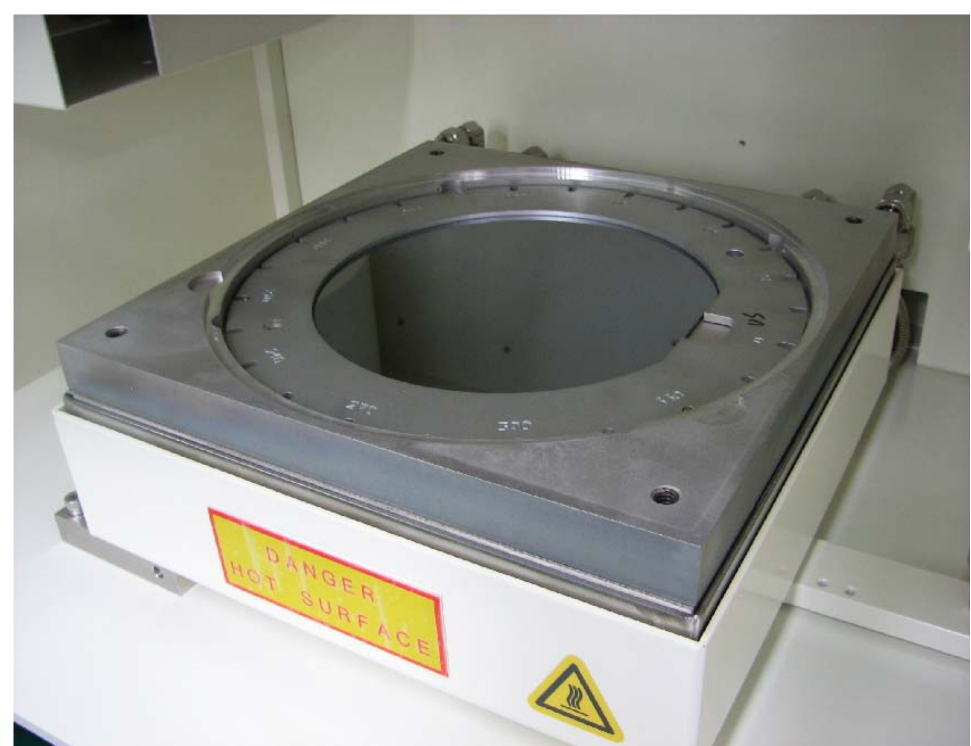
NOTE: There are 2 methods of compensation for the refraction of the quartz plate.

1st- Performing the first measurement (no film) with the quartz plate. This is the simplest method.

2nd- Subtracting the offset. Perform a "Single Scan" when the wafer stage is at a similar temperature to its First Scan. Then subtract this measured stress as an offset from the subsequent Temperature measurements.

Procedure for Temperature Measurements

1. Install the wafer locator ring on the hot plate measurement platform and place the wafer, face up, in the ring.



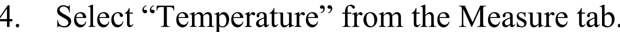
2. Place the quartz plate above the wafer on the inside ledge of the stage.

3. Place the Heat Shield on top of the stage. The cut-outs go to the back for the plumbing. The slot will go across the wafer from left to right. This is where the laser shines through to the wafer. The four thumb-screws are for location. Just get them started. There is no need for any significant torque.

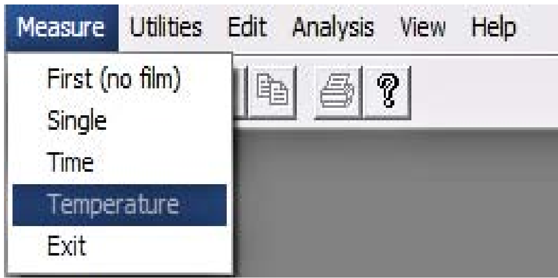
WARNING: There is no interlock for the door. It is possible to open the door when the Stage is very hot. Please use caution when opening the door. Check the Eurotherm temperature. This top reading is from a thermister inside of the hot plate.

The Eurotherm readings are in Celsius. The top temperature is the temperature of the stage (e.g. 48°C). The bottom temperature is the current set point. (e.g. 45°C)

Do not adjust the Eurotherm via the buttons on the front. All of the controls needed are within the WinFLX software.

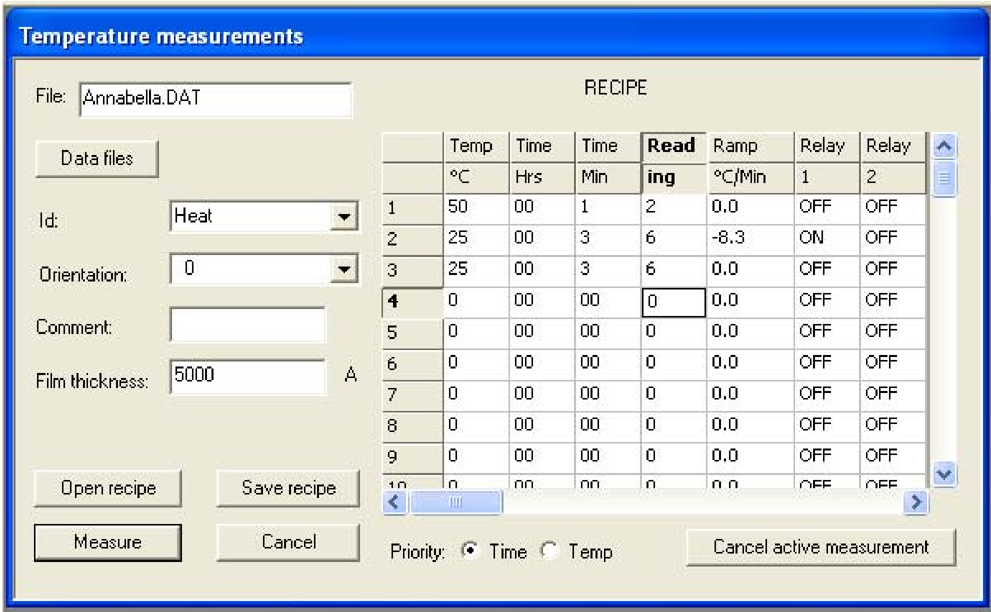


4. Select "Temperature" from the Measure tab.



All the fields displayed in the Stress-Temperature dialog box can be edited; entering information in the Comment field is optional.

5. Enter the filename in the **File** field (the software assigns the extension.DAT automatically) to save the data points. To save the data into a previously existing file, click on the **Data files** button, a file selection dialog box displays. Choose the desired filename from the list.

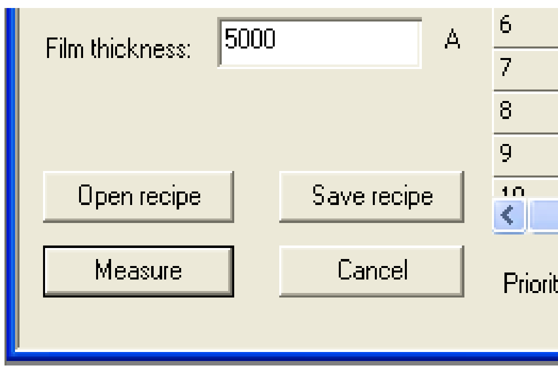


ID: This drop down menu will give the choice of any ID of a wafer that is within this selected file.

Orientation: The default will be zero. The drop down menu will give the choices of all the orientations of this particular ID within this particular File. Verify the orientation is the angle to be measured (especially if it was an angle different from the default of Zero).

Comment: This has no effect on the scan. It is for the user's convenience.

Film Thickness: Must be entered, otherwise an error will pop-up “Cannot have a Thickness of Zero”. Thickness values are entered in terms of Angstroms.

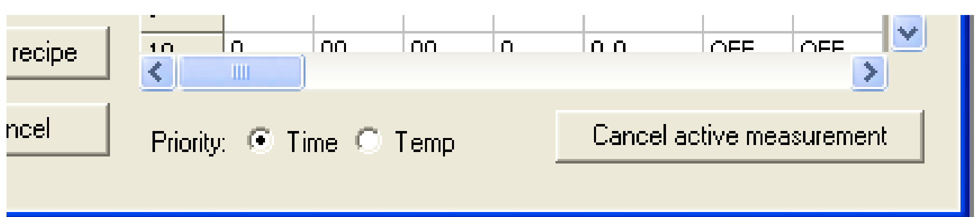


Open Recipe: This button will open a file selection dialog box which will contain all the previously saved recipes within the selected file.

Save Recipe: This button will allow you to save the recipe you’ve created within the selected file.

Measure: Once the desired recipe is loaded or created, press this button to begin the measurements.

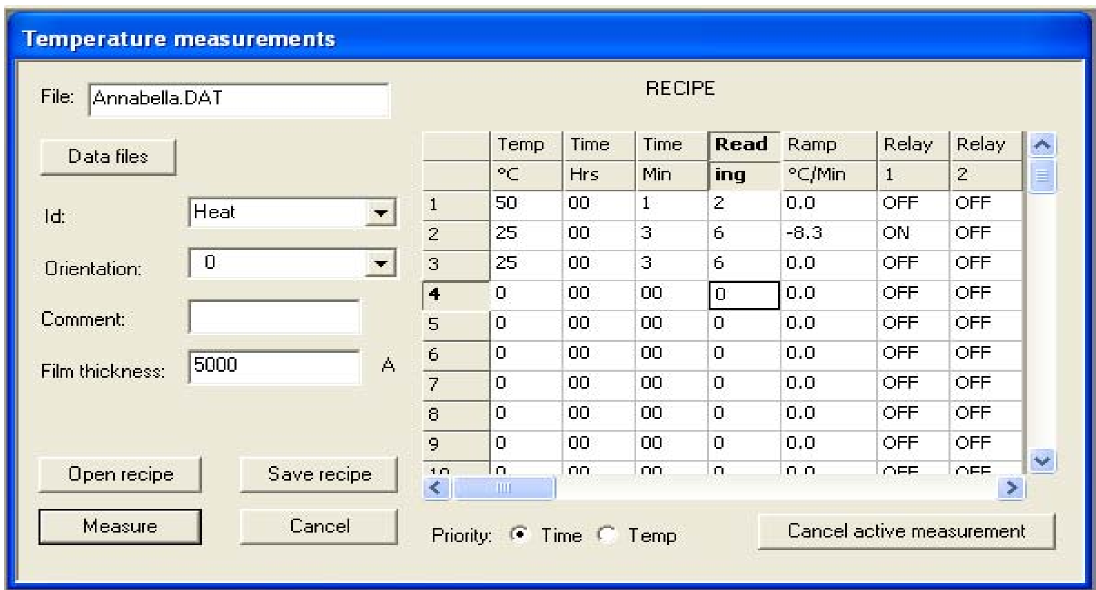
Cancel: This button will close the “Temperature Measurement” window, and the graph created during the temperature measurement.



Priority Time: With Priority Time selected, the instrument will do a measurement with respect to time elapsed. This is according to the recipe and is regardless of whether or not the programmed temperature was achieved. Select this if you want to get the measurements done in a specific amount of time.

Priority Temp: With Priority Temp selected, the instrument will perform a scan when the programmed temperature is actually achieved, regardless of how much time it takes.

Cancel Active Measurement: Temperature measurements might be very long. It is always possible to stop the instrument from completing a test. If the “Cancel Active Measurement” button is pressed, the instrument will complete the current scan (it may seem as though it is performing one last scan). It will then stop. All of the completed scans will still be saved automatically. They can be recalled in the editor menu.



Creating a Recipe

Each line of the Recipe is numbered and referred to as a “session”. The entire recipe when executed is referred to as an “Experiment”. The sessions are performed sequentially. The 4th column is different depending on the Priority selected. With “Time” selected the 4th column will be “Reading”. With “Temp” selected it will be “Temp Steps”.

Temp °C: The desired temperature to be achieved in this session.

Time Hrs: The number of hours spent during this session. The default is 0.

Time Min: The number of minutes spent during this session. The default is 0.

Reading: This column appears only with Priority of Time selected. It designates how many readings will be taken during this session. The instrument can only perform measurements as quickly as every 30 seconds. (As in the session above, the instrument can perform no more than 6 scans during the 3 minute session).

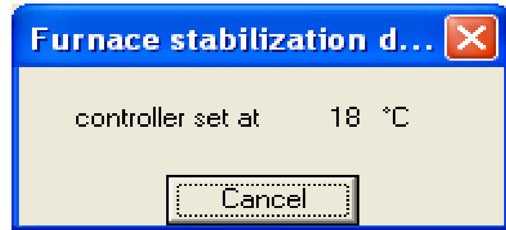
Ramp °C/Min: This is the temperature rate of rise. This will be automatically calculated once the Temp °C and Reading fields are entered. Entering a different value in this cell will adjust the Reading cell, if priority time was selected. If values are entered in both the Time and Ramp fields, the value in the Time field takes precedence.

Temp Steps: This column appears only with Priority Temp selected. This is how many scans the instrument will perform while trying to achieve the temperature. For instance if the session was climbing from 20°C to 90°C, to and the Temp Steps entered was 5, then there would be a measurement every 14°C. (34°C,48°C,62°C,76°C,90°C).

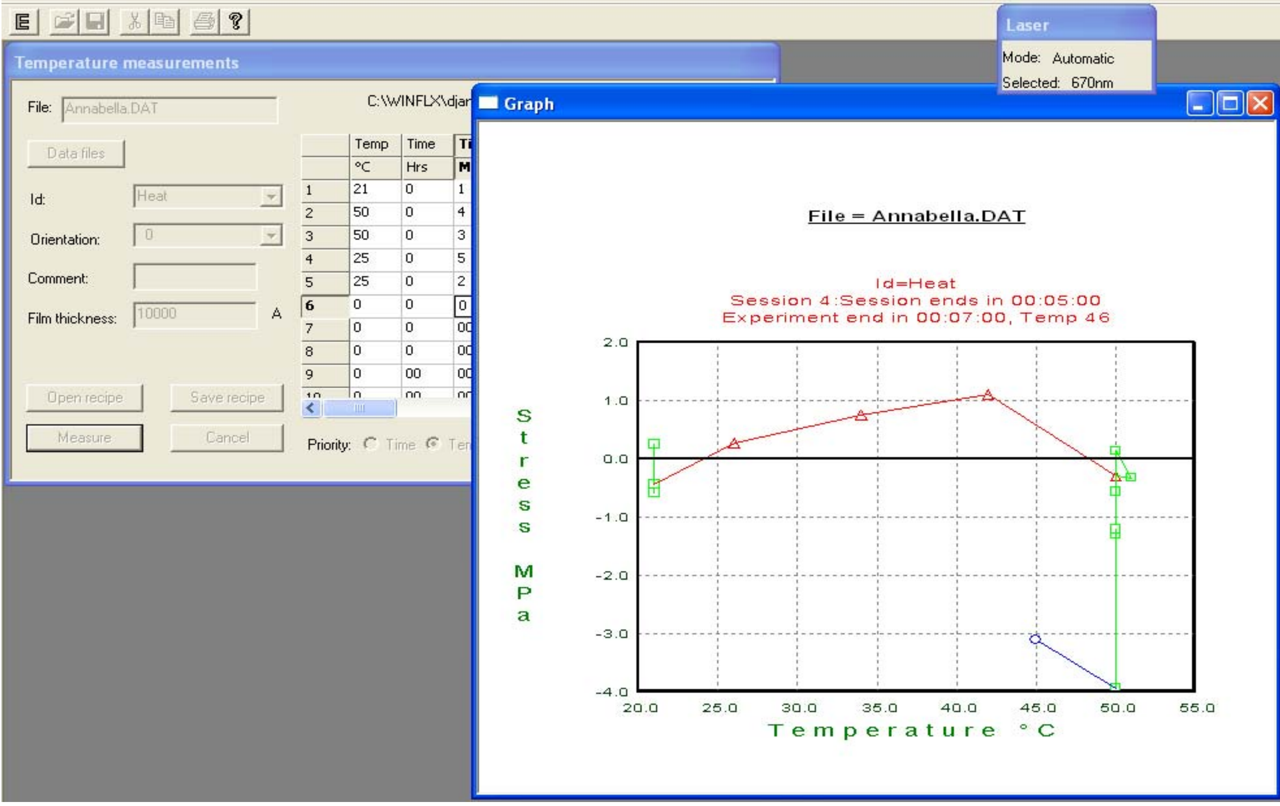
Relay 1: This is the solenoid valve on the back of the instrument. Turn it on for cooling sessions.

Relay 2: This column does not have a function for model 2320-S.

6. Once the appropriate recipe is loaded or created, press the “Measure” button. There will be a pop-up window titled ‘Furnace Stabilization”. It calibrates itself starting from 0°C up to the current room temperature. This sequence is not part of the time elapsed during the experiment. The clock begins once the instrument begins with its first scan.



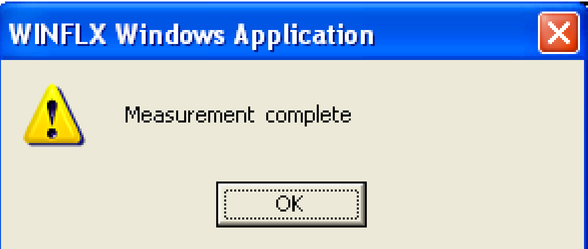
7. Once the Eurotherm is stabilized the experiment will begin and the pop-up graph will appear. This will plot Stress as a function over temperature. It will tell you which file the data is going to, the wafer Identity, the current session and time remaining therein, as well as the time remaining in the entire Experiment.

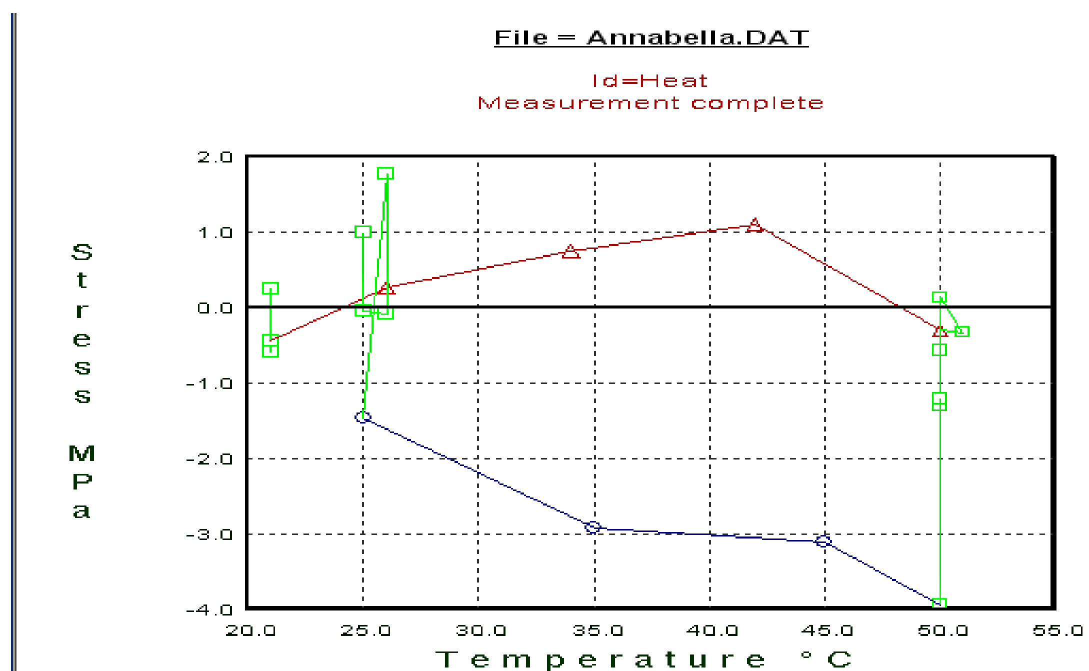


8. Green squares denote where sessions are holding a temperature. Red triangles and lines denote sessions with a temperature increase. Blue circles and lines denote sessions with a decrease in temperature.

9. When the final session of the Experiment has been completed the pop-up graph will read “Measurement Complete”. There will be an additional pop-up window that also reads “Measurement Complete”.

NOTE: If the last session of the experiment was a cooling step and Relay 1 was left on, the solenoid will stay on even though the experiment is over. once the “OK” button is clicked, then the solenoid will close again.





10. The pop-up graph that was created can be saved. Every scan will automatically be saved, however this graph can only be recalled if deliberately saved.
11. Be careful not to open the door until the stage has cooled to a safe temperature.

NOTE: Since it is not safe to manipulate the heat shield nor the wafer at high temperatures, a 3-D measurement cannot be done in conjunction with Temperature measurements.

4.1.5 Lo-Temp Measurement

1. Be sure the manual valve and liquid Nitrogen are attached to the instrument.

2. Set the pressure on the LN2 to 100psi (.7 Mpa)
3. Keep the manual valve closed until the cooling step of the recipe.
4. Be sure the solenoid valve is disconnected from the "cooling in" port on the back of the instrument.
5. Be sure the electrical connection from the solenoid valve IS connected. (there will be an error if that circuit is open.)
6. During any cooling step, manually open the valve that allows LN2 to flow into the "cooling in" port on the back of the instrument.
7. When the cooling step is over, close the manual valve.
8. For regular use, connect CDA (or Nitrogen) to the solenoid valve.
9. Connect the solenoid valve to the "cooling in" port on the rear of the instrument.

4.2 Performing 3-D Measurements

3-D measurements are groups of First measurements on the same wafer at different orientations. The more scans taken the more accurately representational the graph will be. Deflection and Radius graphs only require one series of Scans be they First scans or Single Scans. Stress graphs will require 2 groups of scans; one group of First scans before the deposition, and one group of Single scans post deposition.

The following table shows the intervals available. The locating rings have notches every 15 degrees. This allows the choice of 2,3,4,6, or 12 scans. Remember scans are diameters. (scan at 0 degrees has all the same points as a scan at 180 degrees)

Orientation (degrees)	**0**	**15**	**30**	**45**	**60**	**75**	**90**	**105**	**120**	**135**	**150**	**165**
2 scans	0						90					
3 scans	0				60				120			
4 scans	0			45			90			135		
6 scans	0		30		60		90		120		150	
12 scans	0	15	30	45	60	75	90	105	120	135	150	165

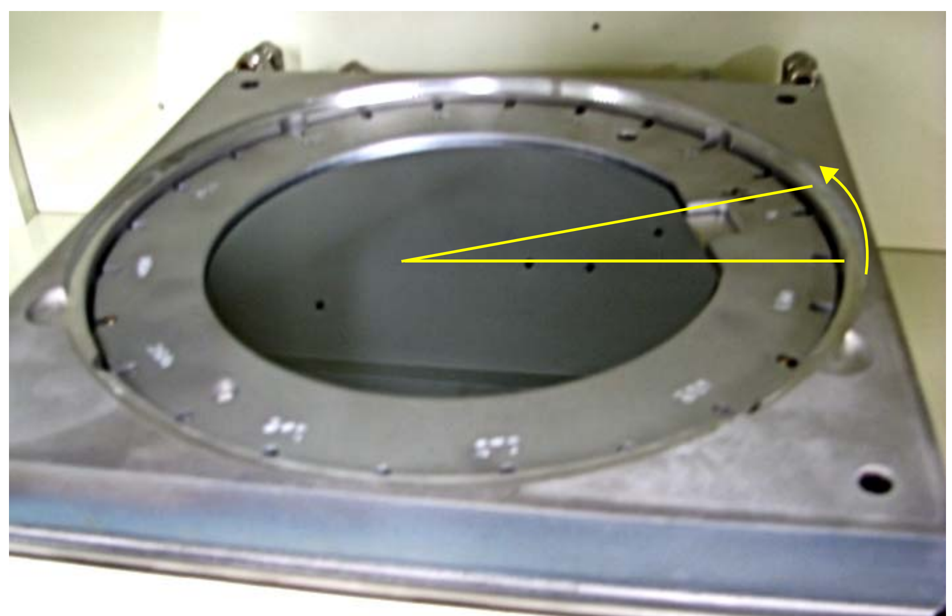
The convention universally adopted in mathematical writings as well as the Flexus 2320-S is that 0 degrees is a horizontal line (the X- axis) and positive angles increase when turning Counter Clock Wise.

A Wafer with its flat at 0 degrees is as if its flat was at 3 O'Clock, 90 degrees has the flat at 12 O'Clock, etc.

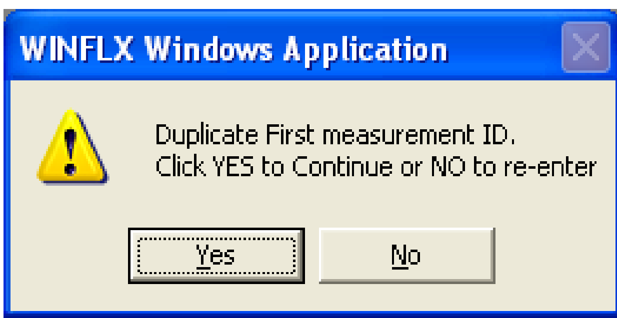
4.2.1 Performing a series of First Scans

1. Place the wafer in the instrument so that its flat or notch is at 0 degrees.

2. Perform a First Measurement.
3. Keep the First Measurement window open.
4. Rotate the wafer ring and wafer counterclockwise to the desired interval depending on how many scans are going to be used to map the wafer. The Flexus software will only recognize groups of scans if they begin at 0 and increase in order.



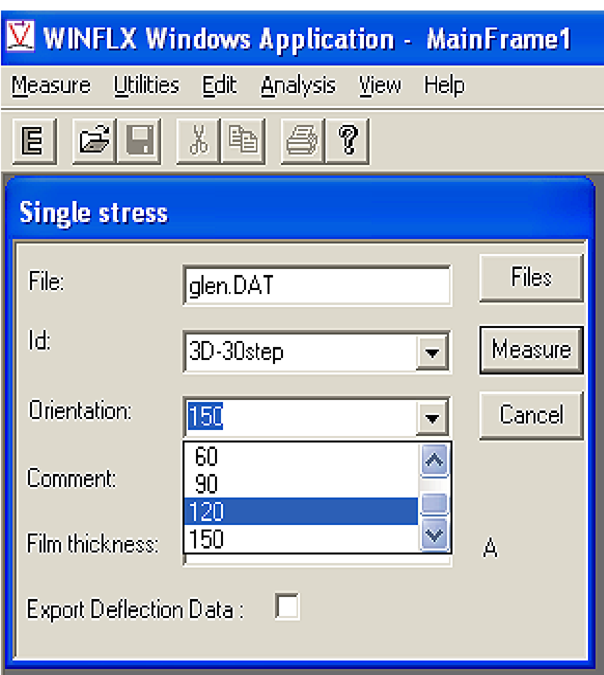
5. Return to the First measurement window, change the Orientation field from 0 to the new interval (example shows 12 scans which is a scan every 15 degrees)
6. It is very important that the ID is the same for all of the scans. A warning window will appear informing the User that the ID is a duplicate. Typically this window will prompt the user to change the ID so that it is unique for each wafer. However, it is important that this series of scans all have the same ID, although the orientations will vary. Click "Yes".



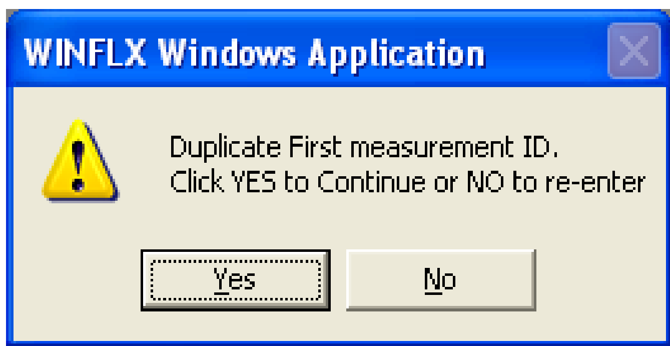
7. Once all of the scans in a series (group) are taken it is possible to create a Radius or Deflection graph.

4.2.2 Performing a Series of Single Scans.

1. After the deposition, begin the series of scans with the flat or notch of the wafer at 0 degrees.
2. Values may not be entered into the orientation field. They must be selected from the drop down menu. Be sure to follow the same sequence as during the First Scans or other group of scans you wish to calculate stress between.



3. It's very important that the ID is the same for all of the scans. A warning window will appear informing the User that the ID is a duplicate. Typically this window will prompt the user to change the ID so that it is unique for each wafer. However, it is important that this series of scans all have the same ID, although the orientations will vary. Click “Yes”.



5 MANAGING DATA FILES

This chapter describes how to

- Copy, save, delete and rename data records
- Export, merge and print data files
- Edit data records

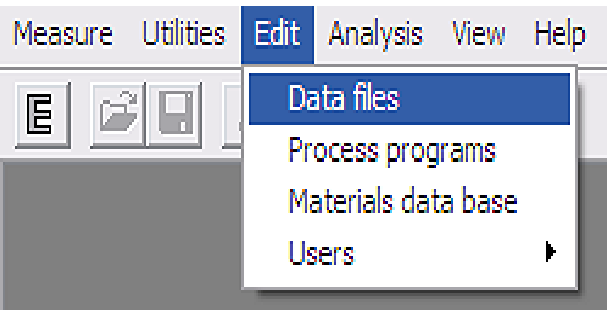
The procedures in this chapter assume a knowledge of instrument controls and basic operations such as starting and shutting down the instrument. As well, the procedures assume a knowledge of how to take measurements.

5.1 WORKING WITH DATA FILES

Once measurements have been taken, you can display the saved data file (extension .DAT) to alter, delete, or merge records, and plot graphs or trends. The procedures in this section describe how to display and work with data files.

There are 2 ways to open a .DAT file

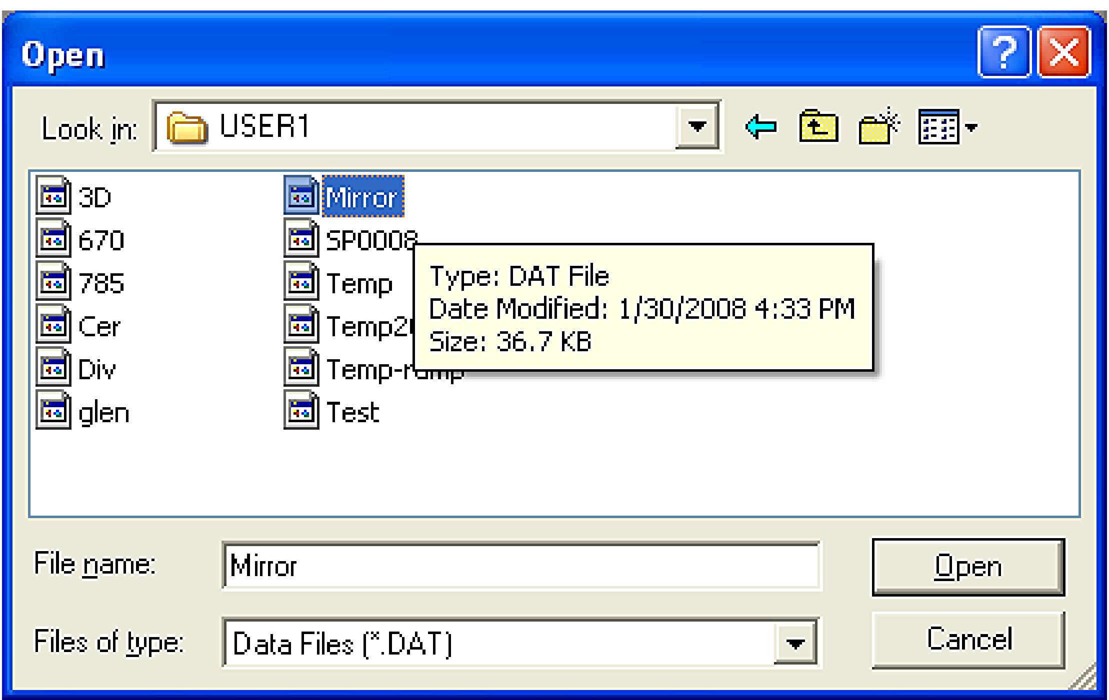
1st- Select the “Edit” tab on the main screen. Select “Data Files”.



2nd- Click on the E button. (E is for Editor Menu)

Both of these methods will take you to the same place. A window will appear with the most recent User's Folder in the "Look In" field. The body of the window displays all of the files with .DAT extensions.

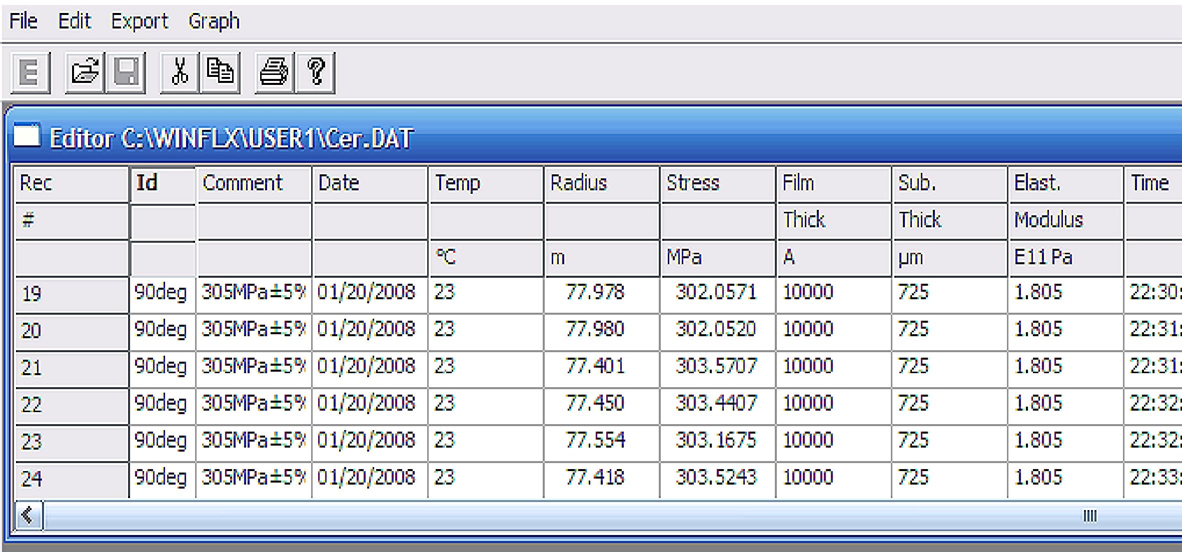
Highlighting the file will reveal its size and when it was last modified. In the example below the file named "Mirror" is 36.7 KB large, and was last manipulated on 1/30/2008 at 4:33 PM.



5.2 USING FILE MENU OPTIONS IN THE EDITOR WINDOW

Select a DAT File by clicking the "Open" button. The file will open to a spread sheet. This is similar to an Excel spreadsheet, but only certain fields may be manipulated. In this section are procedures for:

- Loading files
- Merging files
- Deleting files
- Deleting records
- Recalculating Stress by changing Film thickness or Substrate thickness.



Rec #	Id	Comment	Date	Temp °C	Radius m	Stress MPa	Film Thick A	Sub. Thick µm	Elast. Modulus E11 Pa	Time
19	90deg	305MPa±5%	01/20/2008	23	77.978	302.0571	10000	725	1.805	22:30:
20	90deg	305MPa±5%	01/20/2008	23	77.980	302.0520	10000	725	1.805	22:31:
21	90deg	305MPa±5%	01/20/2008	23	77.401	303.5707	10000	725	1.805	22:31:
22	90deg	305MPa±5%	01/20/2008	23	77.450	303.4407	10000	725	1.805	22:32:
23	90deg	305MPa±5%	01/20/2008	23	77.554	303.1675	10000	725	1.805	22:32:
24	90deg	305MPa±5%	01/20/2008	23	77.418	303.5243	10000	725	1.805	22:33:

Record #: Each line is a record number which contains all the data stored for each scan. A single file may only have up to 1000 records.

ID: This is the wafer identifier. This can be edited in the Editor window.

Comment: This is where the comments become valuable. They potentially help the user navigate the spread sheet which may have up to 1000 records. This can be edited in Editor.

Date: The date the scan was taken in DD/MM/YYYY format.

Temp: The temperature of the stage in degrees Celsius as read by the Eurotherm at the time of the scan.

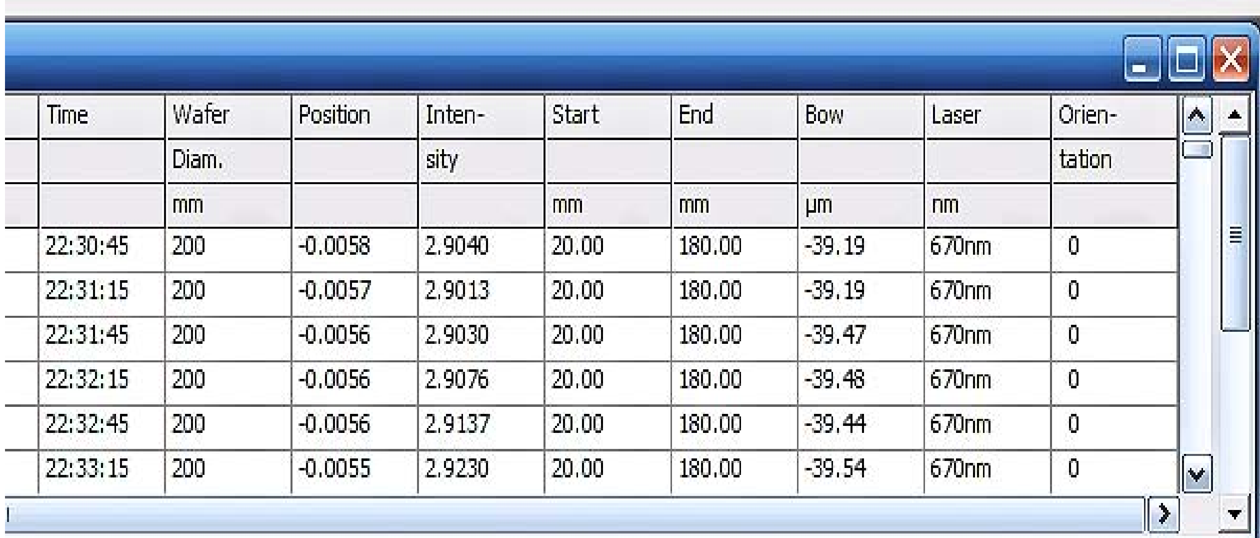
Radius: The calculated radius of the wafer for that scan. This is in meters. For large radius scientific notation will be used. (e.g. a Radius of 42,360 meters will read “4.236E4”). A smile is considered a positive radius. A frown is considered a negative radius.

Stress: This field is the calculated stress in terms of megapascals (MPa) or Dynes per centimeters squared depending upon the most recently selected unit of torque in the Process Program.

Film Thickness: This is the thickness of the deposition in terms of angstroms. This field can be edited and Stress will be calculated accordingly.

Sub. Thick: This is the Substrate Thickness in terms of microns (mm). This field can be edited and Stress will be calculated accordingly.

Elast. Modulus: This field is the coefficient of the elastic expansion for the Substrate. (e.g. 1.805 is the modulus for silicon.) This field can be edited and Stress will be calculated accordingly.



Time	Wafer	Position	Inten-	Start	End	Bow	Laser	Orien-
	Diam.		sity					tation
	mm			mm	mm	µm	nm	
22:30:45	200	-0.0058	2.9040	20.00	180.00	-39.19	670nm	0
22:31:15	200	-0.0057	2.9013	20.00	180.00	-39.19	670nm	0
22:31:45	200	-0.0056	2.9030	20.00	180.00	-39.47	670nm	0
22:32:15	200	-0.0056	2.9076	20.00	180.00	-39.48	670nm	0
22:32:45	200	-0.0056	2.9137	20.00	180.00	-39.44	670nm	0
22:33:15	200	-0.0055	2.9230	20.00	180.00	-39.54	670nm	0

Time: This is the time that the scan was taken in terms of hours, minutes, and seconds.

Wafer Diam.: This is the diameter of the wafer in terms of millimeters.

Position: This is the position of the laser-beam on the detector (zero is the center of the detector) also known as the DIFF.

Intensity: This is the amount of light reaching the detector in terms of volts. Nominally bare silicon will reflect approximately 3.0 volts.

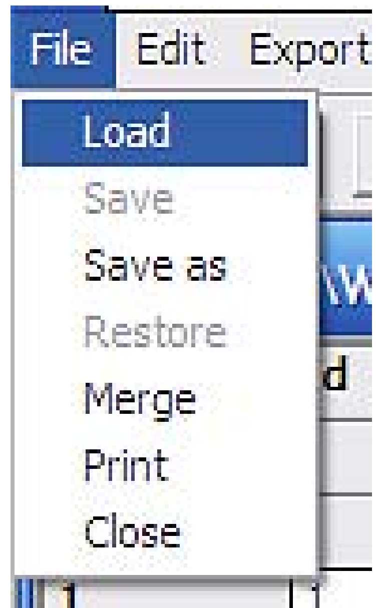
Start: This is the position of the first point of the scan in terms of millimeters from left to right (Autoscan on a 150mm wafer will start at 15mm).

End: This is the position of the last point of the scan in terms of millimeters from left to right (Autoscan on a 150mm wafer will end at 135mm).

Bow: This is the maximum amount of deflection from zero amongst the fifty points of the scan with zero being a line drawn from the first to the fiftieth point. This is in terms of mm.

Laser: This is the selected laser for the scan. The 670nm is the Red laser, the 780nm is the Infrared laser.

Orientation: This is the angle of the wafer as entered by the operator for this scan.



Load: This will open a different DAT file.

Save: Will save the current DAT file with the same name.

Save as: Will save the current DAT file and prompt a new name.

Restore: Will return the current DAT file to its previously saved state.

Merge: Allows the combining of 2 DAT files into one larger DAT file. Note that a single DAT file can only have up to 1000 records.

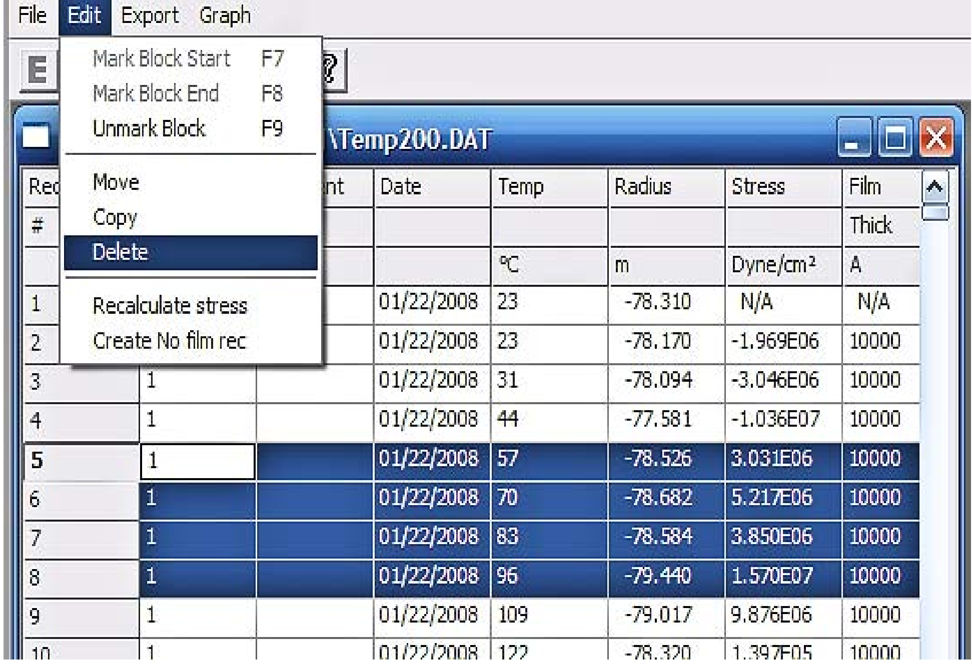
Print: Will print the spreadsheet of the current DAT file.

Close: Will exit the current DAT file.

5.2.1 Deleting Records

1. Highlight the rows to be deleted.
2. Go to the "Edit" tab with the DAT file open. Select "Delete" and press enter to delete.

   NOTE: The delete button on the keyboard will NOT delete these selected rows. The Right-Click and delete will NOT work either.



5.2.2 Move Records

This feature is for moving records around within the DAT file. This function does not enable moving records from one file to another

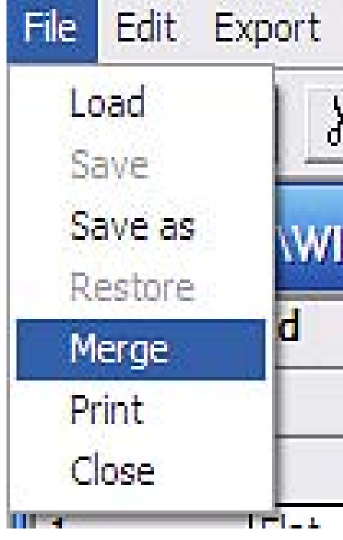
1. Highlight the rows to be moved.
2. Select “Move” from the “Edit” tab of the DAT toolbar.
3. Double click on the record that is before where the highlighted records are to be placed. The records should immediately appear there.

5.2.3 Copying Records

This function works exactly the same as “Move Records”. This function does not enable moving records from one file to another.

1. Highlight the rows to be moved.
2. Select “Copy” from the “Edit” tab of the DAT toolbar.
3. Double click on the record that is before where the highlighted records are to placed. The records should immediately appear there.

5.2.4 Merging Data Files



1. With one of the data files to be merged open, go to the “File” tab and select “Merge”.
2. The list of DAT files within the folder will pop-up.
3. Select the other DAT file that is to be merged with the currently opened DAT file.
4. Click on the “Open” button. The records of this file will be merged into the beginning of the currently open file.

5.2.5 Recalculating Stress

1. Change the film thickness or substrate thickness, or elastic modulus in a record that will be the first record in a group of records to be recalculated. Initially the Stress will be recalculated for just this record. In order to change a large group of records begin by editing the first record of the group.

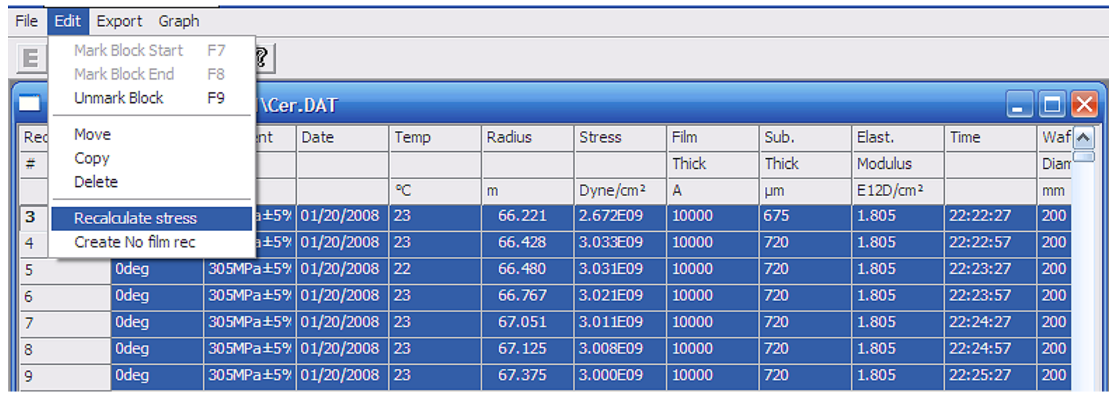
us	Stress	Film Thick	Sub. Thick	Elast. Modulus
	MPa	A	µm	E11 Pa
.991	0.0000	N/A	720	1.805
.329	-1.9209	10000	720	1.805
.813	-1.3553	10000	720	1.805

Example shows the Substrate thickness field being changed. The Stress calculation is done as soon as the new value is entered.

Radius	Stress	Film Thick	Sub. Thick	Ela Mo
m	MPa	A	µm	E1
-116.991	0.0000	N/A	720	1.8
-115.329	-1.6883	10000	675	1.8

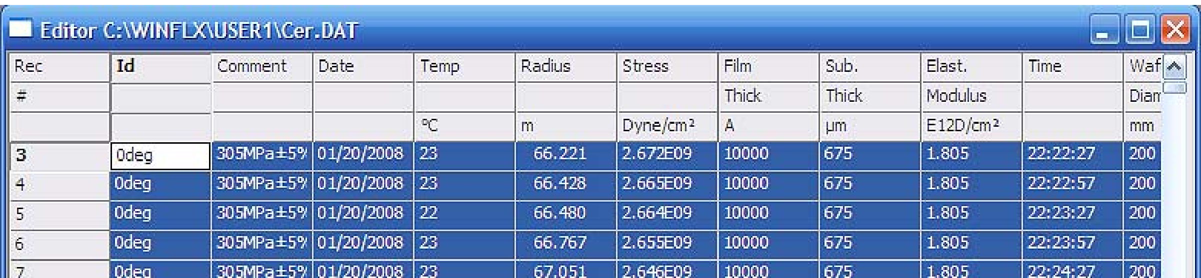
Example shows the new substrate thickness entered. Notice the recalculation of Stress.

2. Select the block of records, starting at the edited record.



Rec #	Id	Comment	Date	Temp	Radius	Stress	Film Thick	Sub. Thick	Elast. Modulus	Time	Waf Diam
				°C	m	Dyne/cm²	A	µm	E12D/cm²		mm
3		a±5%	01/20/2008	23	66.221	2.672E09	10000	675	1.805	22:22:27	200
4		a±5%	01/20/2008	23	66.428	3.033E09	10000	720	1.805	22:22:57	200
5	0deg	305MPa±5%	01/20/2008	22	66.480	3.031E09	10000	720	1.805	22:23:27	200
6	0deg	305MPa±5%	01/20/2008	23	66.767	3.021E09	10000	720	1.805	22:23:57	200
7	0deg	305MPa±5%	01/20/2008	23	67.051	3.011E09	10000	720	1.805	22:24:27	200
8	0deg	305MPa±5%	01/20/2008	23	67.125	3.008E09	10000	720	1.805	22:24:57	200
9	0deg	305MPa±5%	01/20/2008	23	67.375	3.000E09	10000	720	1.805	22:25:27	200

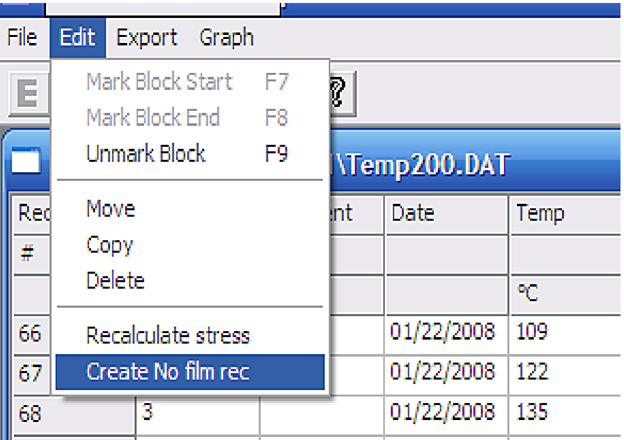
3. When "Recalculate stress" is selected all of the changes in the first record of the highlighted records will be propagated to every record selected. All of the stress calculations will be redone.



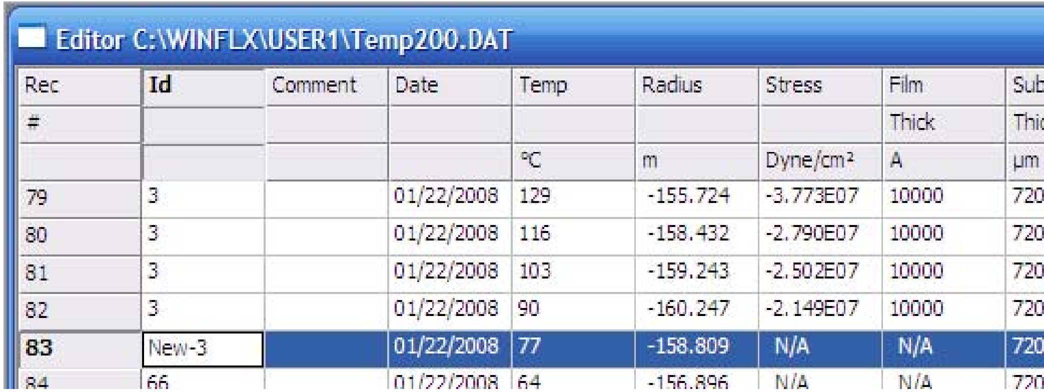
Rec #	Id	Comment	Date	Temp	Radius	Stress	Film Thick	Sub. Thick	Elast. Modulus	Time	Waf Diam
				°C	m	Dyne/cm²	A	µm	E12D/cm²		mm
3	0deg	305MPa±5%	01/20/2008	23	66.221	2.672E09	10000	675	1.805	22:22:27	200
4	0deg	305MPa±5%	01/20/2008	23	66.428	2.665E09	10000	675	1.805	22:22:57	200
5	0deg	305MPa±5%	01/20/2008	22	66.480	2.664E09	10000	675	1.805	22:23:27	200
6	0deg	305MPa±5%	01/20/2008	23	66.767	2.655E09	10000	675	1.805	22:23:57	200
7	0deg	305MPa±5%	01/20/2008	23	67.051	2.646E09	10000	675	1.805	22:24:27	200

5.2.6 Converting a Single Scan to a First Scan

1. Highlight a record to be converted from a post deposition scan to a first scan.
2. Select “Edit” tab inside the Editor application window. Select “Create No film rec”



3. The “Stress” and “Film Thickness” fields will turn to “N/A”. This will be the new “most recent” First measurement. Subsequent scans with this Identity will refer to this record as the first scan. If the “ID” is changed, this new “ID” will be available in the drop down menu when doing scans within this folder.



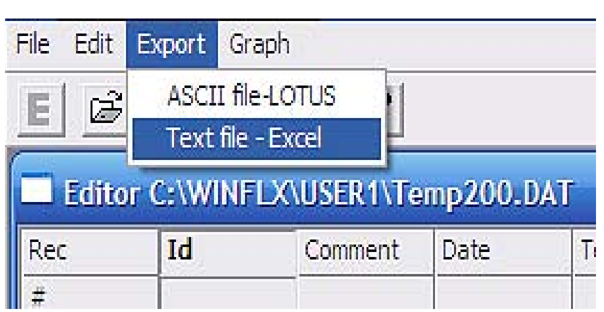
Editor C:\WINFLX\USER1\Temp200.DAT

Rec #	Id	Comment	Date	Temp °C	Radius m	Stress Dyne/cm²	Film Thick A	Sub Thic µm
79	3		01/22/2008	129	-155.724	-3.773E07	10000	720
80	3		01/22/2008	116	-158.432	-2.790E07	10000	720
81	3		01/22/2008	103	-159.243	-2.502E07	10000	720
82	3		01/22/2008	90	-160.247	-2.149E07	10000	720
83	New-3		01/22/2008	77	-158.809	N/A	N/A	720
84	66		01/22/2008	64	-156.896	N/A	N/A	720

This feature is most useful for first scans mistakenly taken as single scans. It’s also very useful when seeking to measure stress between a previously applied deposition and a new deposition.

5.2.7 EXPORTING DATA

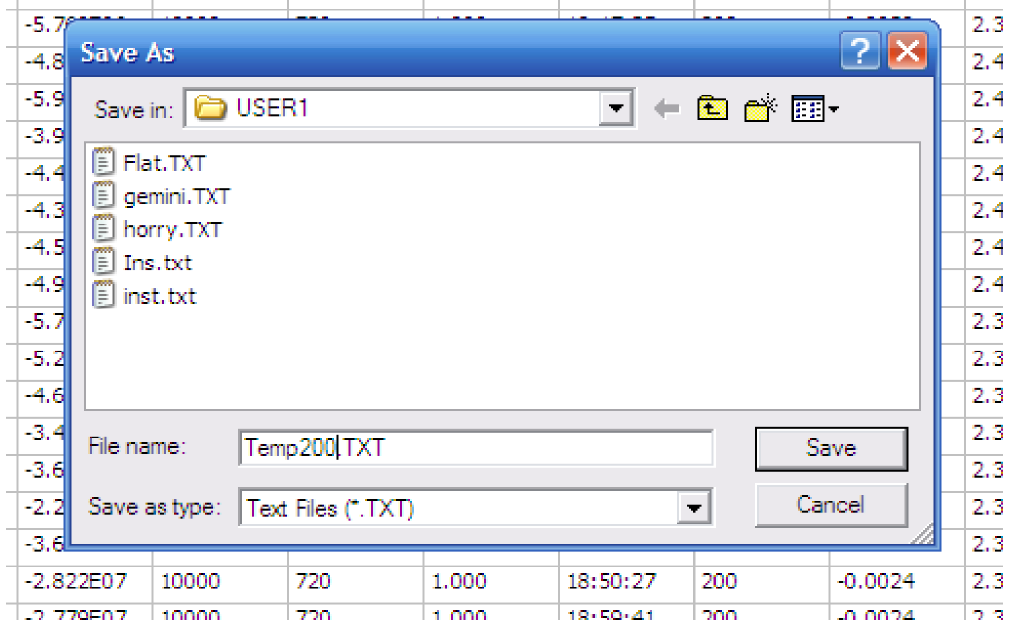
1. Open a data file.
2. To export all of the data within the currently opened DAT file select the “Export” tab from the Editor Application window.
3. Selecting “ASCII file-LOTUS” or “Text file - Excel” makes no difference. The software will only export files with a .TXT extension.



NOTE: “.TXT” files may be imported into Excel or other spreadsheet software. Excel is not provided with the Felxus 2320-S by TOHO;

ASCII (American Standard Code for Information Interchange) Text file (.TXT) is an ASCII file.

4. Name the new file. The data will export to the User’s folder. Click ‘Save” and the files have been exported.



5. If choosing to save the data in rows only, the record fields of the data file appear as 14 consecutive rows. The row headings will not be exported unless the whole file is exported.

6 CREATING AND DISPLAYING GRAPHS

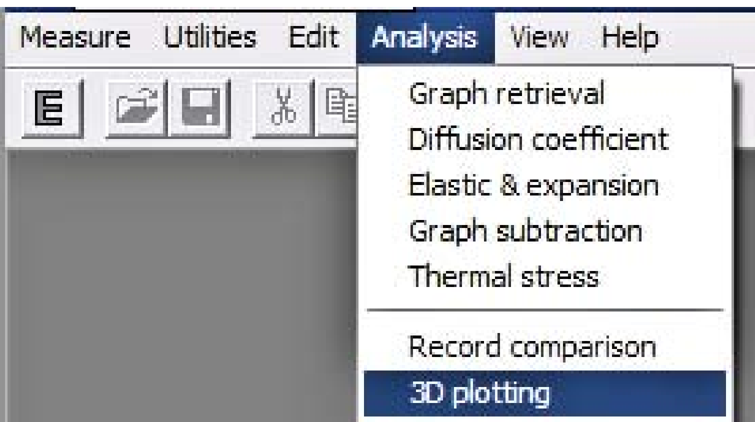
This chapter describes the operation of the instrument. It describes how to create, edit, and display 3-D data, and plot graphs and trends.

6.1 CREATING 3-D GRAPHS

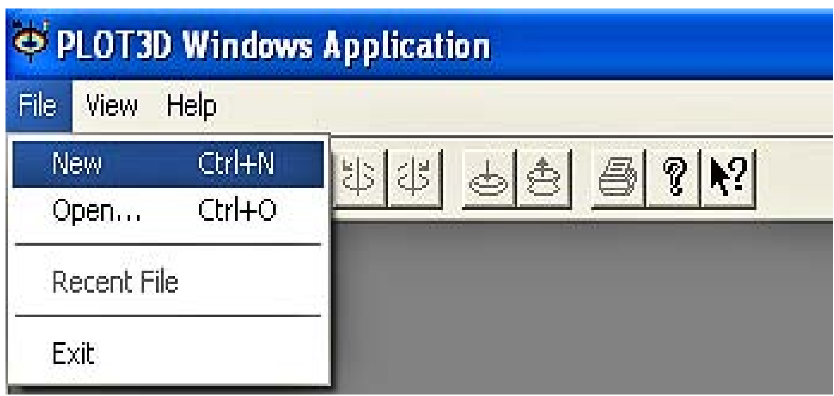
This section explains how to Select groups, tag and untag groups. This section also explains how to create Deflection, Radius, and Stress 3-D plots as well as manipulate the image with Tilting, Spinning, Amplification, and color representations.

6.1.1 Creating a Deflection 3-D Plot.

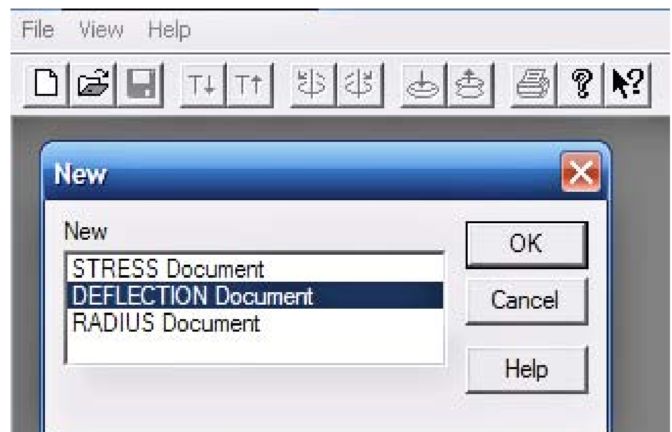
1. On the main application screen select the “Analysis” tab. Click on “3D plotting”.



2. The screen will become the “PLOT3D Windows Application”. Go to the “File” tab and select “NEW”.

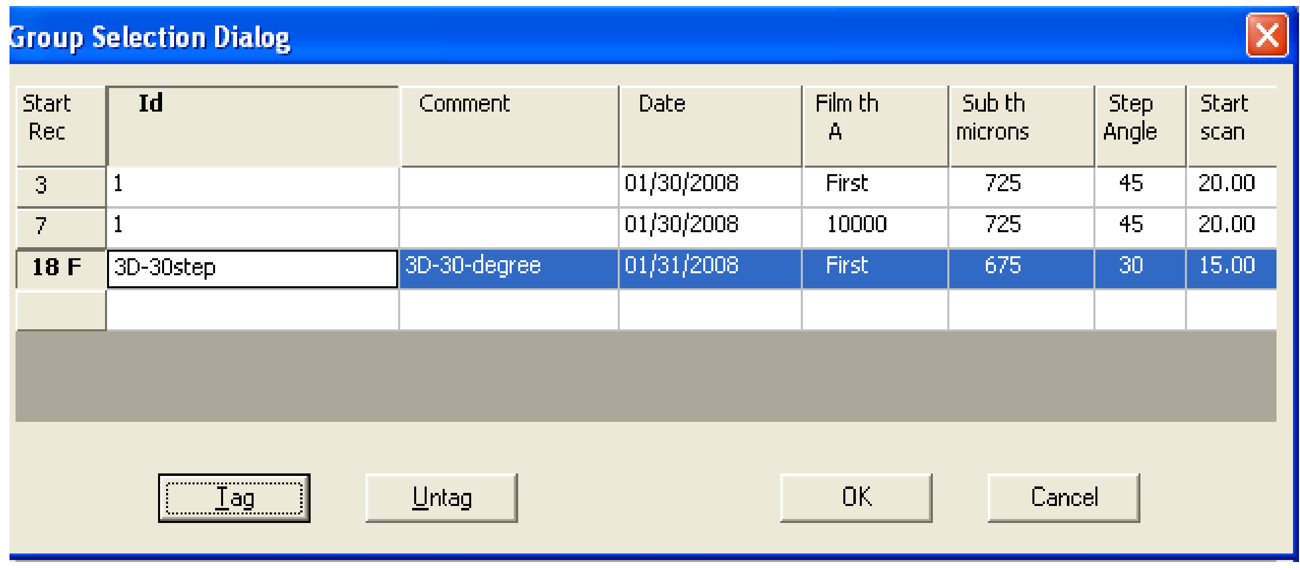


3. Select "DEFLECTION Document" from the "NEW" window that appears.

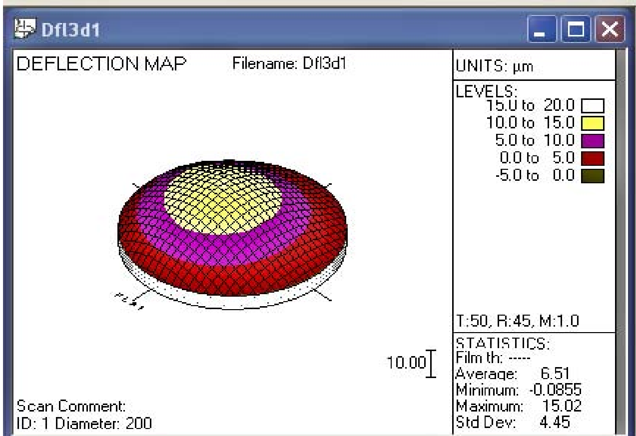


4. A Window will appear called "Group Selection Dialog". It lists the "Start Records" for groups. A Start Record is the 1st record in a group. The number in the "Start Rec" column refers to the record number in the Editor Application for this folder.

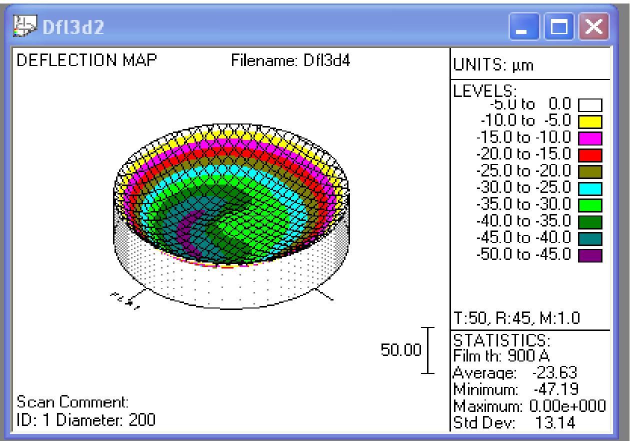
5. For a Deflection graph only one group needs to be tagged. To Tag a record just highlight it and then press the "tag" button. An "F" (F is for First Measurements) should appear next to the Start Record Number. To Remove the tag, press the "Untag" button. Tagging One group "F" and another group "S" (S is for Single Scans) will produce a graph that depicts the difference in deflection between the 2 groups.



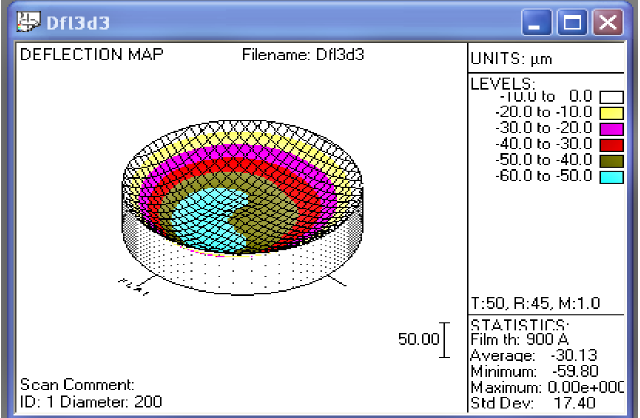
6. Press "OK" and the graph will appear. This graph will have real time controls for Rotation (45 degree movements), Tilt (profile to top view), and Amplification.



7. A Deflection map created from just one group marked "F" will give a map of the Deflection across the wafer. The map shown to the left was a group of First measurements. This graph represents the shape of the wafer before the deposition.



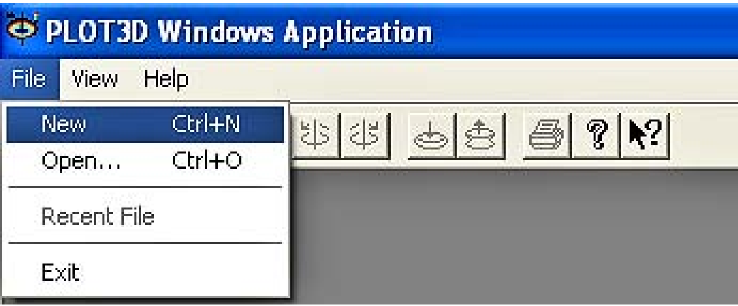
8. A Deflection Map created from just one group, but made of Single Scans will also be tagged with "F". This graph created will represent the shape of the wafer after deposition.



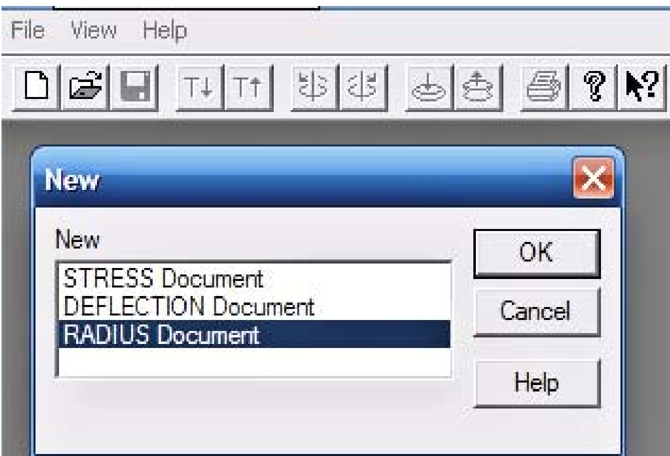
9. A Deflection graph made from Tagging one group as a group of First Scans "F", and another group of scans as a group of Single Scans "S" make a graph depicting the deflection between the 2 curvatures. This is how the deflection has changed from pre deposition to post deposition.

6.1.2 Creating a Radius 3-D Plot

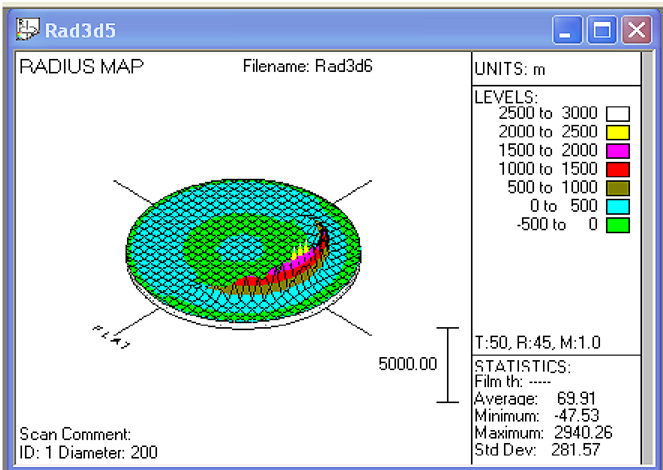
1. In the "PLOT3D Windows Application" go to the "File" tab and select "NEW".



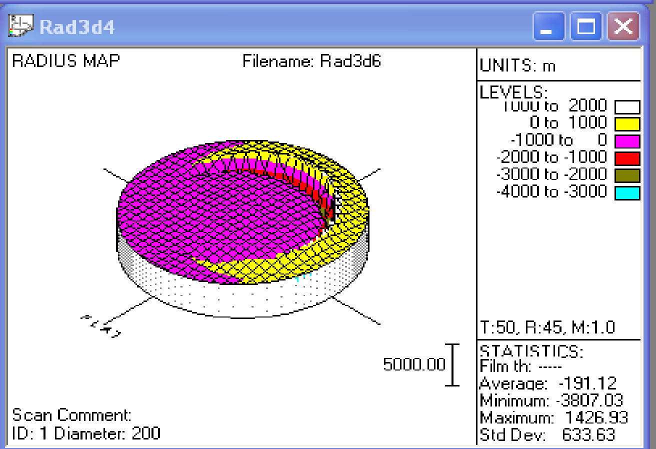
2. Select "RADIUS Document" from the "NEW" window that appears.



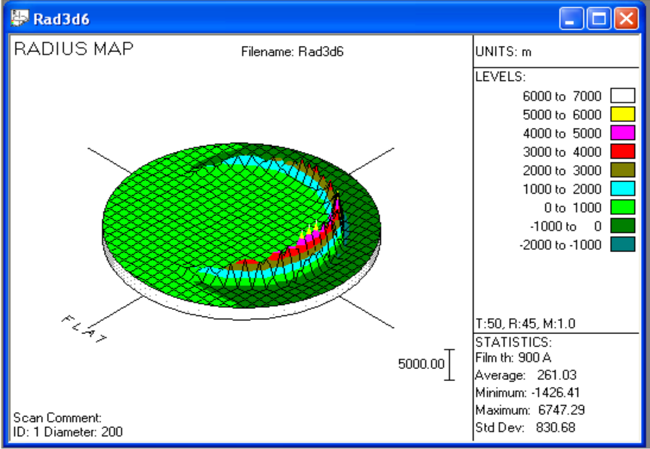
3. A Window will appear called "Group Selection Dialog". It lists the Start Records for groups. The number in the "Start Rec" column refers to the record number in the Editor Application for this folder.
4. For a Radius graph only one group needs top be tagged just like a Deflection graph. To Tag a record just highlight it and then press the "tag" button. An "F" should appear next to the Start Record Number. To Remove the tag, press the "Untag" button. Tagging One group "F" and another group "S" will produce a graph that depicts the difference in Radius between the 2 groups.



5. A Radius map created from just one group marked "F" will give a map of the radius across the wafer. The map shown to the left was a group of First measurements. This graph represents the shape of the wafer before the deposition.



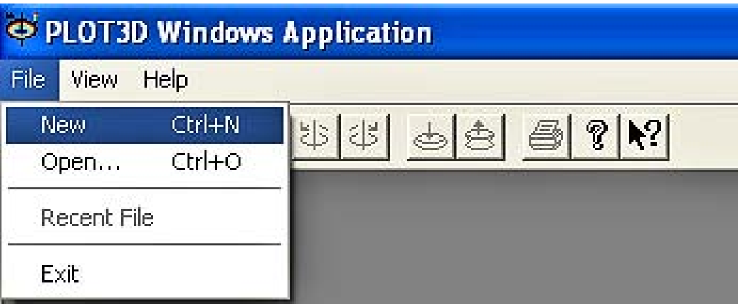
6. A Radius Map created from just one group, but made of Single Scans will also be tagged with "F". This graph created will represent the shape of the wafer after deposition.



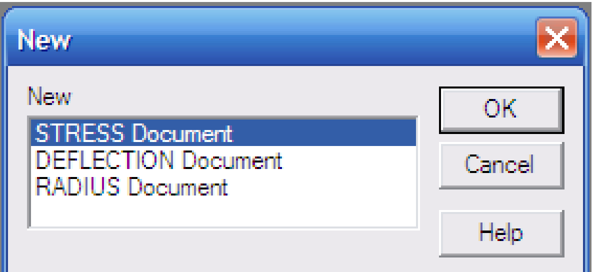
7. A Radius graph made from tagging one group as a group of First Scans "F", and another group of scans as a group of Single Scans "S" make a graph depicting the radius between the 2 curvatures. This is how the radius has changed from pre deposition to post deposition.

6.1.3 Creating 3-D Stress Plot

1. In the “PLOT3D Windows Application” go to the “File” tab and select “New”.



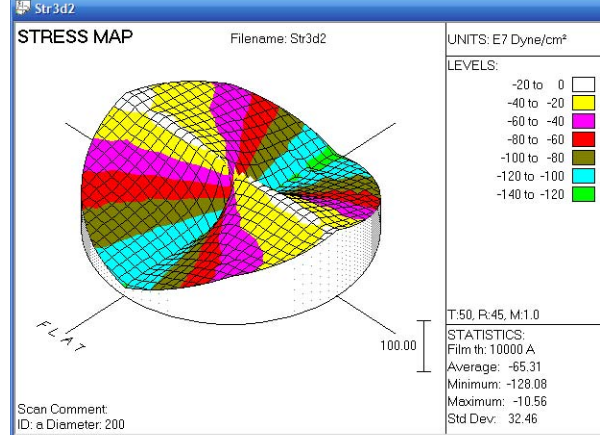
2. Select “STRESS Document” from the “New” window that appears.



3. Tag the First Scan group with “F”. Tag the group of Single scans with “S”. Every time the “tag” button is clicked it will assign an F or an S to the record line currently selected. The same button oscillates between the 2 tags.

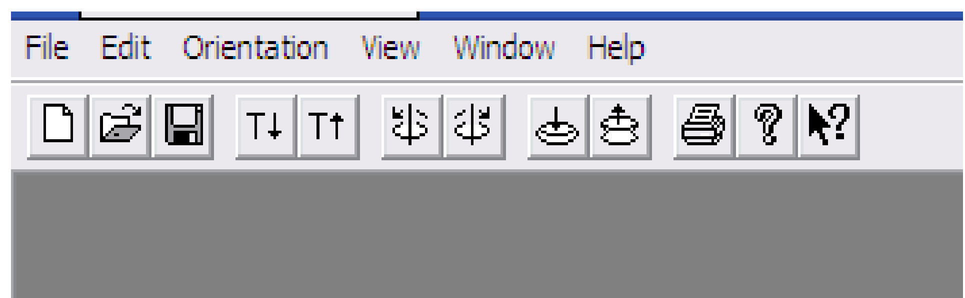
Start Rec	Id	Comment	Date	Film th A	Sub th microns	Step Angle	Start scan
1	1		01/27/2008	First	720	90	20.00
3 F	a		02/13/2008	First	720	45	20.00
7 S	a		02/13/2008	10000	720	45	20.00

4. The graphic will specify the flat or notch orientation, but will not represent it. The image will be a circular wafer. The units of Dynes / cm^2 or MPa come from the Process Program.



6.1.4 Manipulating 3-D Graphs

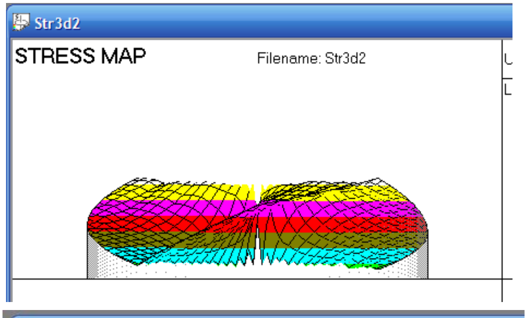
The graphs will pop-up with an isometric view. The tool buttons on the top of the window can adjust Tilt, Spin, and Amplitude.



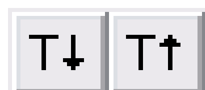
1. This button opens the “NEW” window, for creating a new Stress, Radius, or Deflection Document.
2. This button will open a previously created and saved graph.
3. This button will save the current graph.

4. Tilts the graph towards the User (towards Top View)

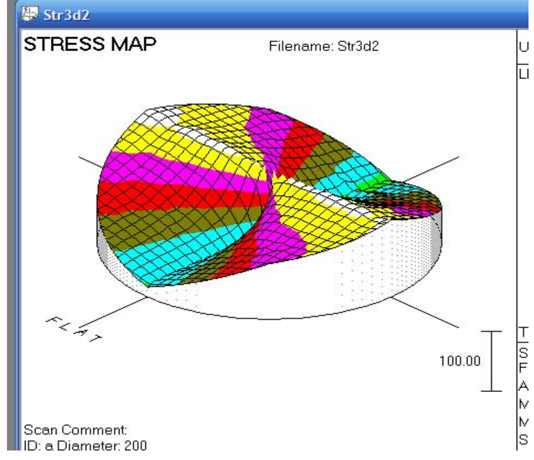
5. Tilts the graph away from the User (towards Profile)
6. Rotates graph 45 degrees Counterclockwise.
7. Rotates graph 45 degrees Clockwise.
8. Turns down the amplitude of the graph (flattens)
9. Turns up the amplitude of the graph.
10. Prints current graph.
11. About Plot 3D: Gives the current version of the 3D software.
12. Help: Currently not an active feature.



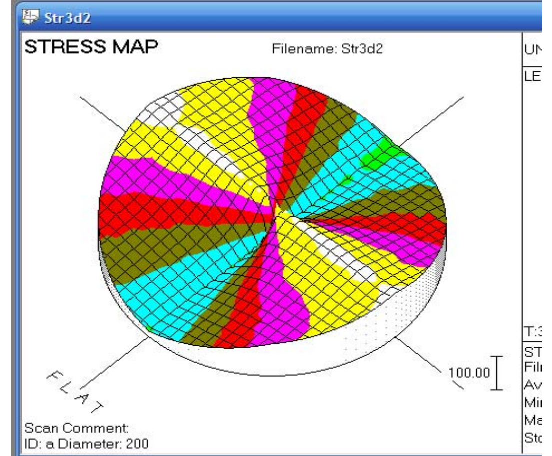
The Tilt feature is controlled by these 2 buttons.



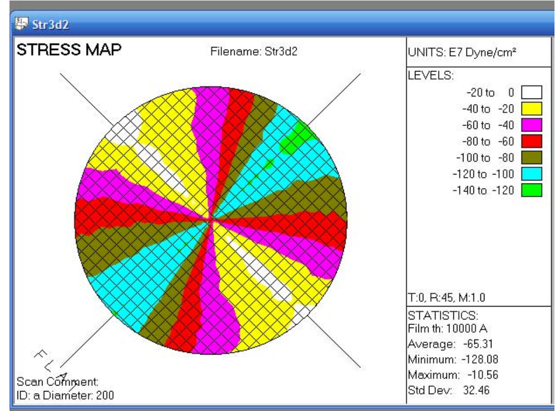
This view is a Stress Map tilted all the way up.



There are only 4 angles the graph can be tilted at. This is one of the middle angles, on the profile side.



This is the angle that is one step away from a top view.



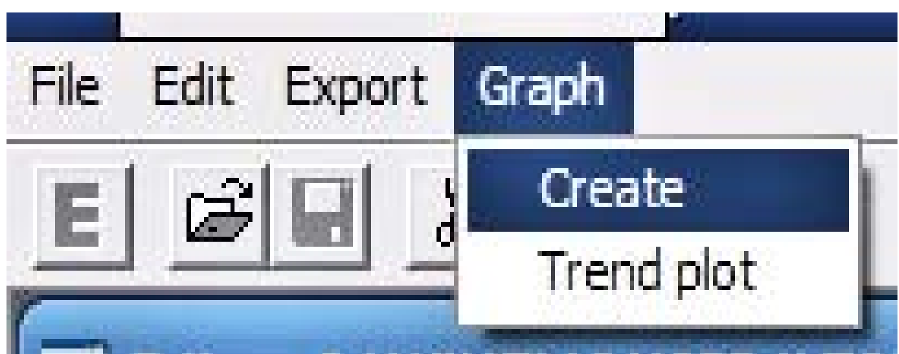
This is the top view of the wafer.

6.2 Creating Graphs from Data Files

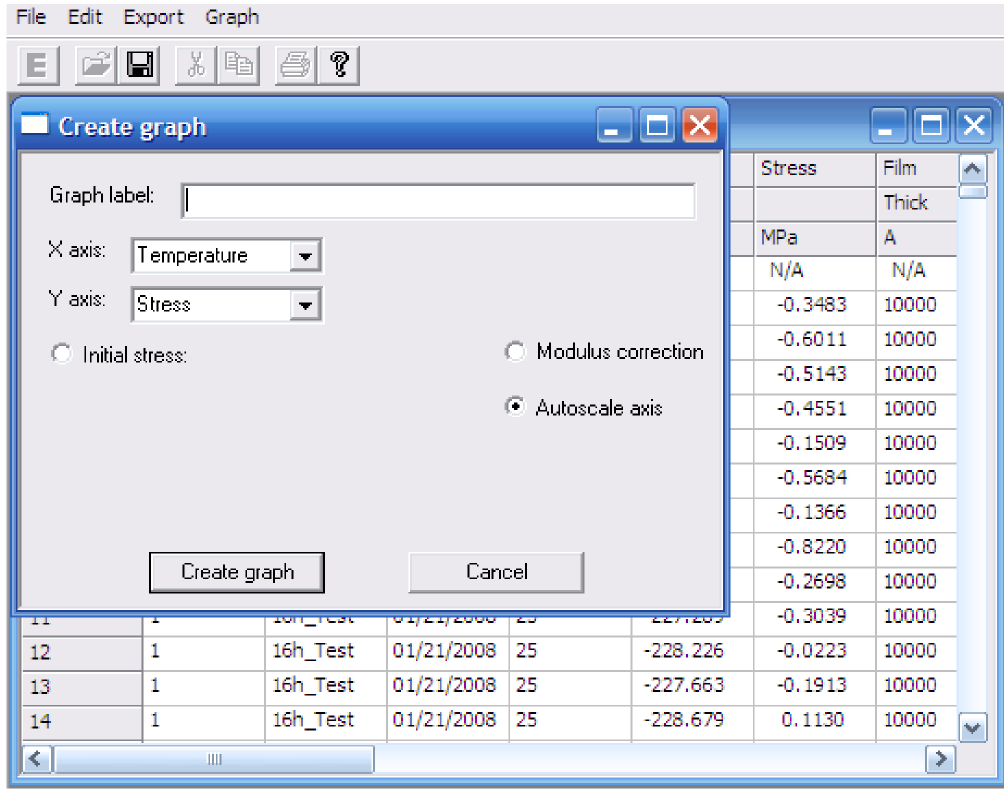
Use this option to create graphs from the raw data files. You have the option of creating a graph from the entire data file or from a selected block. Without a data line (record) selected the software assumes to use the entire data file.

6.2.1 To create a graph:

1. Open the Editor Window and select the ".DAT" file that contains the data to be graphed.
2. If using the entire DAT file then proceed to the "graph" tab and select "Create".
3. If using only certain records, select a block by highlighting them, then go to the "graph" tab and select "Create".

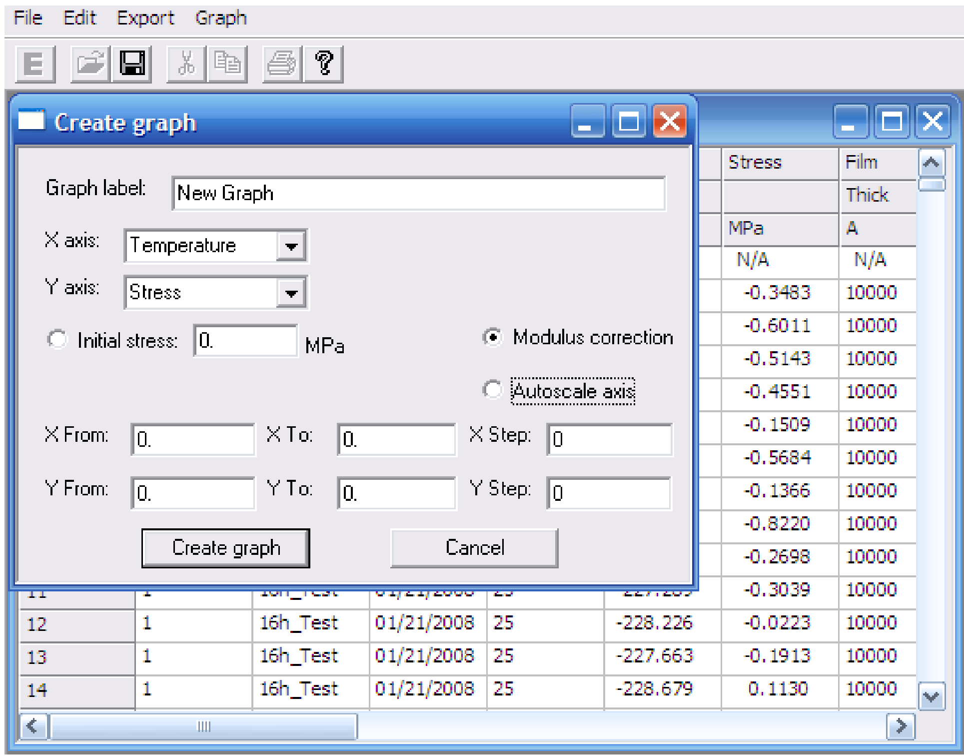


A window will appear with several options.

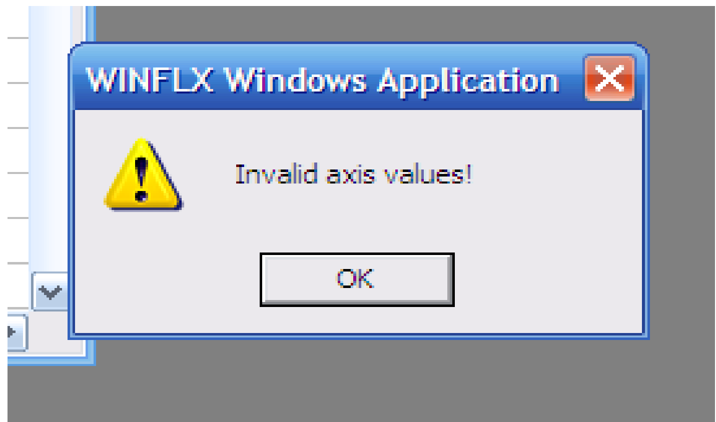


Field	Description
Graph Label	The label to be displayed above the graph. You can enter any combination of characters and numbers.
X	The X-axis of the graph (left to right). Choices available from the drop-down list are Time, Stress, Bow, Record Number, Temperature, and Light Intensity. If you select Time or Stress, an additional field is displayed next to the field to allow you to enter Initial Time or Stress respectively.
Y	The Y-axis of the graph (up and down). Choices available from the drop-down list are Stress, Bow, Record Number, Temperature, and Light Intensity. If you select Time or Stress, an additional field is displayed next to the field to allow you to enter Initial Time or Stress respectively.
Initial Stress Initial Time	When one axis is Time or Stress, there will be a button that appears in case you want to create an offset for the graph. Initial time is entered in hours and minutes, and initial stress in MPa or dynes/cm^2. MPa or dynes/cm^2 is determined by the most recently opened Process Program.
Modulus Correction	To apply the modulus correction to the data, choose the Modulus Correction button. The dot in the center of the circle indicates that this option is activated; to not apply the Modulus Correction, choose the Modulus Correction button until the circle in the center of the button disappears.
Autoscale Axis	Autoscale is the default. Once Autoscale Axis is unselected, additional options will appear.
X From:	Starting X value.
Y From:	Starting Y value.
X To:	Ending X value.
Y To:	Ending Y value.
X Step:	Distance between grid markings on the X-axis.
Y Step:	Distance between grid markings on the Y-axis.
Create Graph	Creates a graph.
Cancel	Cancels the application.

4. The image below shows the “Auotscale axis” button unselected. The default for each field is “0”. With “Autoscale axis” unselected, it is important to enter values.

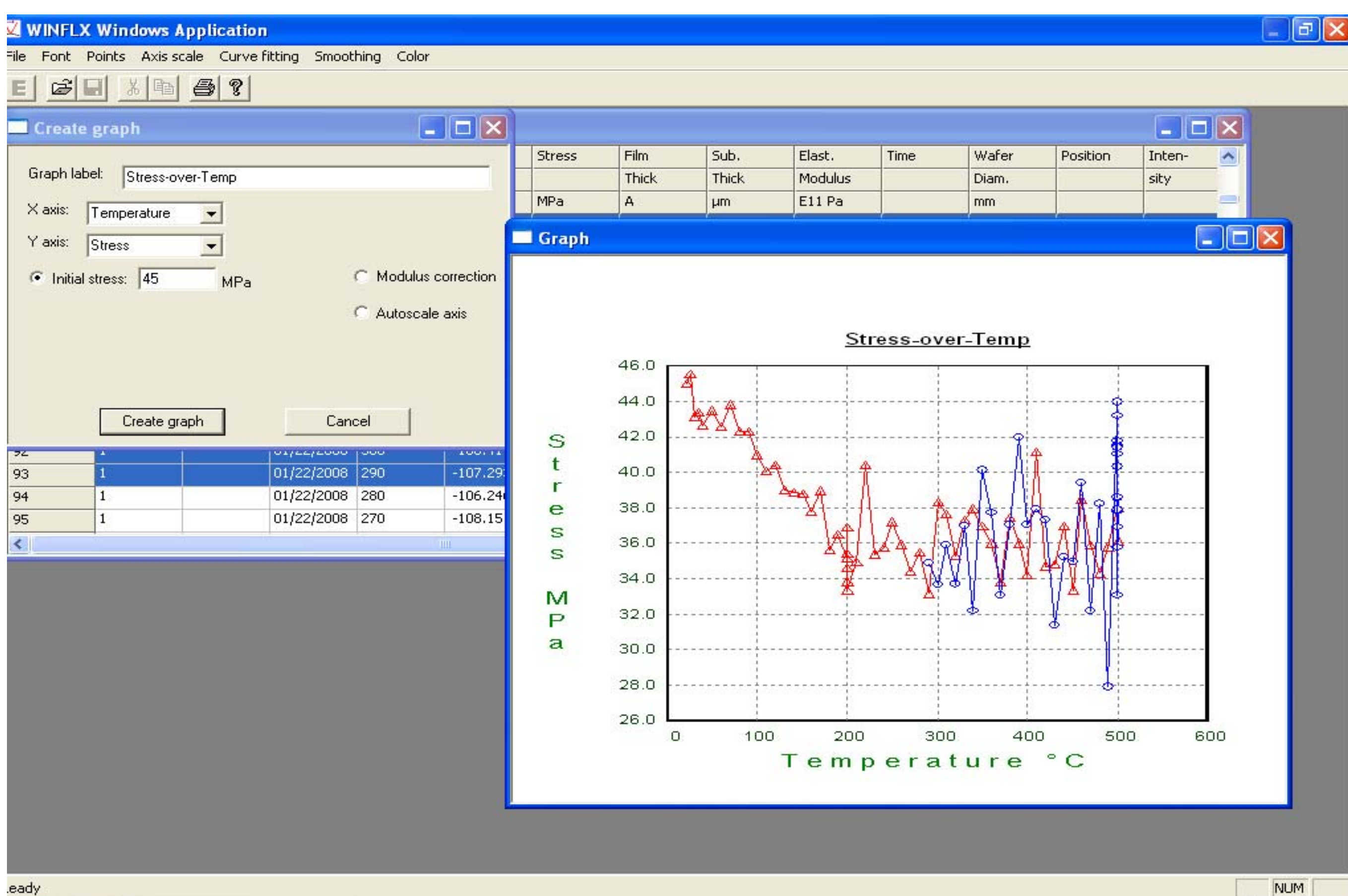


5. The default for each field is “0”. With “Autoscale axis” unselected, it is important to enter values. If left at zero an error window will appear:



6. If this happens, simply click “OK”. Then select “Autoscale axis” or enter values.

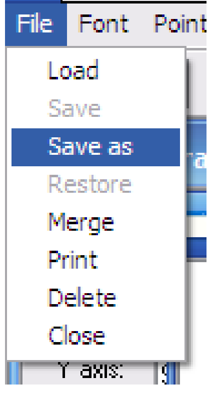
7. Click the "Create Graph" button. A graph will appear.



In the image above notice the offset is 45 MPa. This will be the value of the first scan selected and the subsequent plots will be relative to this first plot.

For graphs other than Temperature the plots will be Blue circles connected by a blue line by default.

Notice when Temperature is selected, increasing temperatures will be denoted by Red triangles, cooling temperatures are denoted by Blue circles.



8. To save the graph, choose Save As or Save from the "File" tab. When a graph is first created and unmanipulated only "Save As" is available. "Save" is available after the initial graph is changed (points, lines, colors, smoothing, etc.)

6.2.2 Graph Options

You have the following options in the File tab menu:

Load: Loads a previously saved graph. This will not open a new window. This will replace the existing graph window with this graph. (Press **Restore**, to return to the original graph)

Save: This is grayed out initially when a graph first appears. This is used when a graph has been manipulated, in order to save the changes to it.

Save as: Saves the graph as a GRP file.

Restore: Use this to return the graph to its original state.

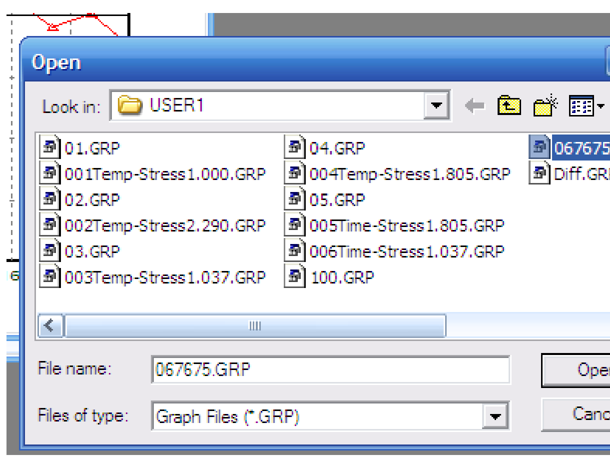
Merge: Graphs may only be merged if they have the same attributes. (e.g. a Stress/ Temperature graph may only be merged with another Stress / Temperature graph)

The Graph on the Left is a Stress/Temp graph. The graph on the Right is that same graph merged with another Stress/Temp graph.

Print: Will print the graph only, not the screen.

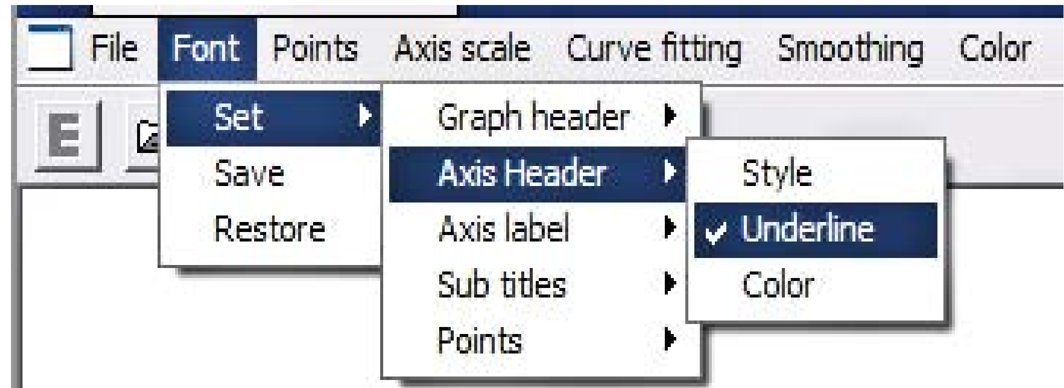
Delete: Deletes the graph from this folder. It will open a window called “Open”, when you select the file in the “Open” window it will be deleted.

Close: Closes the graph.



6.2.3 Font Options

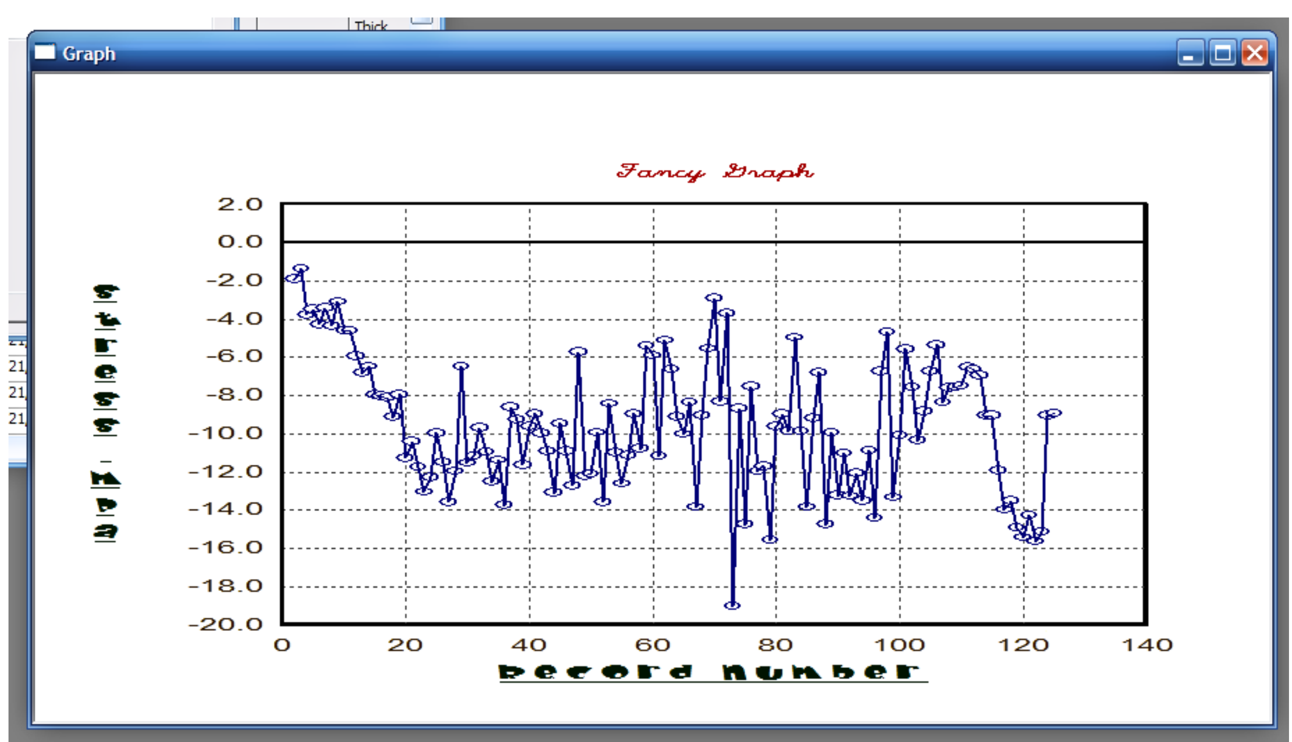
The following options are available under the "Font" tab:



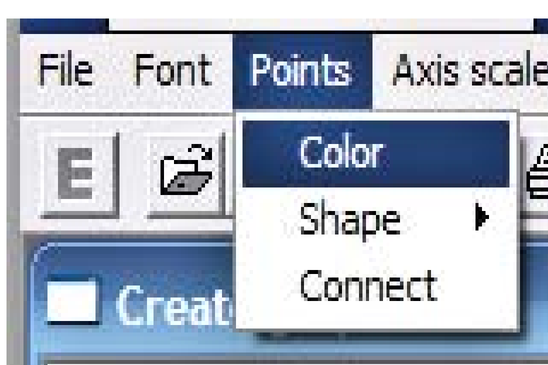
Set: Allows changing of the Graph Header, Axis Header, Axis Label, Subtitles *(Points does nothing under the Font tab. Go to "Points" tab to manipulate the appearance of the Points on the graph.)*

Save: Will change the default for font style, underlining, and color for the Graph Header, Axis Header, Axis Label, and Subtitles to the current selection. Future graphs will then have these settings as the default.

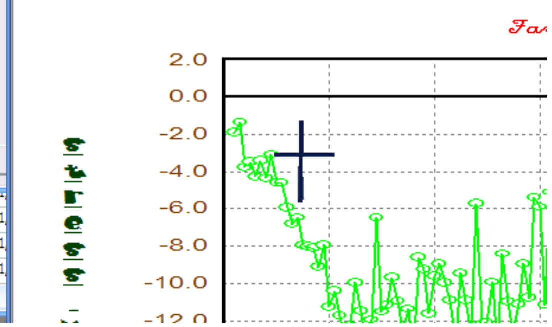
Restore: Will return the font settings to the last Saved style.



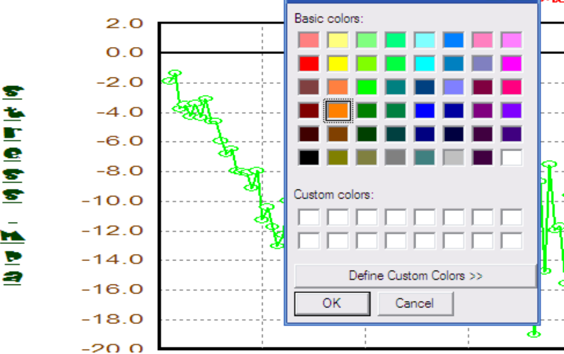
6.2.4 Points Options



Color: Select Color from the Points tab, then click. The menu will disappear. Bring the cursor over to the graph. It should change from the standard arrow into a cross.

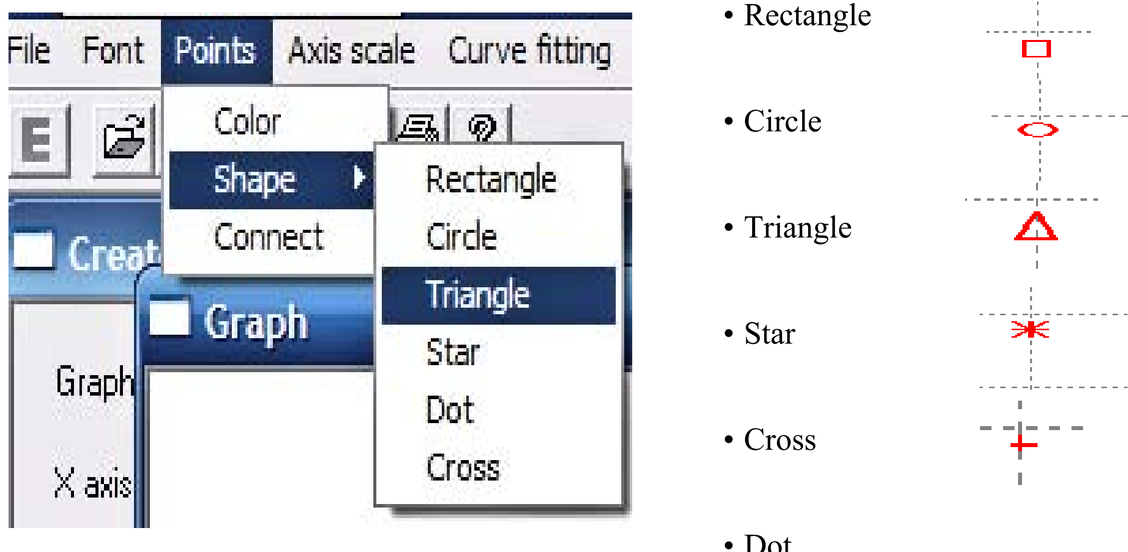


Bring the cross onto the graph and click on one of the points of the graph. A color pallet will appear.

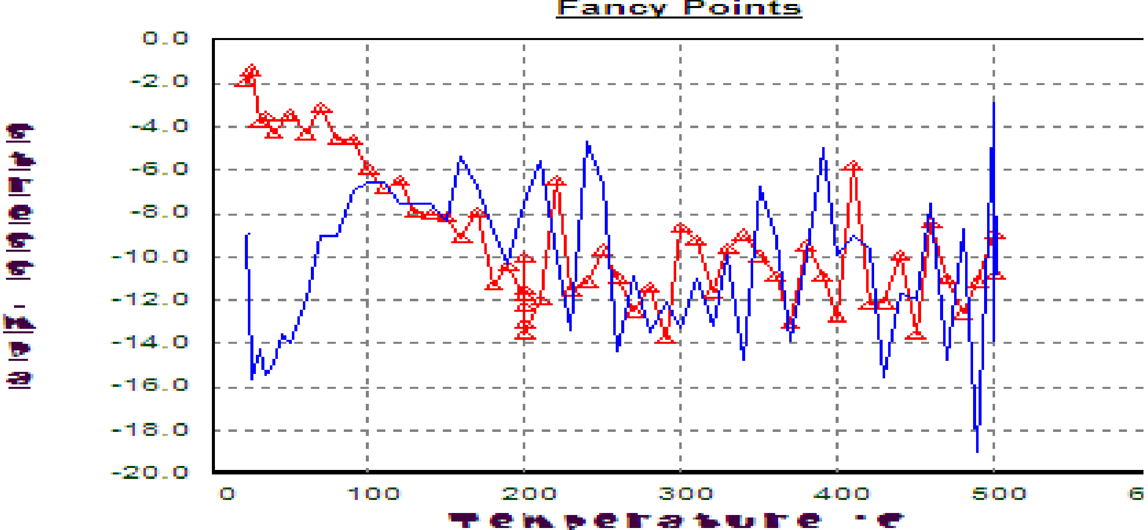


After the new color is selected, click on "OK" and the new color will be applied to the points and the connecting line (if present).

Shape: The default shape for the points on the graph are circles.



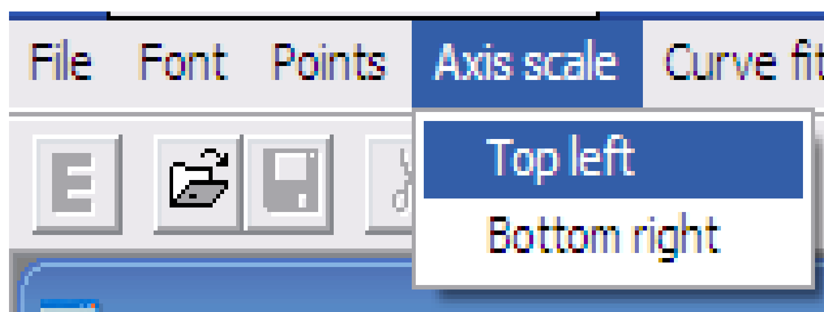
Dot: Selecting “Dot” is like selecting no point markings. There will be a single pixel at each data point with “Dot” selected, however this is most likely used when the points are “connected”. The example below has the Blue Line with “Dot” selected, and the Red Line with “triangle” selected. Both lines are “connected”.



Connect: This selection will connect as well as disconnect. Once selected the cross will appear. Move the cross to the graph and click on a point of the line to be connected or disconnected. This will connect (or disconnect) all of the data points. A straight line will be drawn (or removed) between each data point progressing left to right.

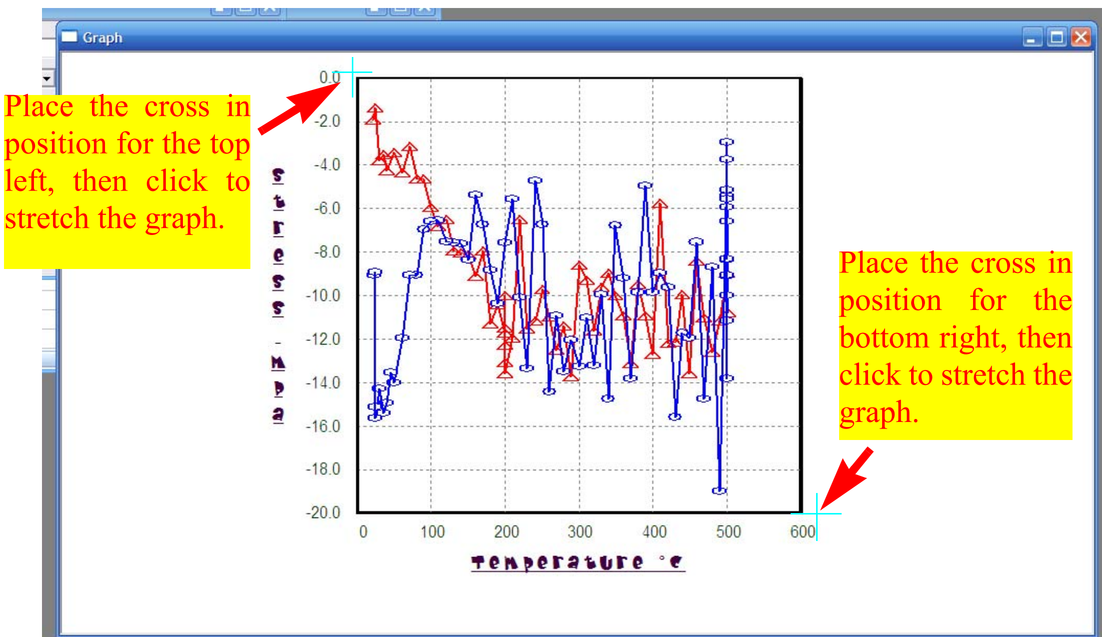
6.2.5 Axis Scale Options

Axis Scale: Will stretch the graph within the graph window.



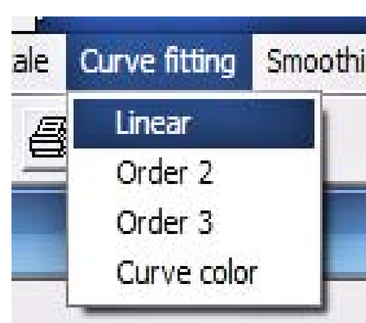
Top left: Select "Top Left" from the Axis scale tab. The cursor will become a cross. Move the cross to the desired top left corner of the graph area. The graph will stretch accordingly.

Bottom Right: Select "Bottom Right" from the Axis scale tab. The cursor will become a cross. Move the cross to the desired bottom right corner of the graph area. The graph will stretch accordingly.



6.2.6 Curve Fitting

Curve Fitting will express the graph or part of a graph as a mathematical function.

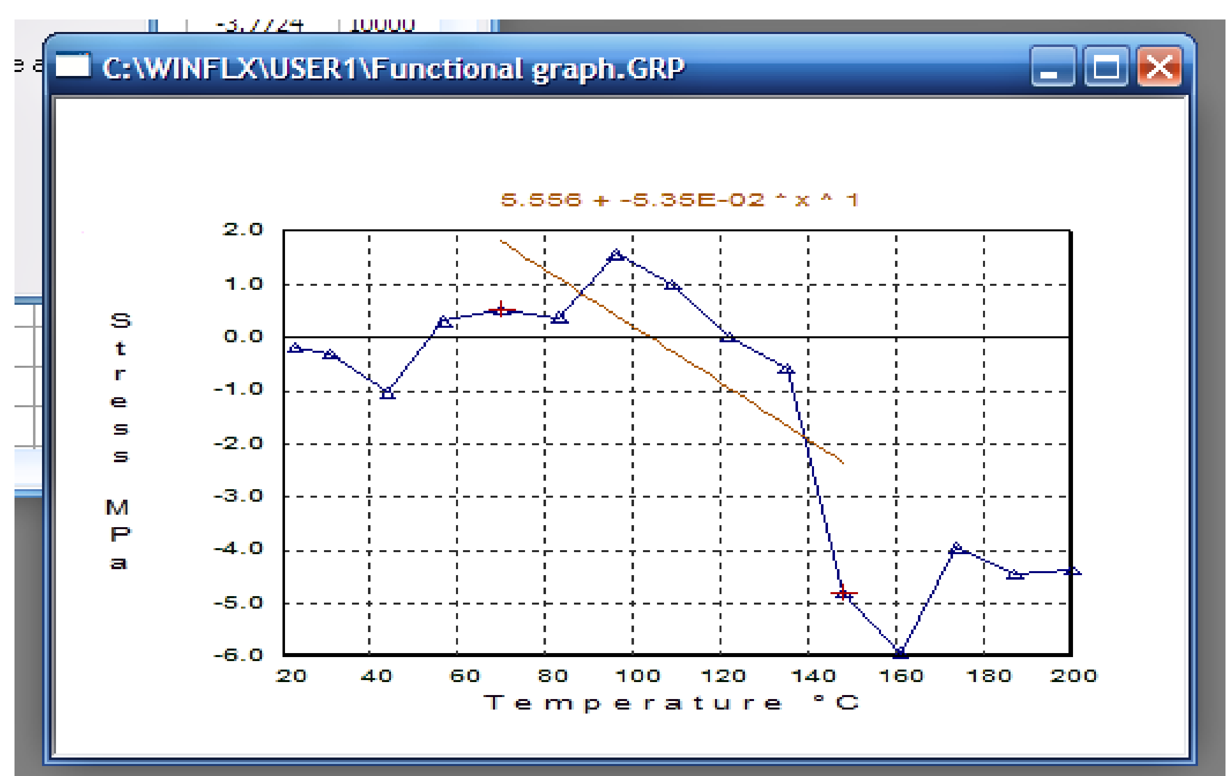


"Linear" gives the function of a line**.**

"Order 2" gives the function of a curve.

"Order 3" gives the function of a complex curve *(an "S" shape)*

1. For a **Linear** curve fit, select "Linear" from the Curve fitting tab.
2. The cursor will become a cross. Click on the start and the end point for the portion of the graph to be expressed as a linear function.

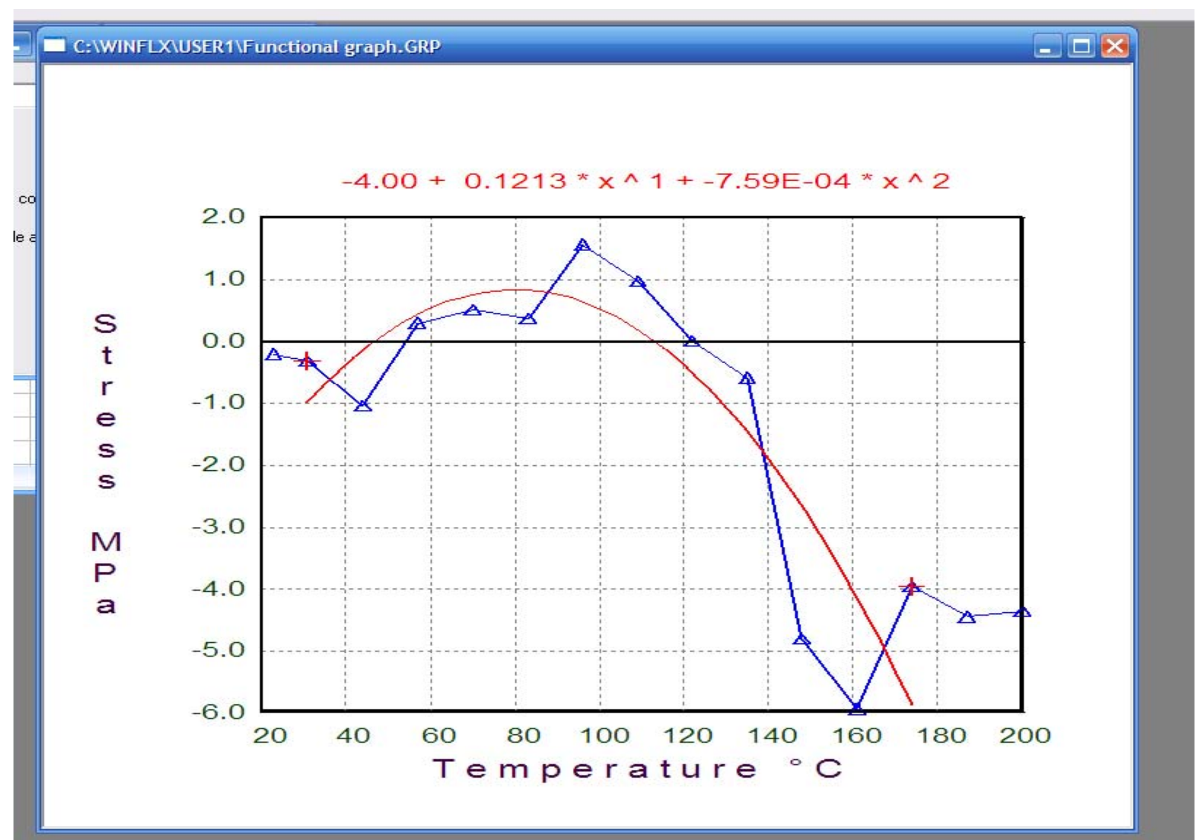


In the example above, the section from 70 °C to 150 °C was selected. The function between these 2 points is graphed. The mathematical equation will appear above the graph. (To change the font or color or style modify "Subtitles")

The equation given reads "5.556 + -5.35E-02*x^1".

This is more commonly expressed as: $y = -.0535x + 5.556$

1. For an **Order 2** curve fit, select "Order 2" from the Curve fitting tab.
2. The cursor will become a cross. Click on the start and the end point for the portion of the graph to be expressed as a single curved function.

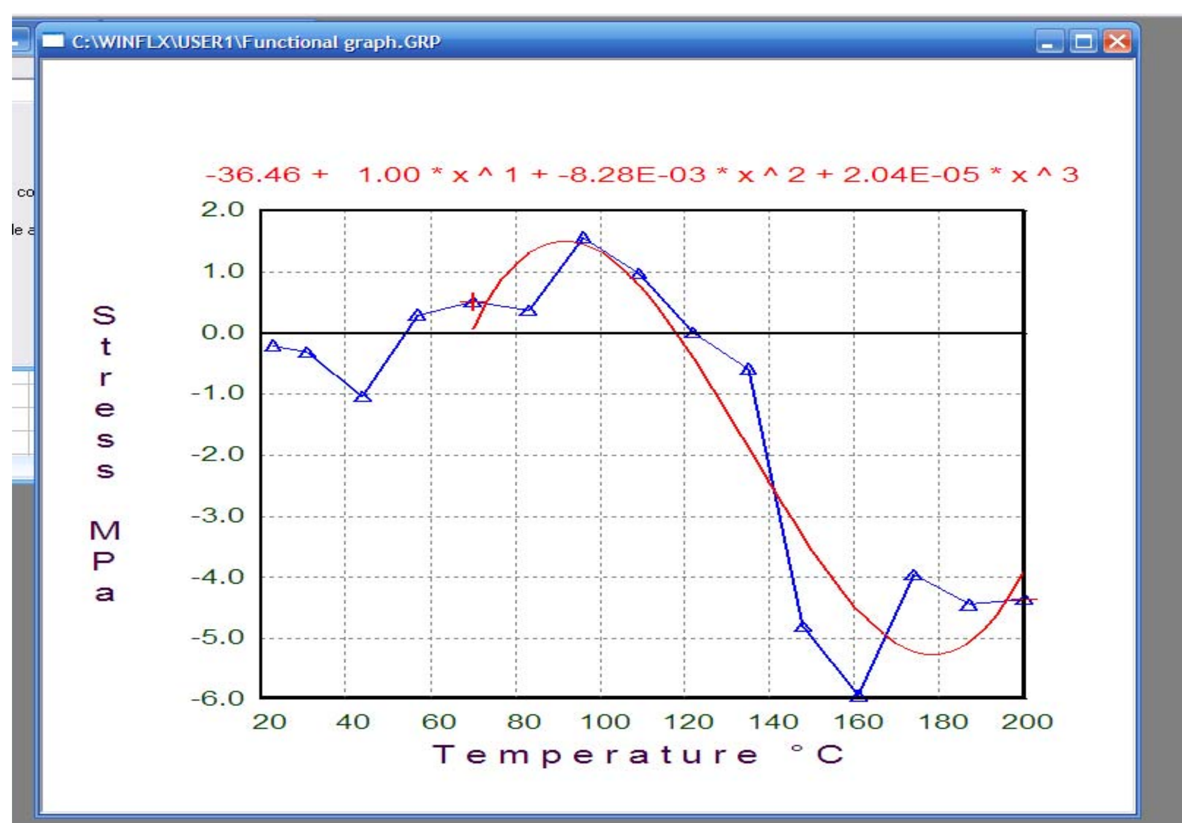


In the example above, the section from 30 °C to 170 °C was selected. The function between these 2 points is graphed as a single curve. The mathematical equation will appear above the graph.

The Equation reads "-4.00 + 0.1213*x^1 + -7.59E-04*x^2"

This is more commonly expressed as: $y = -0.000759x^2 + 0.1213x - 4$

1. For an **Order 3** curve fit, select “Order 3" from the Curve fitting tab.
2. The cursor will become a cross. Click on the start and the end point for the portion of the graph to be expressed as a double curved function.

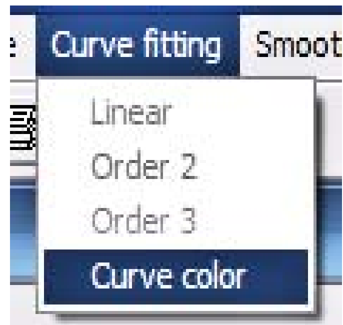


In the example above, the section from 70 ^oC to 200 ^oC was selected. The function between these 2 points is graphed as a double curving function. The mathematical equation will appear above the graph.

The Equation reads “-36.46 + 1.00*x^1 + -8.28E-03*x^2 + 2.04E-05*x^3”

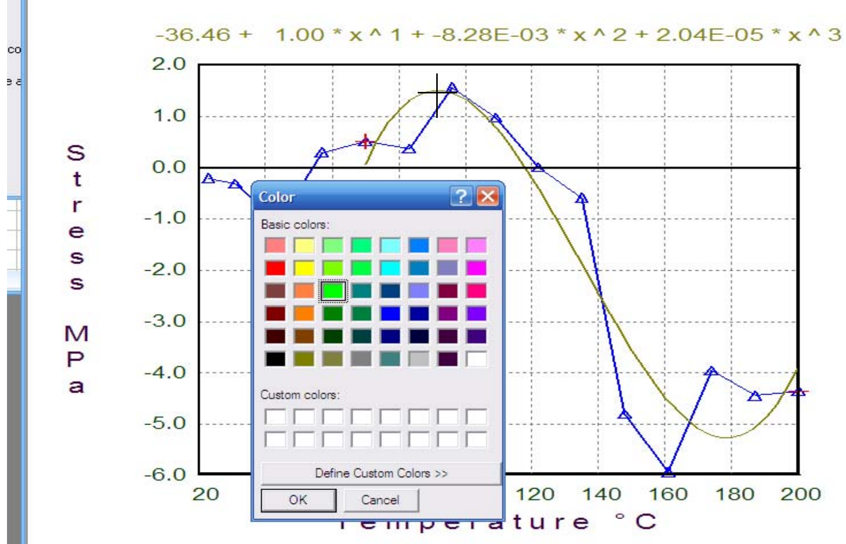
This is more commonly expressed as:

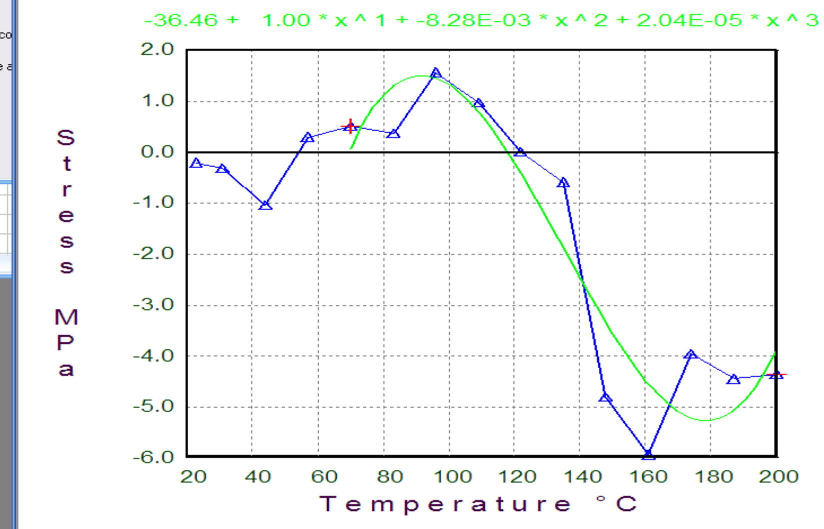
$y = -0.0000204x^3 - 0.00828x^2 + 1x - 36.46$



NOTE: Curve color does nothing. It will open a color pallet, but selecting a color and pressing “OK” does nothing.

To change the color of the curve go to the “Points” menu, select color, then click the cross on a section.

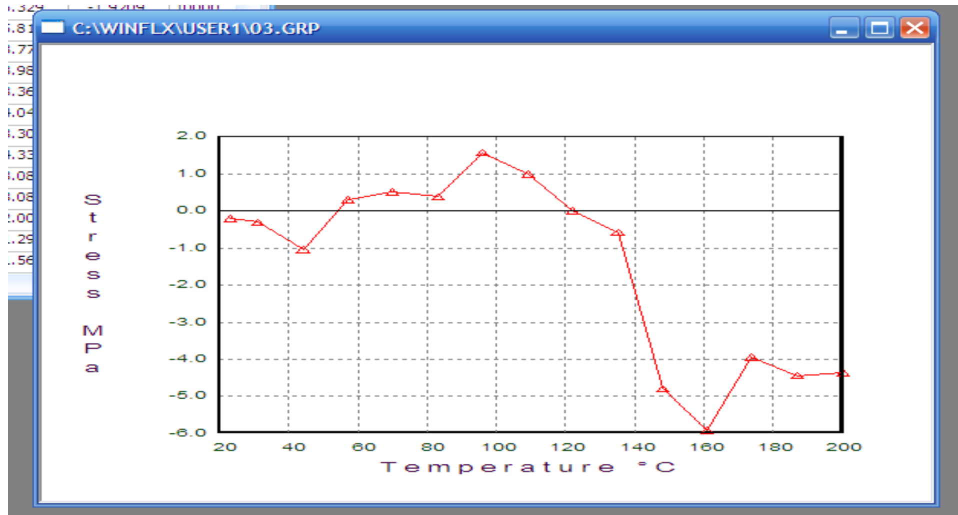




This will change the color of the curve on that graph and the color of the font for the equation.

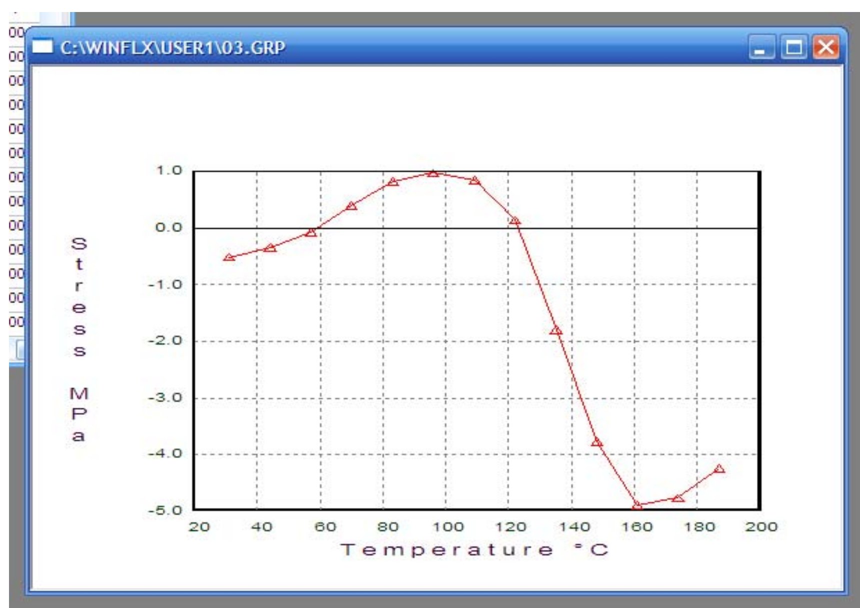
6.2.7 Smoothing

Use the Smoothing menu to reduce the amount of noise found in a graph. Smoothing can be performed for three, five, seven or nine points.



The image above shows a graph before any smoothing has been applied. Notice the first 3 points have temperatures of 22°C, 31°C, and 42°C.

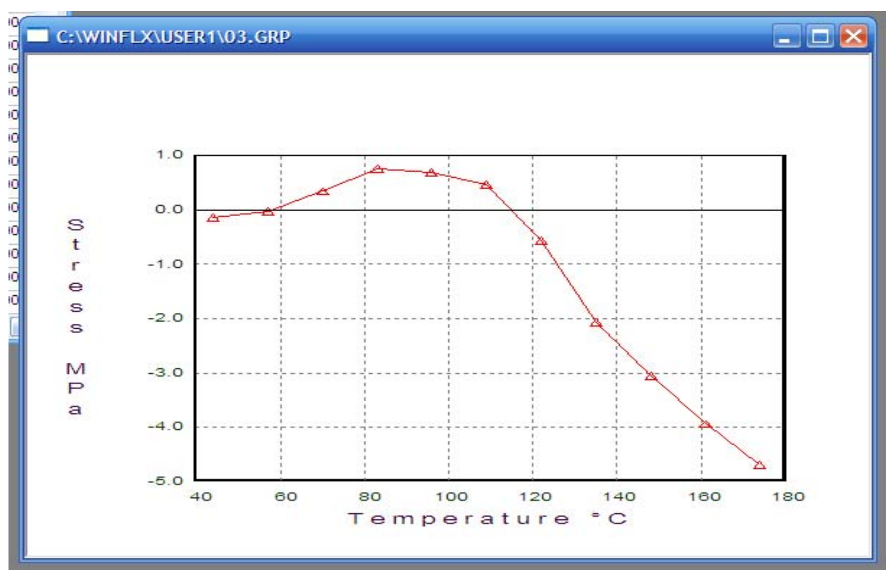
The image below shows this same graph with 3-Point smoothing applied. The software takes the average of the nearest 3 points at every point to plot the smoothed graph. Notice there are now fewer points. The 1st point is now the average of what were the first 3 points of the original graph.



The new 1st point is now at 32°C. (22+31+42=96; 96/3= 32 average)

5-point smoothing

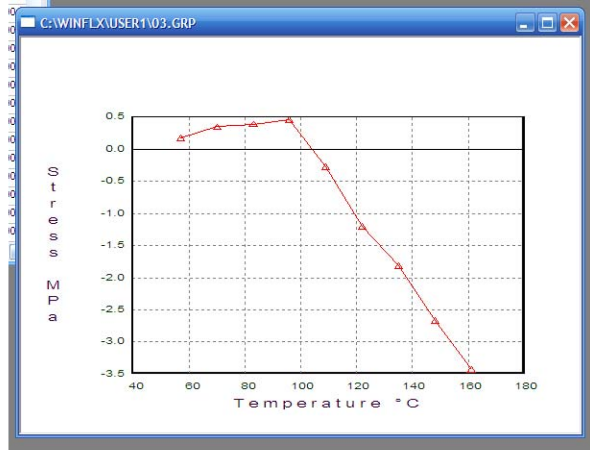
The image below shows this same graph with 5-Point smoothing applied. The software takes the average of the nearest 5 points at every point to plot the smoothed graph. Notice there are now fewer points. The 1st point is now the average of what were the first 5 points of the original graph.



The new 1st point is now at 45°C. (22+31+42 +58 + 71 =225; 225/5= 45 average)

7-point smoothing

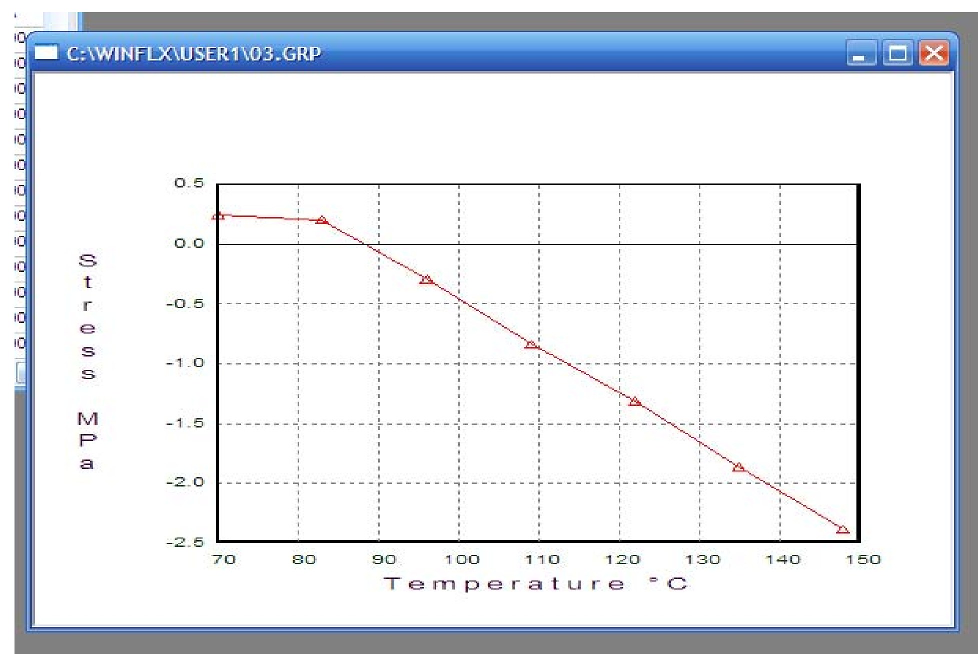
The image below shows this same graph with 7-Point smoothing applied. The software takes the average of the nearest 7 points at every point to plot the smoothed graph. Notice there are now fewer points. The 1st point is now the average of what were the first 7 points of the original graph.



The new 1st point is now at 58°C. (22+31+42 +58 + 71 +83 + 98 =406; 406/7= 58 average)

9-point smoothing

The image below shows this same graph with 9-Point smoothing applied. The software takes the average of the nearest 9 points at every point to plot the smoothed graph. Notice there are now fewer points. The 1st point is now the average of what were the first 9 points of the original graph.



The new 1st point is now at 71°C.

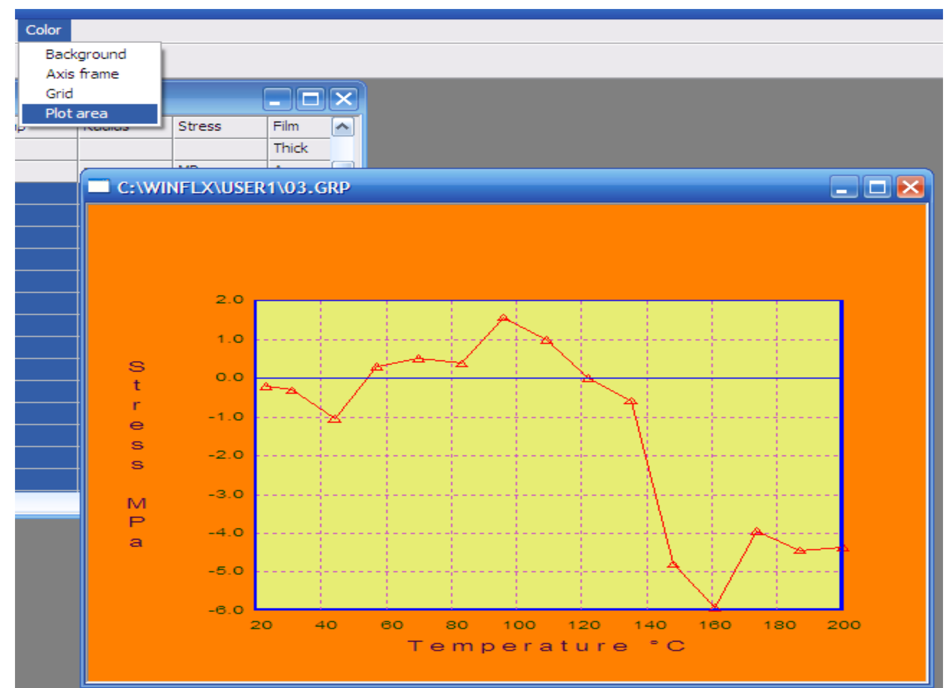
(22+31+42 +58 + 71 +83 + 98 + 111 + 122=639; 639/9 = 71 average)

The new last point is now 148°C.

(98 + 111 + 122 + 134 + 146 + 160 + 174 + 187 + 200 = 1332; 1332/9= 148 average)

6.2.8 Setting the Colors of a Graph

Use the Color menu to set or change the color of the background, axis frame, grid, or plot area of the graph.



The image to the left has:

Orange background

Blue Axis Frame

Violet Grid

Custom Yellow Plot Area

To change the background color:

1. Choose Background from the Color menu.
2. The color dialog box displays. Select the desired color and click OK. Then the graph re-displays with the selected background color.

To change the axis frame color:

1. Choose Axis Frame from the Color menu.
2. The color dialog box displays. Select the desired color and click OK. Then the graph re-displays with the selected axis frame color.

To change the grid color:

1. Choose Grid from the Color menu.
2. The color dialog box displays. Select the desired color and click OK. Then the graph re-displays with the selected grid color.

To change the color of the plot area:

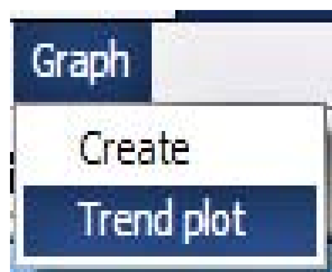
1. Choose Plot Area from the Color menu.
2. The color dialog box displays. Select the desired color and click OK. Then the graph re-displays with the selected plot area color.

6.3 CREATING A TREND PLOT

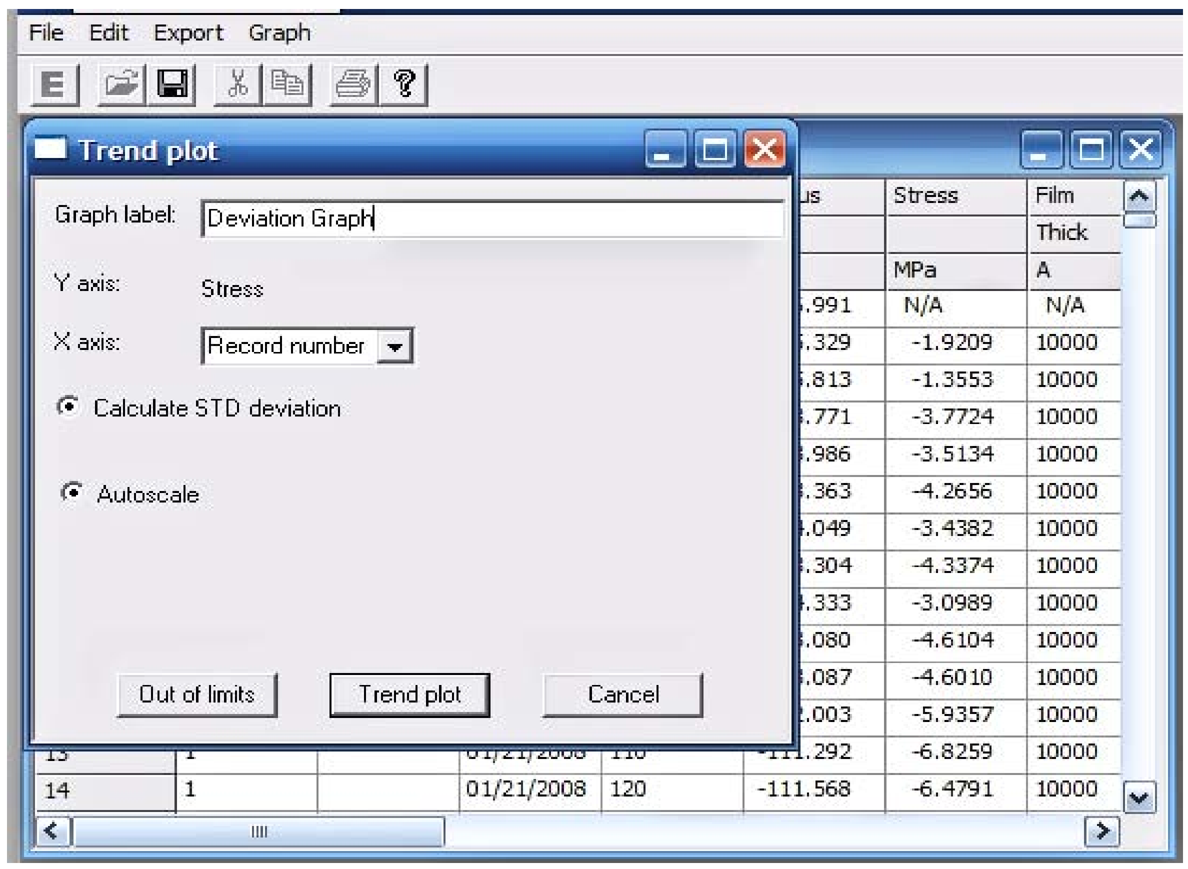
Use this option to plot trends from the raw data files. You have the option of generating a trend plot from the entire data file or from a selected block.

To generate a trend plot:

1. Display a data file in the Data Editor window:
   - Choose Trend Plot from the Graph menu in the Data Editor window.

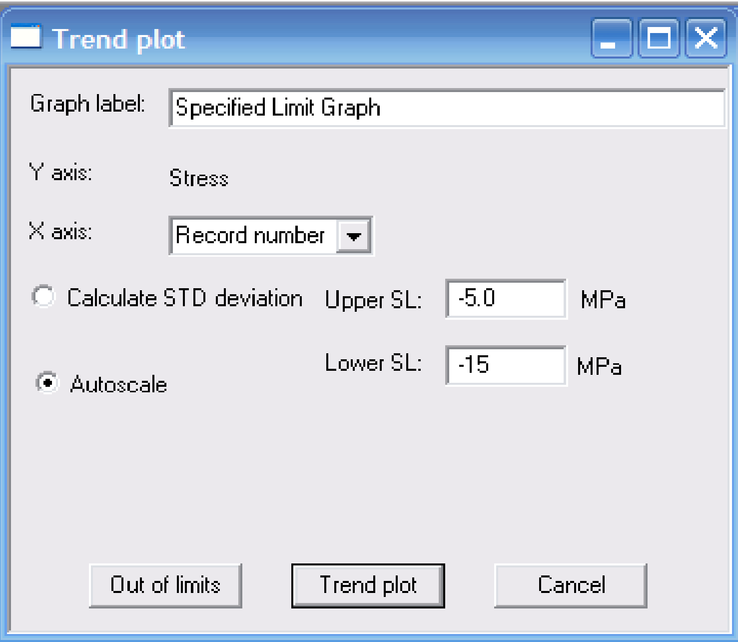


   - A window will appear.



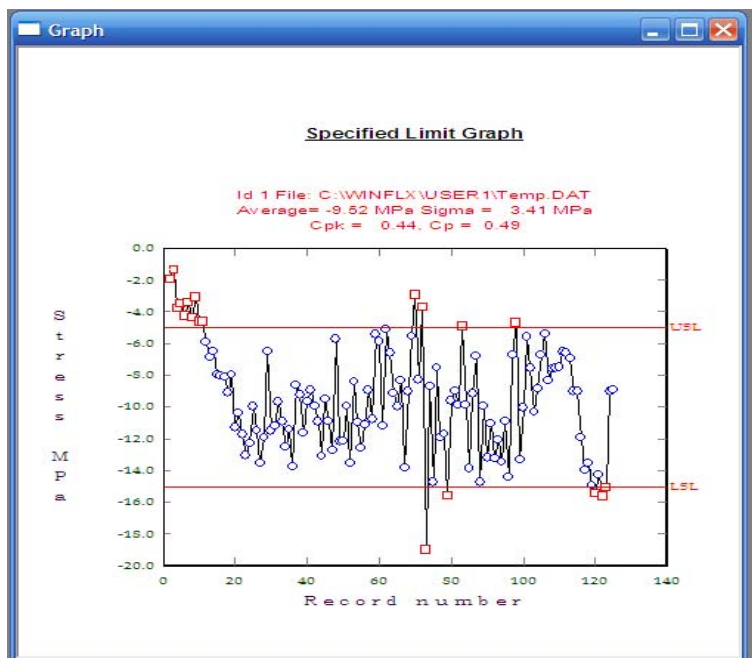
- Enter values for the fields using the following list.

Field	Description
Graph Label	The label to be displayed at the top of the trend plot. You can enter any combination of characters and numbers.
Y axis	The Y-axis is set to Stress and cannot be changed.
X axis	The X-axis of the graph. Choices available in drop down menu are Record Number, Date, and Days.
Calculate STD deviation	Calculates the standard deviation. (standard deviation is the square root of variance). This is selected by default. Click on this to unselect this feature. Fields for Upper SL and Lower SL will appear.
Upper SL	The Upper Specification Limit in MPa or dynes/cm^2. The selected units of Stress MPa or dynes/cm^2 is determined by the most recently opened Process Program.
Lower SL	The Lower Specification Limit in MPa or dynes/cm^2. The selected units of MPa or dynes/cm^2 is determined by the most recently opened Process Program.
Autoscale	Autoscale is selected by default. Click on this to unselect this feature. Fields for X from, X to, X step, Y from, Y to, and Y step.
X From:	Starting X value.
Y From:	Starting Y value.
X To:	Ending X value.
Y To:	Ending Y value.
X Step:	Distance between grid markings on the X-axis.
Y Step:	Distance between grid markings on the Y-axis.
Out of limits	When clicked gives the record numbers and Stress data for scans outside of the standard deviation or specified Upper and Lower Limits.
Trend plot	Creates a graph with calculations for the average and standard deviation (Sigma).
Cancel	Cancels the application.



2. With "Calculate STD deviation" unselected, fields for Upper and Lower Stress Specification will appear. Enter these limits.

3. The Upper SL and Lower SL will be displayed in the graph when the "Trend plot" is created.



4. Cpk is a simple number which measures how close a process is running to its specification limits, relative to the natural variability of the process. The larger the index, the less likely it is that any item will be outside the specs.

5. Cp is Process Capability. Defined as (USL - LSL)/6*Std.Dev

Cpk is defined as the lower of Cpl and Cpu where

$$Cpl = \frac{(Average - LSL)}{3\sigma}, Cpu = \frac{(USL - Average)}{3\sigma}$$

and,

$$Cp = \frac{(Cpu + Cpl)}{2}$$

If the option to calculate the standard deviation was selected in the Graph window, then σ and the average are displayed above the trend plot. Also, note that in the plot

- points within ±σ limits are plotted as squares,
- points within the ±3σ limit but outside the ±σ limits are plotted as circles, and
- points outside the ±3σ limits are marked with an X.

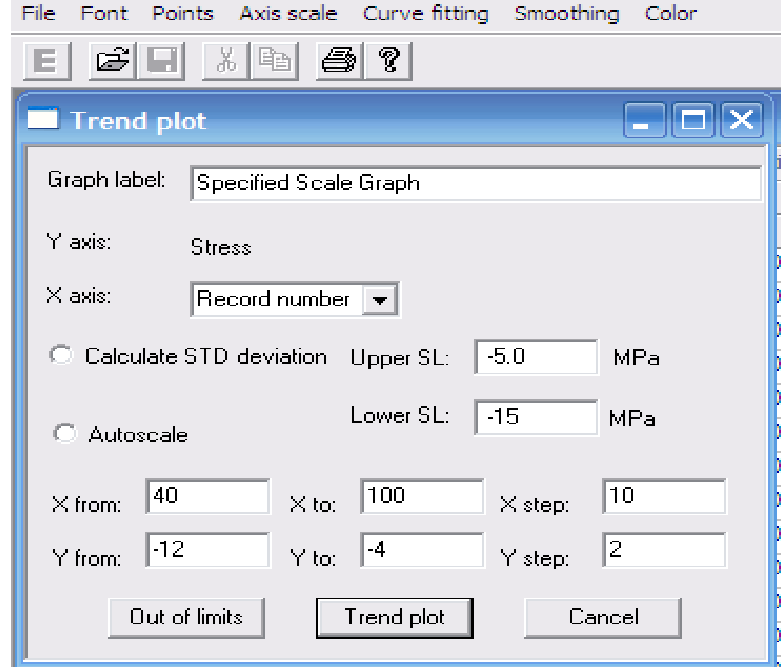
To display a table of the points outside the specification limits, choose “Out Of Limits” from the Trend Plot dialog box. A table of the outlying points displays.

Records out of limits

Rec	Id	Comment	Date	Stress
#				MPa
2	1		01/21/2008	-1.9209
3	1		01/21/2008	-1.3553
4	1		01/21/2008	-3.7724
5	1		01/21/2008	-3.5134
6	1		01/21/2008	-4.2656
7	1		01/21/2008	-3.4382
8	1		01/21/2008	-4.3374
9	1		01/21/2008	-3.0989
10	1		01/21/2008	-4.6104
11	1		01/21/2008	-4.6010
70	1		01/21/2008	-2.9326
72	1		01/21/2008	-3.7140

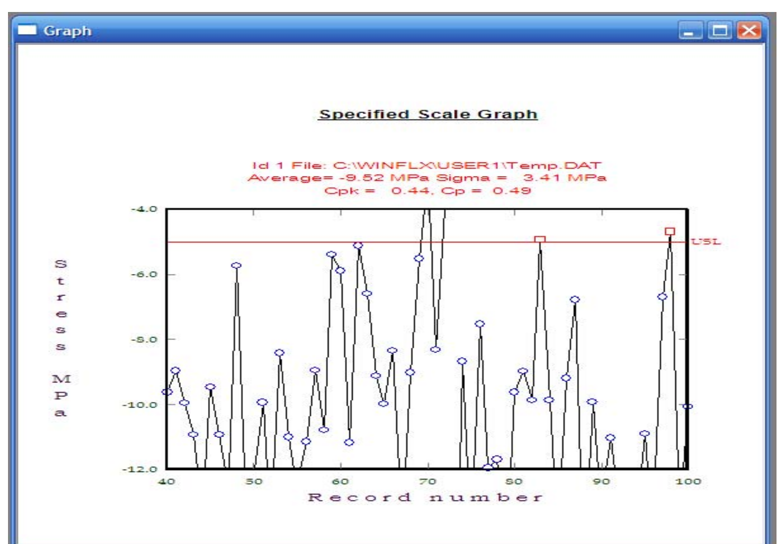
NOTE: This window will only display up to 12 records at a time. The window will not expand. Use the scroll bar to see the remaining records.

6. With Autoscale unselected, select range for the X axis of the graph (record number, date, or days).

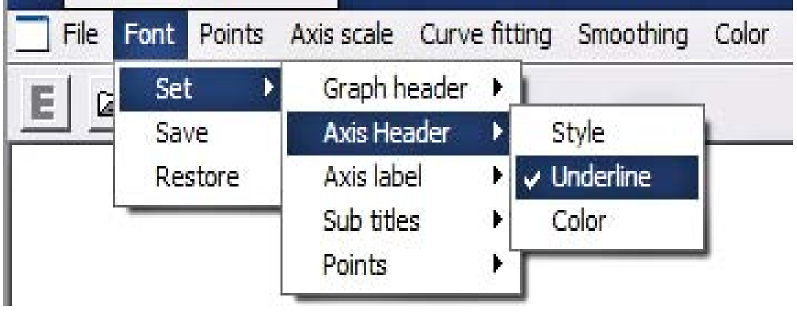


7. Enter beginning and ending points (in terms of Stress) for the Y axis.

8. Only the specified range will appear.

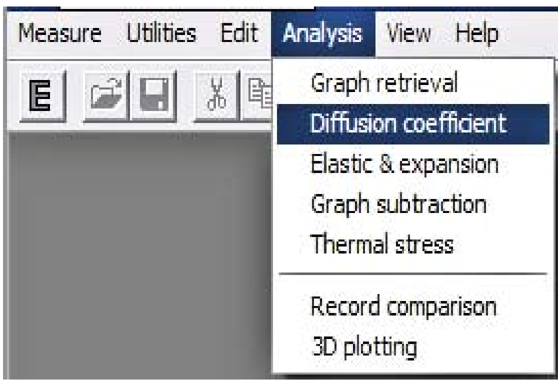


9. All of the same graph options apply to Trend Plots. (Font, Points, Axis Scale, Curve Fitting, Smoothing, Color.)



7 DATA ANALYSIS

This chapter describes how to analyze the data by displaying graphs of file subtraction, thermal stress, elastic and expansion coefficient calculations, and diffusion coefficients.

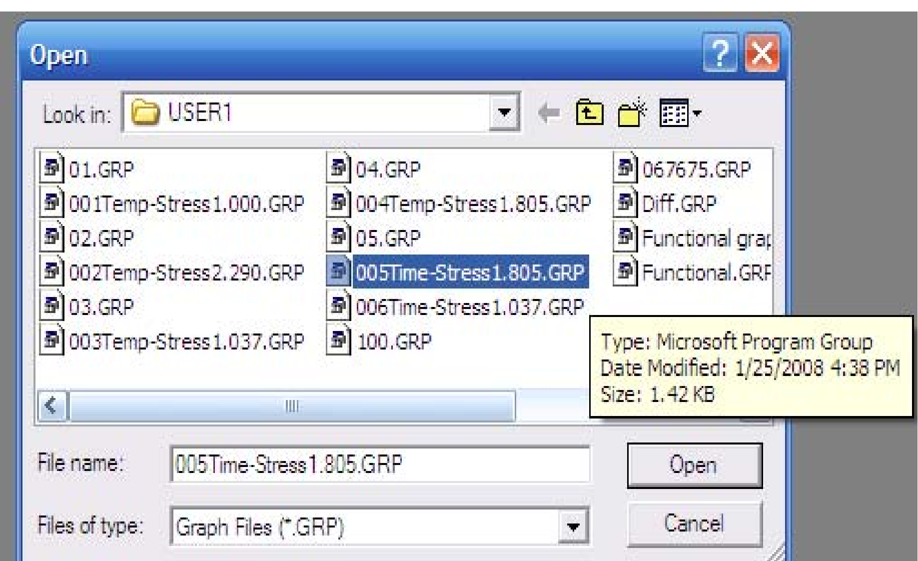


NOTE: “Graph retrieval, Record comparison, and 3D plotting” have been covered earlier in this manual.

7.1 DIFFUSION COEFFICIENT

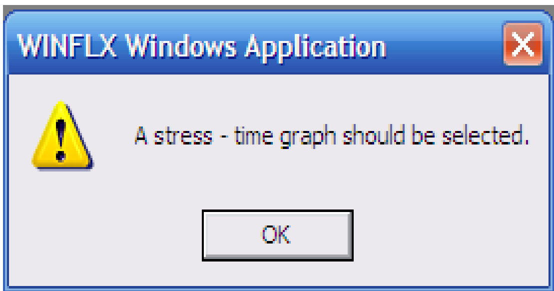
To calculate the diffusion coefficient:

1. Choose Diffusion Coefficient from the Analysis menu.
2. The system displays a dialog box prompting for the desired filename.

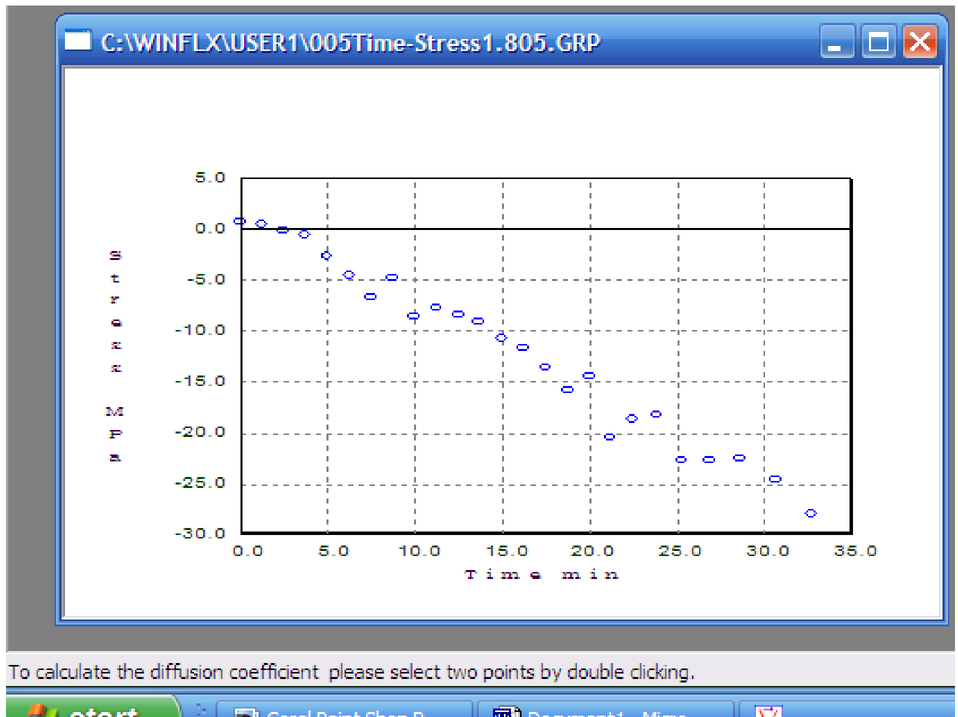


3. Enter or choose the desired filename. Be sure to select a Time- Stress graph.

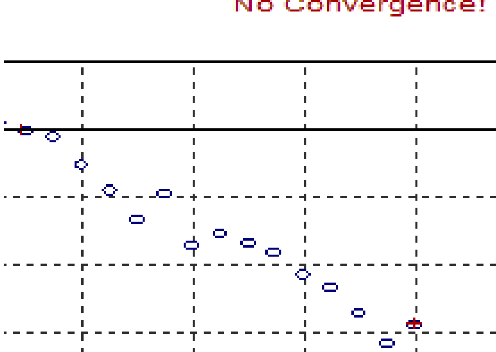
4. If a graph is selected that is not a Time-Stress graph, an error window will appear.



5. When a Time-Stress graph is selected a graph displays. Notice in the bottom of the screen the user is prompted to select two points on the graph by double- clicking on the points.

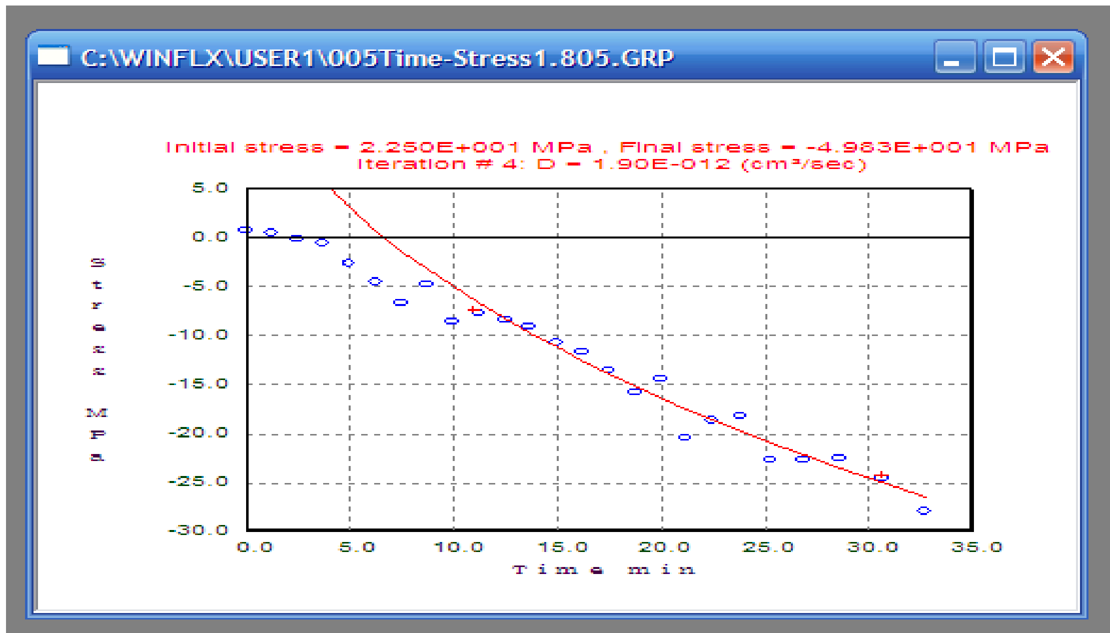


It is very possible that two of the points selected will not converge. If a message appears "No Convergence" simply select two different points.



For details on the equation used to calculate the diffusion coefficient, see Chapter 9, "Theory of Operation."

6. When the two points do converge, an equation will appear with a graphed function.



In the example the Initial Stress reading is "2.250E+001 MPa"

This is more commonly expressed as 22.5 MPa

The initial stress reading is where the stress would be on this curve at time Zero.

In the example the Final Stress reading is " -4.983E+001 MPa"

This is more commonly expressed as -49.83 MPa

The Final Stress reading is the asymptotic stress value that the curve "settles" at.

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

$$\sigma = \sigma_0 - \Delta\sigma\left[1 - \left(\frac{8}{\pi^2}\right)\sum_{1}^{\infty}\left(\frac{1}{(2n-1)}\right)^2 \exp-\left(\frac{(1-2n)^2}{4L^2}\pi^2 Dt\right)\right]$$

where

σ is the stress at time t

σ_0 is the initial stress

$\Delta\sigma$ is the total stress change after completion

n is a running index from 1 to infinity

L is the film thickness

D is the diffusion coefficient

t is the time

7.2 ELASTIC AND EXPANSION COEFFICIENT CALCULATION

The Expansion and Coefficient option under the Analysis menu calculates the film thermal expansion coefficient and biaxial modulus.

The stress change with temperature in the elastic range is governed by the following equation:

$$\frac{d\sigma}{dT} = \left(\frac{E}{1-\nu}\right)_f (\alpha_s - \alpha_f)$$

where

$\frac{d\sigma}{dT}$ is the derivative of stress versus temperature

$\left(\frac{E}{1-\nu}\right)_f$ is the biaxial modulus of the film

α_s is the substrate thermal expansion coefficient

α_f is the film thermal expansion coefficient

The above equation has two unknowns—α_f and $\left(\frac{E}{1-\nu}\right)_f$. To solve these, two temperature cycles are done with two different substrates and the software solves two equations.

To display a graph of the elastic and expansion coefficient calculation:

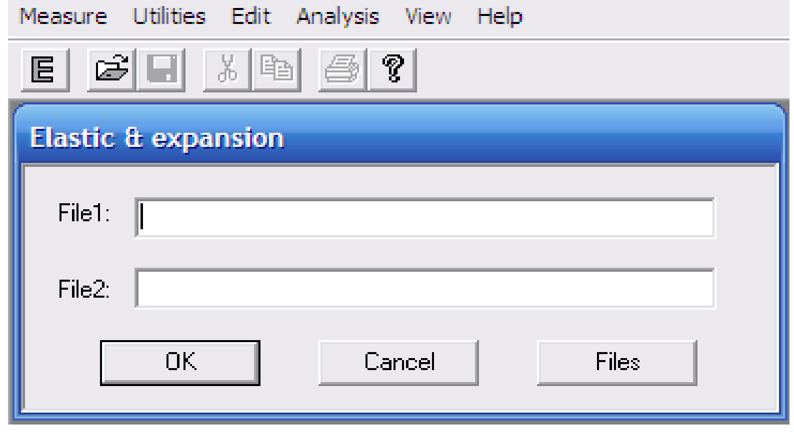
1. Use the Stress-Temperature mode to run two temperature cycles on two different substrates with the same film.

   NOTE: For best results use slow heating or cooling (<5 ^{o} C per minute) to minimize the lag of the wafer temperature behind the heating stage.

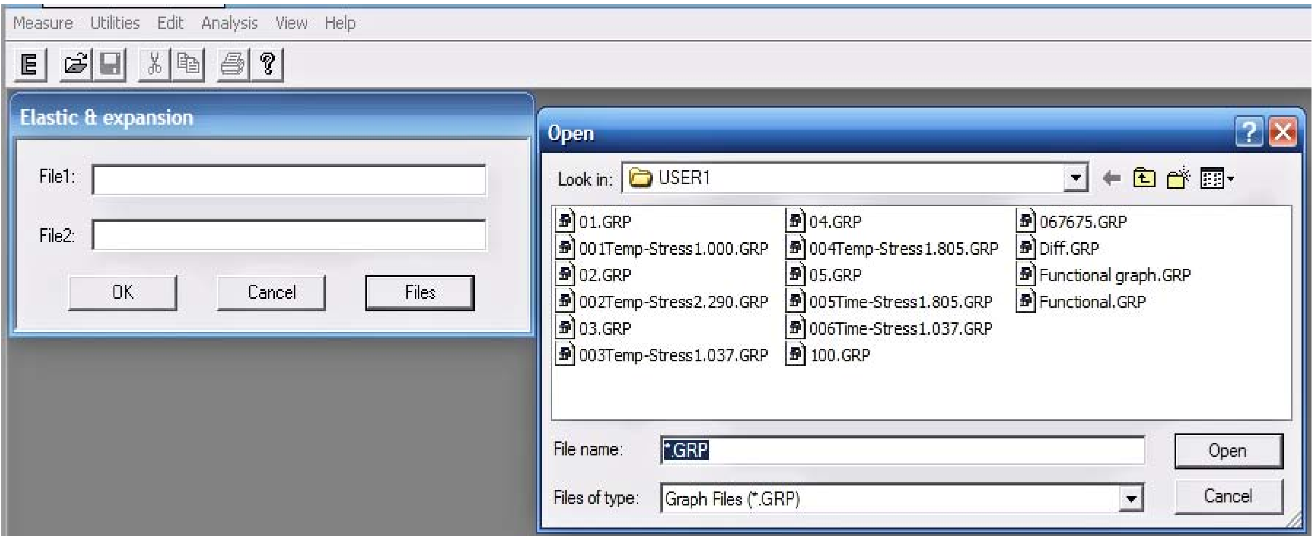
   Use the procedures in "Creating Graphs," to create and save graphs for both the data files.

2. Choose Elastic & Expansion from the Analysis menu.
3. The following dialog box displays:

Analysis View Help
Graph retrieval
Diffusion coefficient
Elastic & expansion
Graph subtraction
Thermal stress
Record comparison
3D plotting

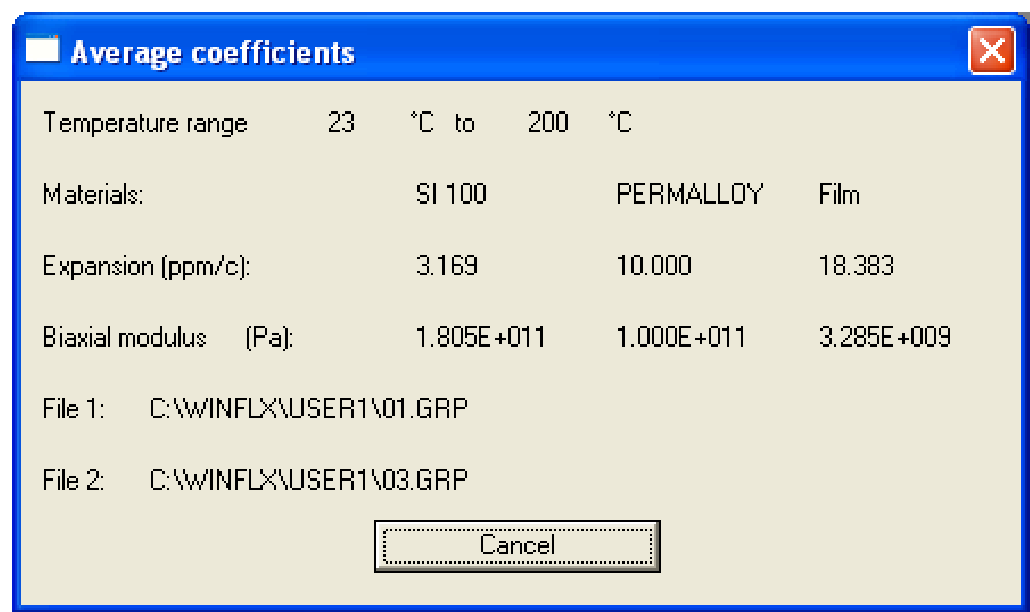


4. Either tab or mouse over to the “Files” button, in order to select graph files.
5. The “Open” window will display all of the GRP (graph) files under the current User.

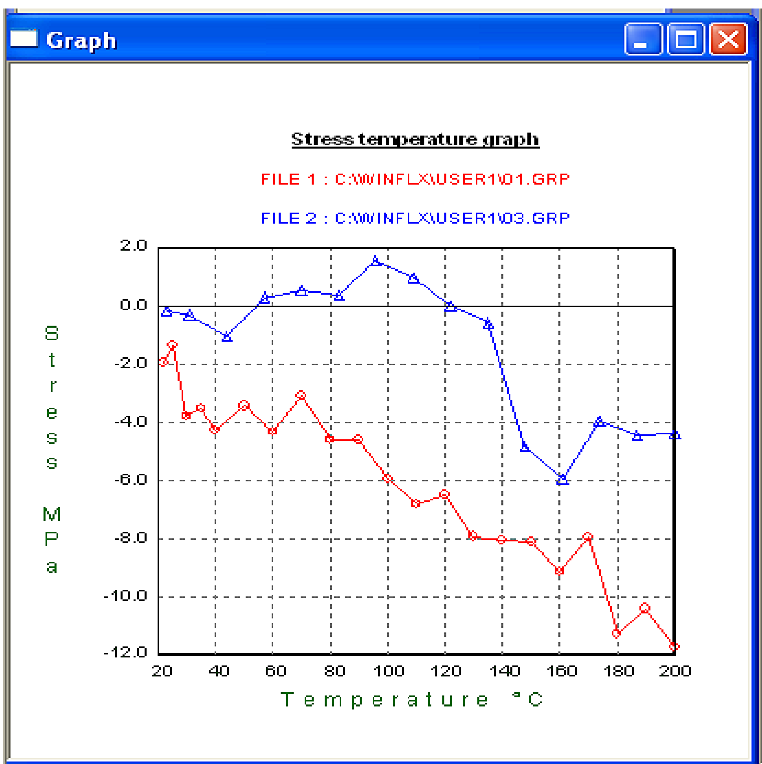


NOTE: graphs have to have the same attributes and only one temperature ramp.

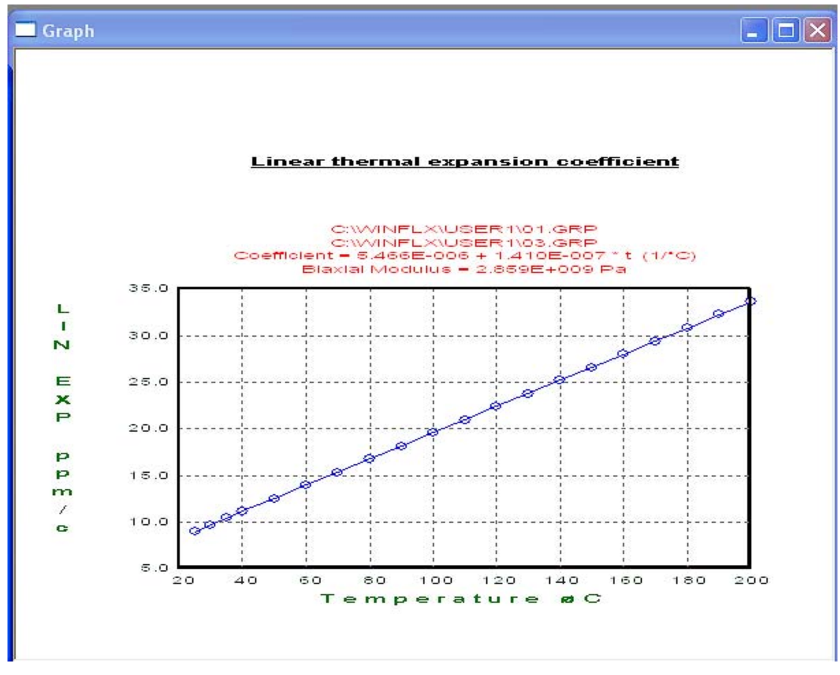
6. When two proper graphs are selected, and the “OK” button is clicked. Three windows will appear. The top window will be “Average coefficients”. This window may be moved around, however the other graphs windows will not move until the “Average coefficients” window is acknowledged by either closing or pressing “Cancel”. This shows the average values of the expansion coefficient and the biaxial modulus.



7. The “graph” window will plot the two Stress/Temperature graphs on the same graph.



8. The “Linear thermal expansion coefficient” graph gives the coefficient and Biaxial Modulus as averaged between the two graphs.



7.3 GRAPH SUBTRACTION

The graph subtraction feature is used for

- Simple graph subtraction for comparison or correction, and
- Multiple films on the substrates

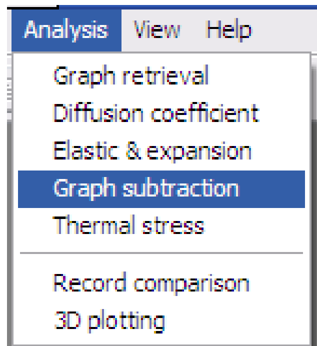
In the case of multi-film use, measure the wafer with Film 1 (thickness t_1) using the Stress-Temperature method and create a graphic file called File 2. Assume the stress measured for this film is σ_1 . Then measure the wafer with Film 1 + Film 2 (thickness t_2) and create a graphic file called File 1. Note: Use the same temperature recipe for both graphs. The stress of the film with Film 1 + Film 2 is

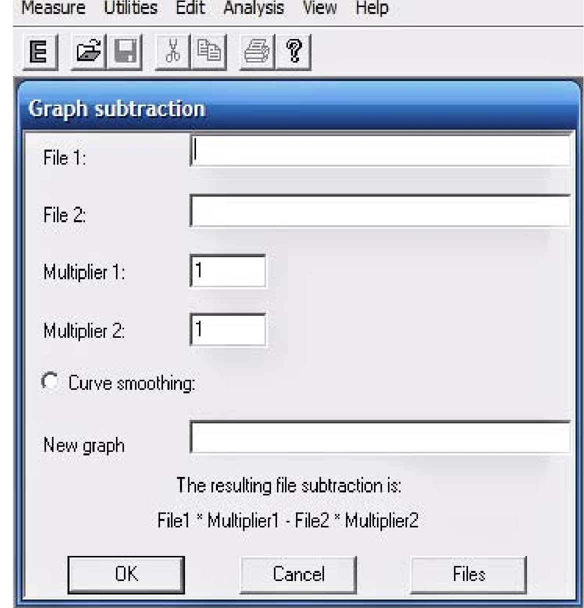
$$\sigma = \frac{(\sigma_1 t_1 + \sigma_2 t_2)}{t_2} = \frac{\sigma_1 t_1}{t_2} + \sigma_2$$

As σ_1 was measured in File 2, σ_2 is calculated by subtracting $\frac{\sigma_1 t_1}{t_2}$ from File 1. This is done by inserting the value of $\frac{t_1}{t_2}$ as the multiplier of File 2 as σ_2 = File 1 – $\frac{t_1}{t_2}$ x File 2. Note that this equation and procedure are valid only if the Film 1 stress is not affected by Film 2.

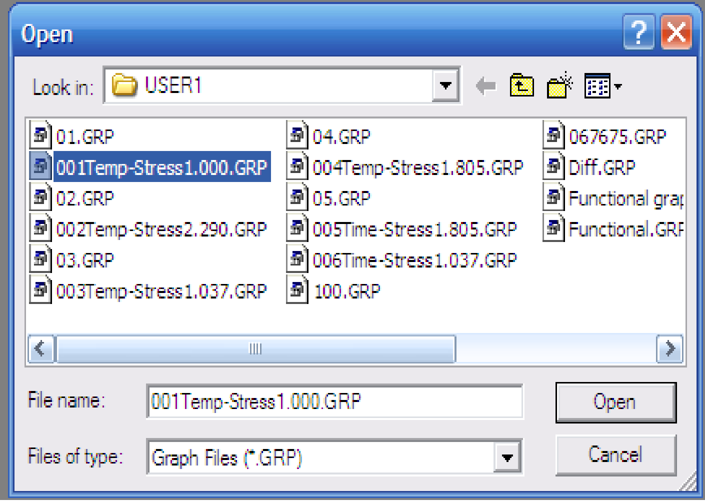
To subtract graphs:

1. Choose Graph Subtraction from the Analysis menu. The following dialog box displays:

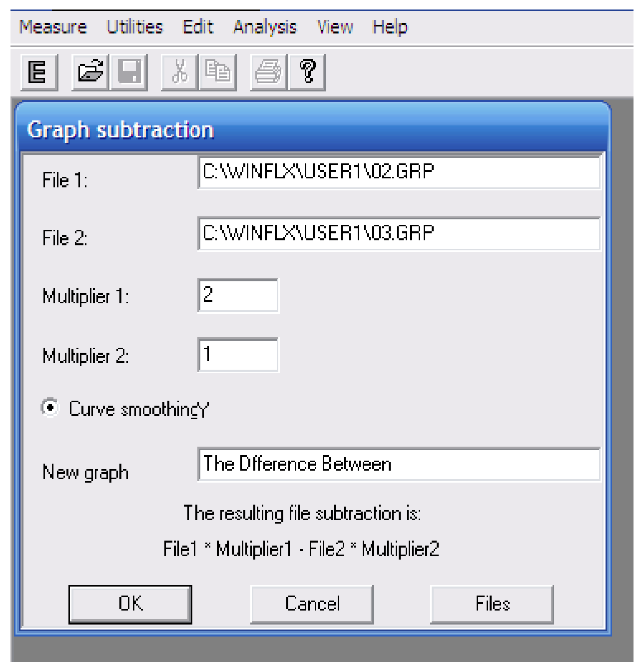




2. Click on the field next to "File 1". Once the cursor is there enter the file name for the 1st graph to be subtracted from. To see a list of available graphs (under the current User) click on the "Files" button. An "Open" window will appear with all the files available.

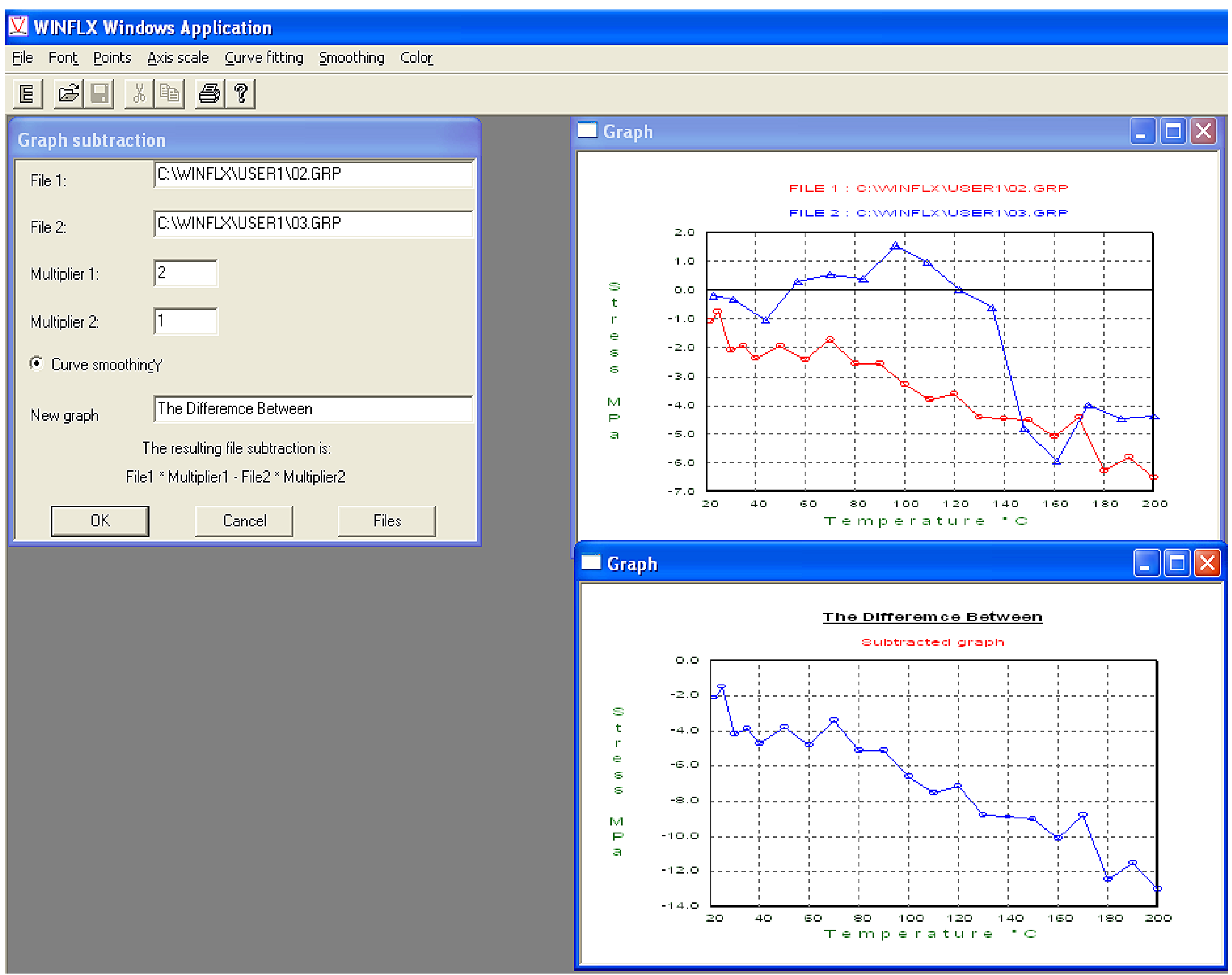


3. Click on the "Open" button. The graph file name should appear in the "File 1" field.
4. Repeat this process for the "File 2" field. This is the graph to be subtracted.
5. With the two File paths entered into the fields, name the new graph in the "New graph" field.



6. Selected Curve smoothing will have a filled circle and a "Curve smoothing Y". Unselected will be an empty circle and read "Curve smoothing N". Curve smoothing reduces noise. Curve smoothing is necessary if the 2 graphs have a different number of points.
7. Click "OK" to create new graph.

8. Two windows will appear: 1) The two graphs superimposed on each other in differing colors and 2) The subtracted graph.



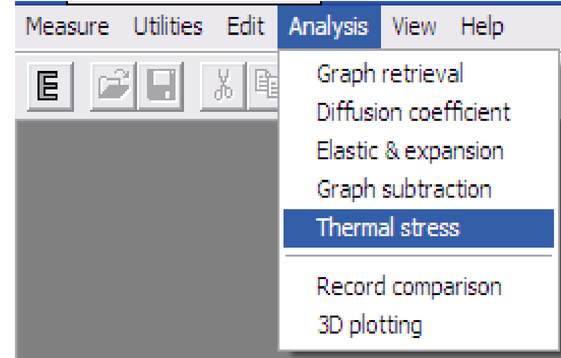
9. Use the multiplier fields if the films of the 2 plots are different thicknesses. (e.g. File 1 has a film thickness of 5,000 angstroms and File 2 has a film thickness of 10,000 angstroms.

10. Choose Save from the File menu to save the graph.

7.4 Thermal Stress

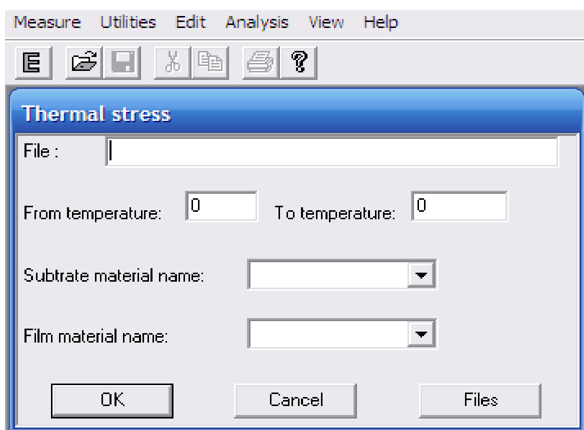
Use the Thermal Stress option to display the thermal stress superimposed on the stress-temperature measurement data.

To display the thermal stress superimposed on the Stress-Temperature graph:



1. Choose Thermal Stress from the Analysis menu.

2. The following dialog box displays:



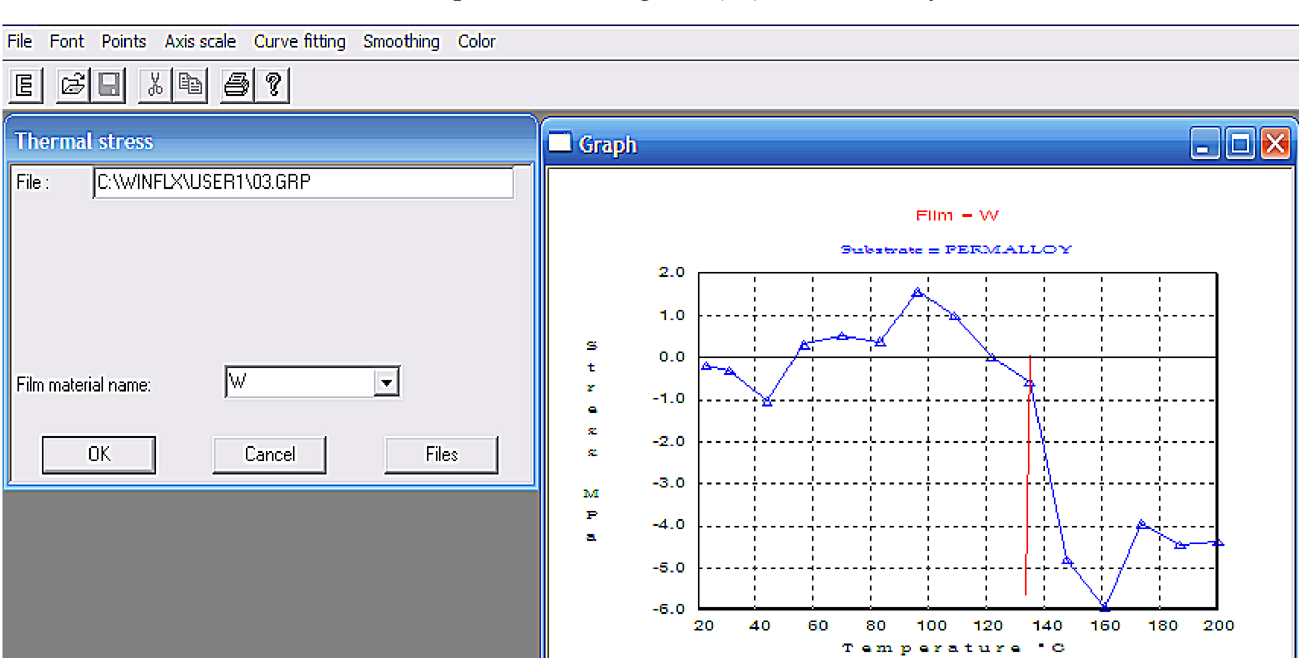
3. Enter the path and name of the file and press ENTER, or choose the Files button to display a list of available files. To change the directory to another User's, use the drop down menu "Look in" in the "Open" window.

4. Enter the **From temperature** and **To temperature** values. *Press TAB to move to the next field.*

5. Enter the **Substrate material name**. Enter the desired substrate name, or use the drop- down menu to select the desired substrate. *Press TAB to move to the next field.*

6. Enter the **Film material name**. Enter the symbol, for example, W for tungsten, or use the pull-down menu to select the desired film material. Choose the OK button or press ENTER to measure the thermal stress.

This is an example of film tungsten (W) on Permalloy.



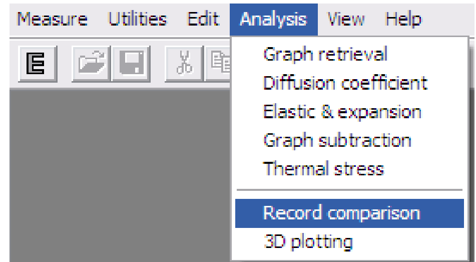
7. Click on a point of the graph and the Thermal Stress linear graph will appear intersecting (in Red) on this point.
8. Choose Save from the File menu to save the graph.

7.5 Comparing Records

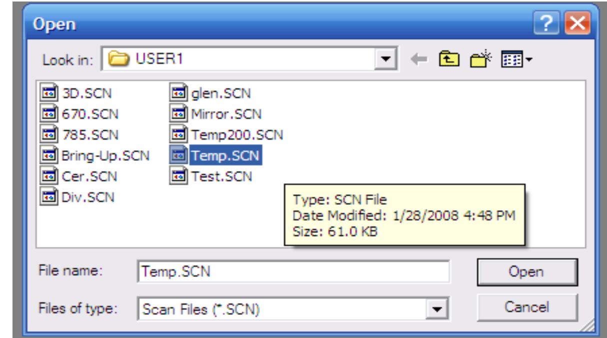
The Record Comparison option in the Analysis menu compares the curves of the first stress and single stress measurements. You can use this option only if you selected the option to save scan (extension.SCN) files when scanning the wafer in First Stress and Single Stress Measurement modes. Also note that the Stress-Time and Stress-Temperature Measurement modes do not create scan files. You can compare Deflection, Light Intensity, Stress Segmentation, and Stress Uniformity. You may also export the angles for each point of the scan.

To compare records:

1. Choose Record Comparison from the Analysis menu.

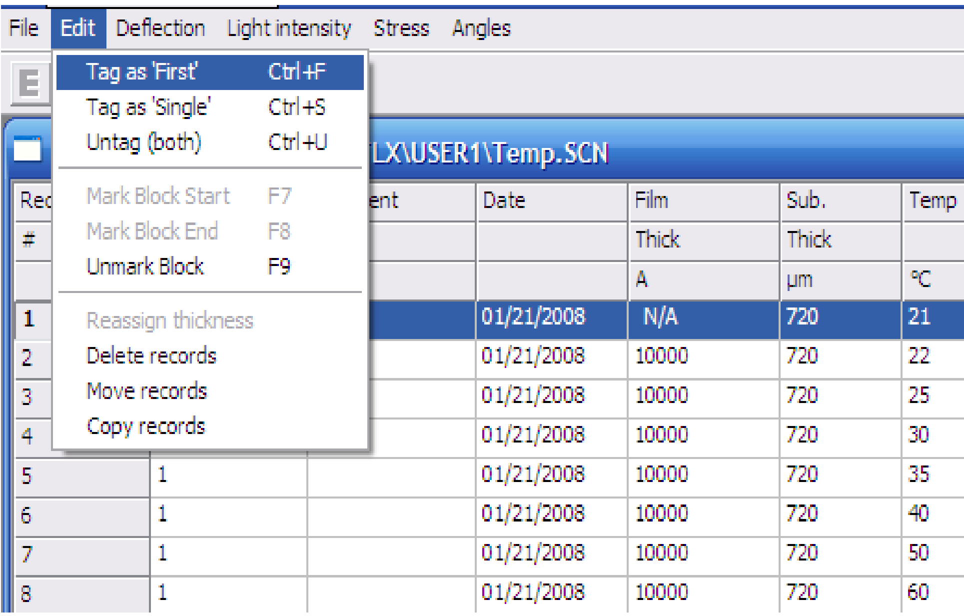


2. An “Open” window will pop up. Select from all of the scan files (SCN) under this User.



3. When the SCN file is opened, all of the records therein will display. You must “Tag” a “First” scan as well as a “Single” scan. The First scan must be a no thickness scan. Under the “Film Thick” column it will read “N/A”.

You can use the Edit menu to select tagging, or you may enter “Ctrl + F” for First scan and “Ctrl + S” for Single scan. An F appears next to the record indicating it is selected as the first measurement. To untag the record, choose Untag (Both) or press CTRL+U from the Edit menu.



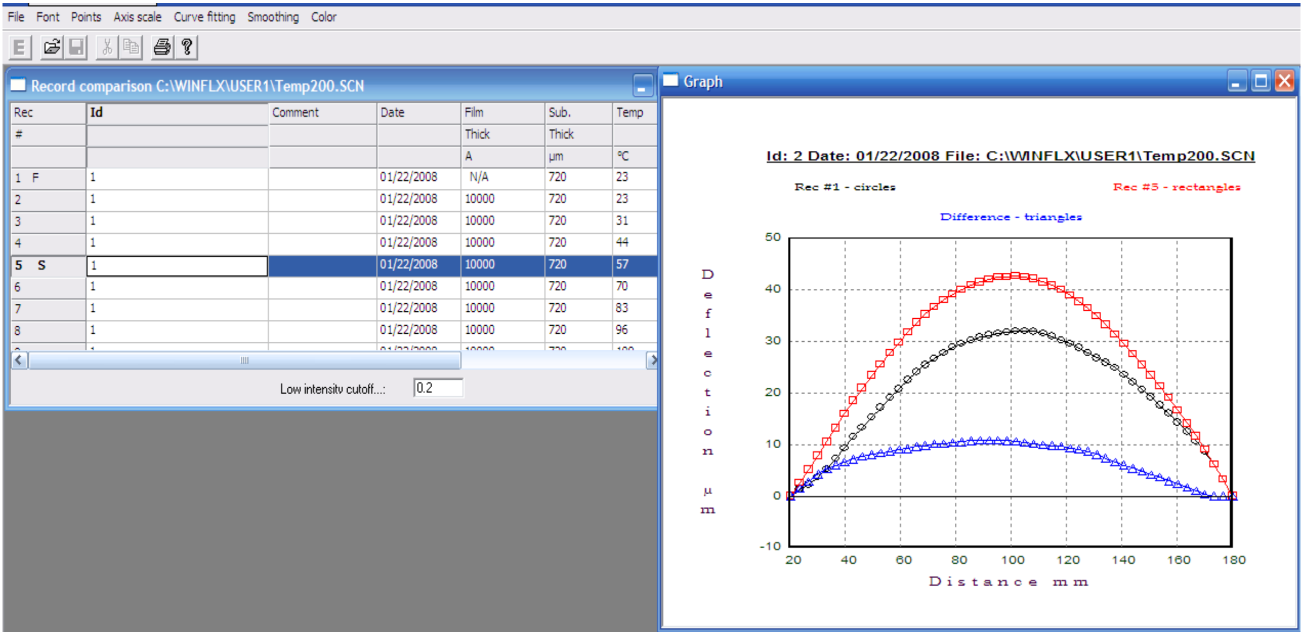
4. To edit a record, use TAB to move to the record. You can edit the ID, Film Thickness (if measured), and Substrate Thickness fields.

NOTE: To select and display only one record, tag only one record as First or Single.

7.5.1 Deflection

1. After selecting the two records, choose Deflection from the menu.
2. A pop-up window will ask whether or not to export the data to a file for every one of the 50 points. The file goes to C:\ WINFLX\File Export. It is stored as a ".TXT" file.

3. A deflection graph similar to the following displays:

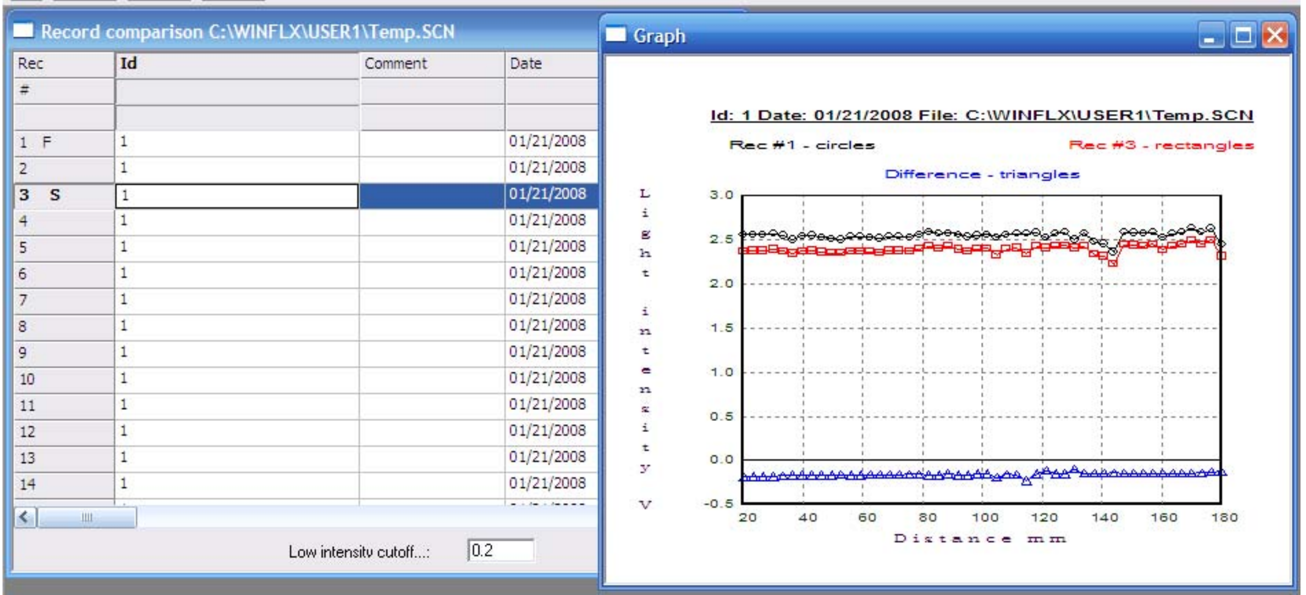


In the plot,

- the deflections of the first measurement are plotted as circles,
- the deflections of the second measurement are plotted as rectangles, and
- the difference between the two measurements are plotted as triangles.

7.5.2 Light Intensity

1. After selecting the two records, choose “Light Intensity” from the menu.
2. An Intensity graph similar to the following displays:

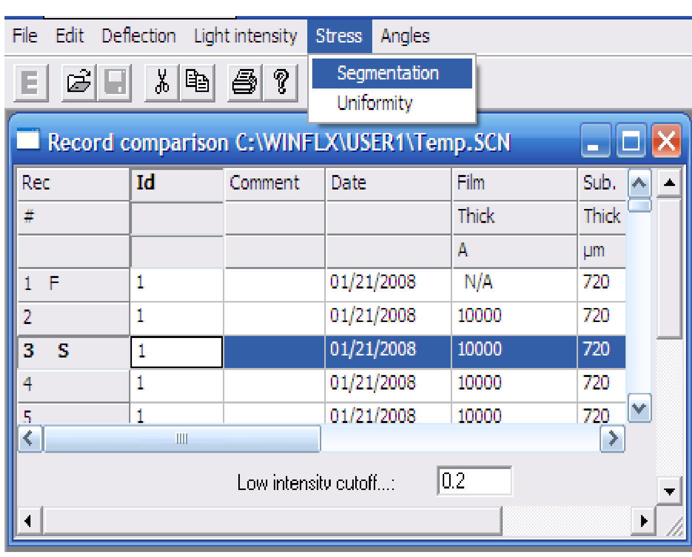


In the plot,

- the intensity at each point of the first measurement is plotted as circles,
- the intensity at each point of the second measurement is plotted as rectangles,
- the difference between the two measurements is plotted as triangles.

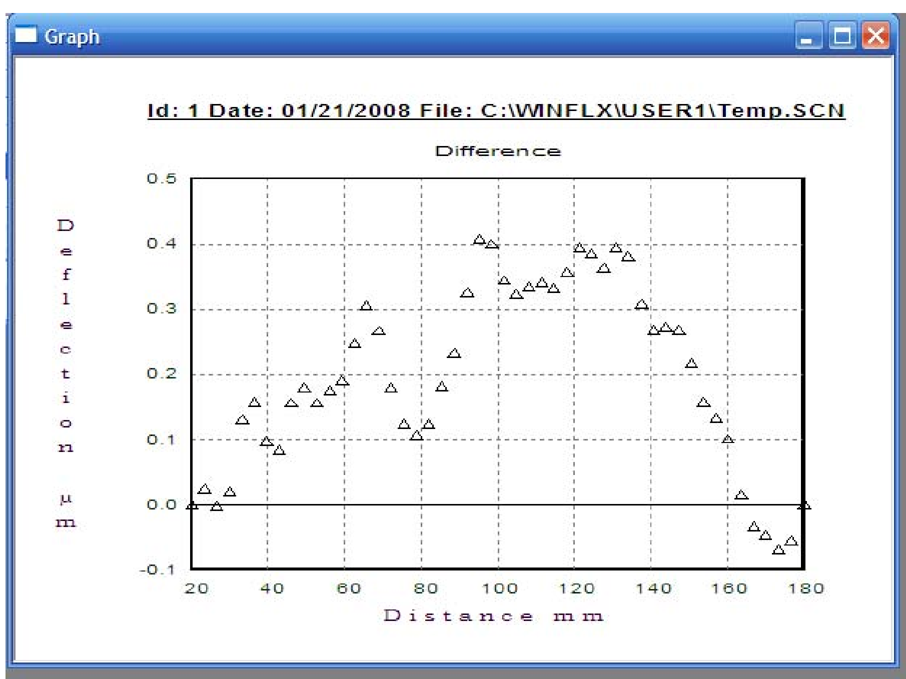
(The software always subtracts the 1st measurement from the 2nd measurement. The negative value is the same difference as a positive difference.)

7.5.3 Stress-Segmentation



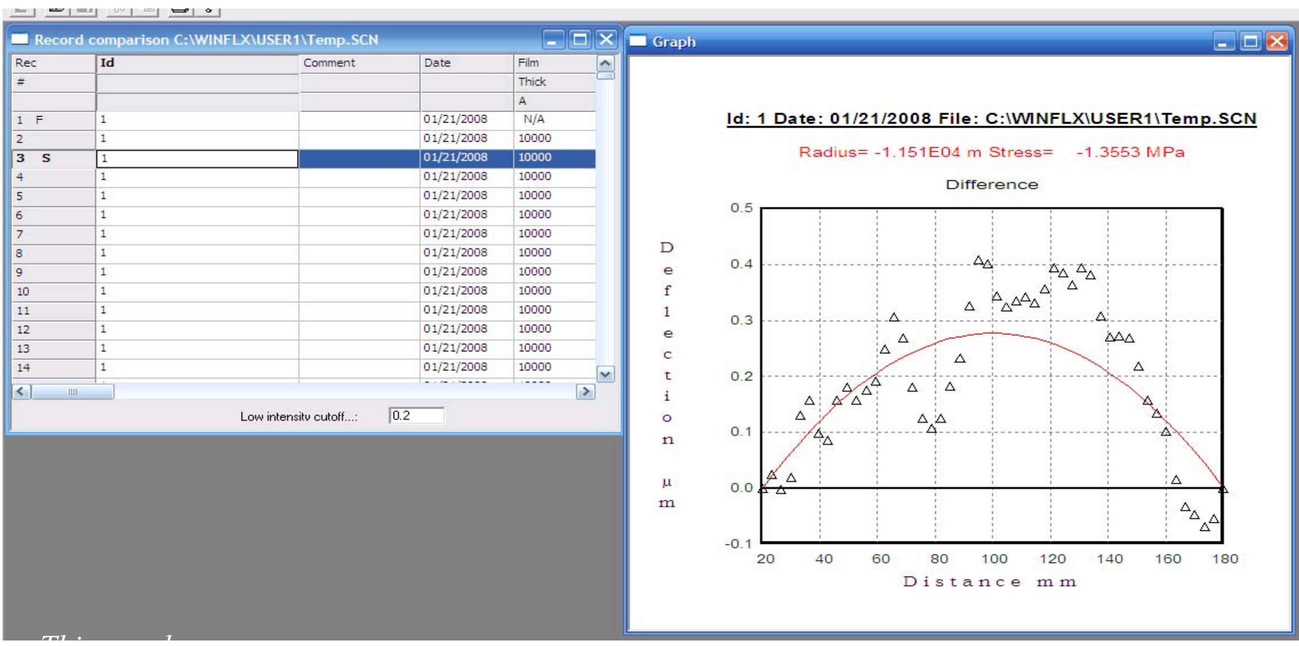
1. After selecting and tagging the two records, choose the Stress tab.
2. Select Segmentation from the Stress tab.

3. A Deflection graph similar to the following displays:

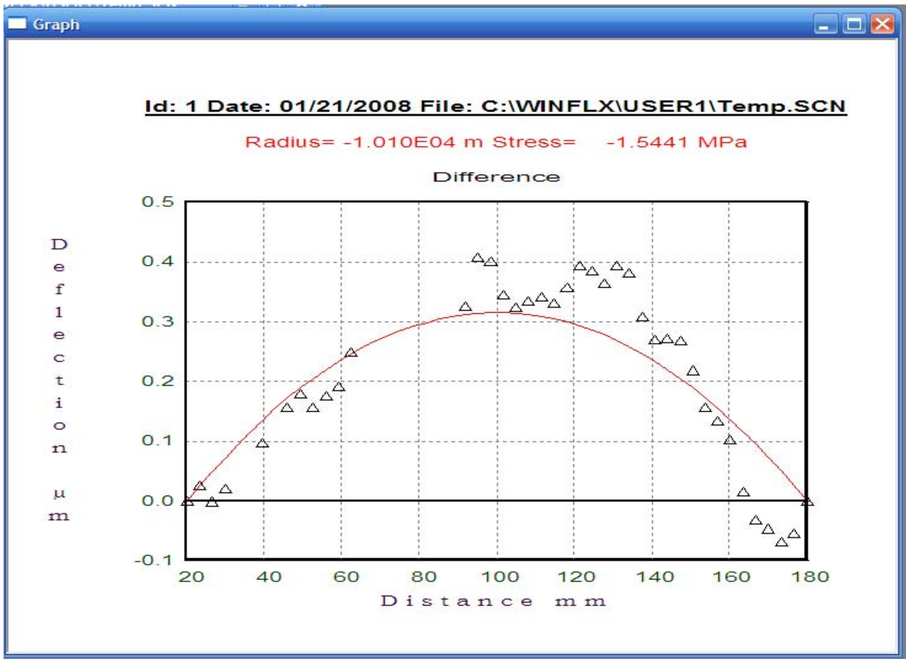


(All of the graph options apply, see section 6.2)

4. The 1st point will be blinking. Use the arrows on your keyboard to navigate through the graph.
5. To delete a point press “D” when the point is blinking.
6. To calculate the Stress and the Radius press “ENTER”.



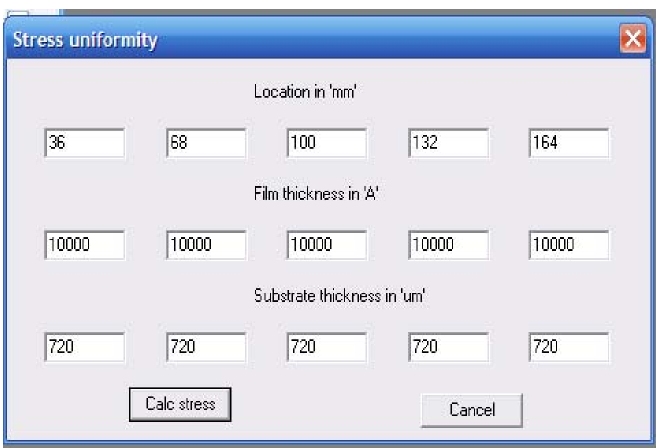
7. The same graph with some points deleted will have a different result:



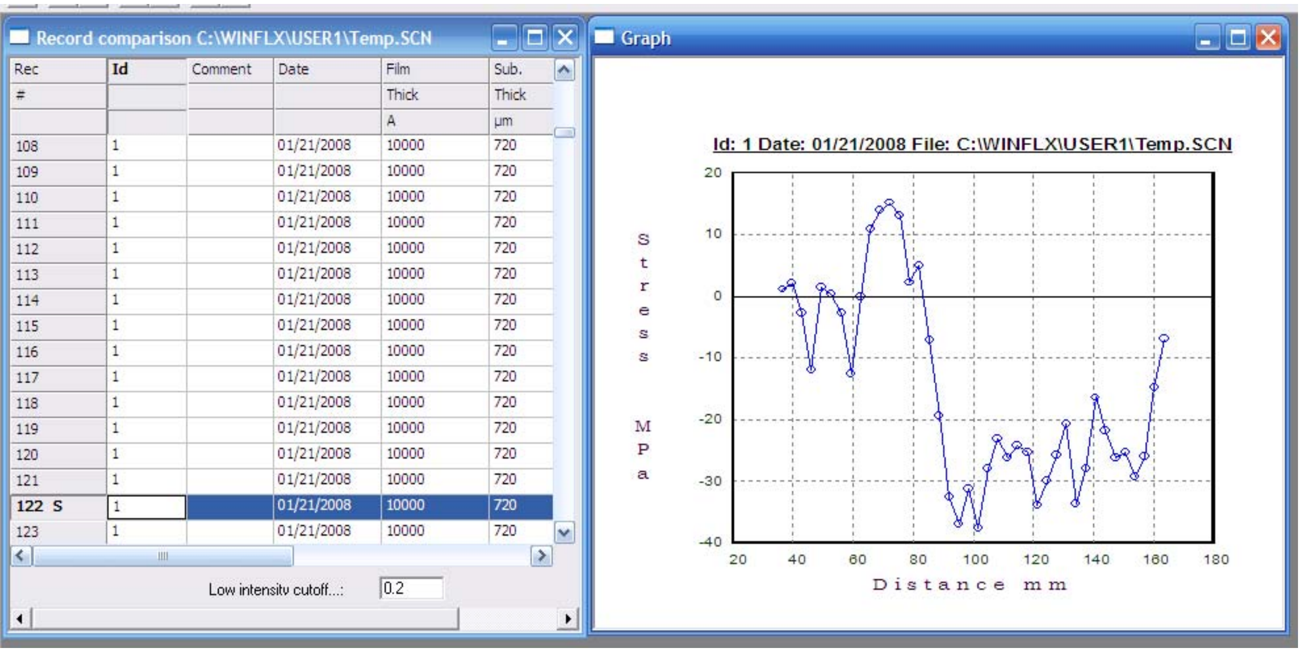
7.5.4 Stress-Uniformity

1. After selecting and tagging the two records, choose the Stress tab.
2. Select Uniformity from the Stress tab.

3. A window will appear. It will have the location for 5 points. Each point has a field for location, film thickness, and substrate thickness.



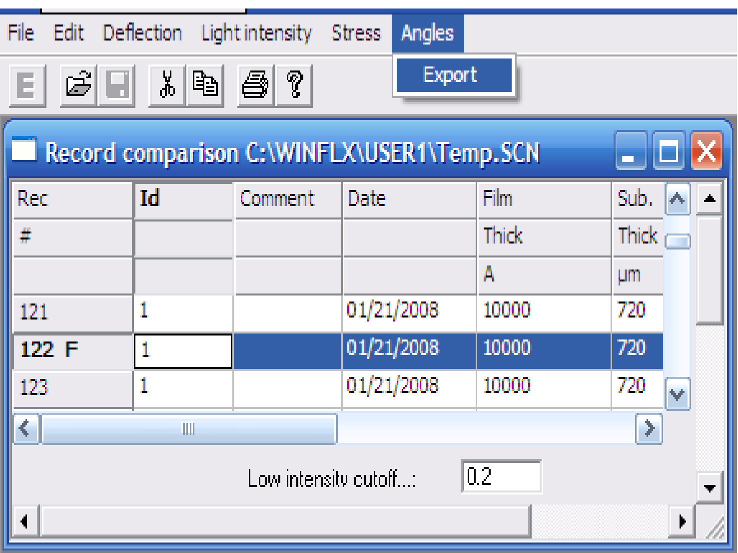
4. Once the points are adjusted for Location, film thickness, and substrate thickness, press the “Calc stress” button to calculate the Stress.



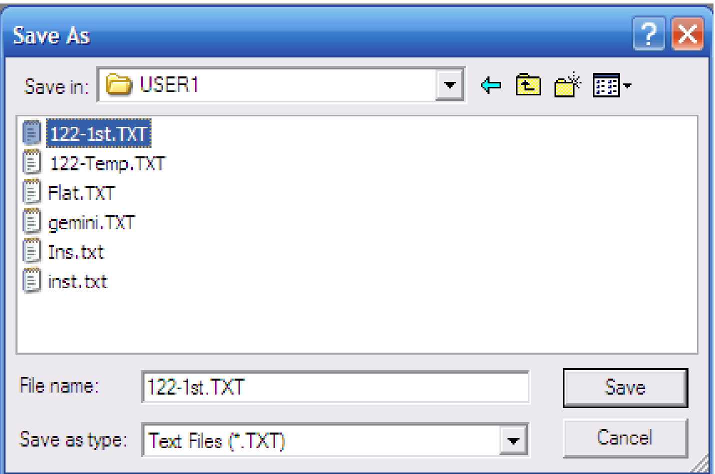
(All of the graph options apply, see section 6.2)

7.5.5 Angles

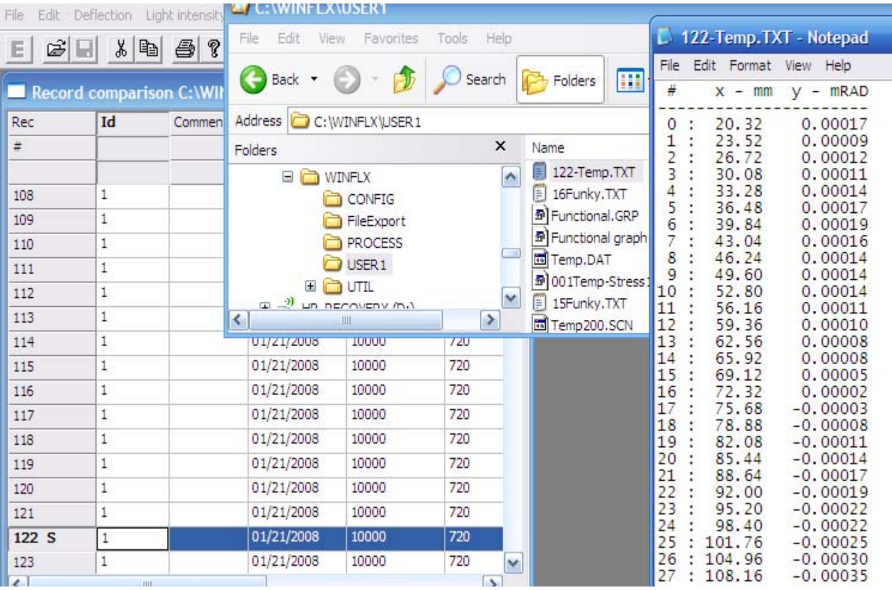
1. After selecting a record and tagging it “First” (**F**)
2. Select the “Angles” tab. Then select “Export”.



3. A “Save As” window will appear. Choose file name for the .TXT file being created.



4. The data will go to the file saved under the current User selected under WINLFLX.



5. The data will be the scan #, the position across the wafer in hundredths of a millimeter, and the Radian (angle). [0.00000 = a perfect 90 degrees]

8 Maintenance

This chapter is intended for the key person responsible for the maintenance of the TOHO FLX-2320-S instrument. The following information is provided in this chapter:

- Calling TOHO Service and other related information
- Getting information about the hardware using the Utilities Menus
- Verifying the calibration of the instrument
- Troubleshooting minor problems
- Moving the laser beam, checking the laser's travel is centered
- Using Calibrated Wafer Sets
- Using Calibrated Mirror Sets

8.1 SERVICE POLICY

The TOHO Instruments Service Organization is available to you in the United States, Europe, and Japan. We also have representatives in The People's Republic of China and Taiwan.

TOHO Technology's commitment is to provide a technical response by telephone within 24 hours, often within the same business day.

- The service organization is available for installing your instrument. To schedule the installation, contact the Customer Service Administrator.
- In the United States, service requests are processed through a central number located in Illinois. Call 773-583-7183 Monday through Friday between 7:00 A.M. and 7:00 P.M., Central Time, to arrange for service or repair work or to order replacement parts.
- Standard on-site service hours are Monday through Friday, 8 A.M. to 5 P.M., local time. You can arrange for other hours through a customized service contract.
- TOHO Technology provides service beyond the original warranty period of 1 year as needed. Repair work performed after the original warranty expires is guaranteed for 3 months. Full service contracts extend the warranty period and can be customized to your specific requirements.

TOHO Technology encourages you to attend a maintenance and repair training course for your instrument. In general, trained customers experience greater instrument uptime and make better use of TOHO Technology service resources. Your sales or service engineer can provide you with the course and fee schedule.

8.2 MAINTENANCE

Use the procedures in this user manual to maintain the components as required. Note the following:

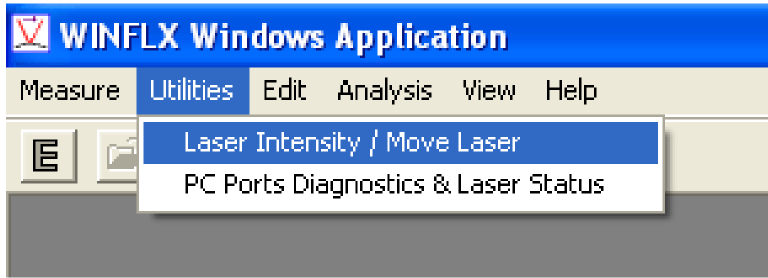
- The Stress readings should stay within 5% accuracy as compared to a calibrated wafer set. (*The radius measurements will not necessarily be within 5%*)
- The flatter the substrate the greater the radius, the instrument is interpreting flatness as a radius, so large radii will not be within a percentage. (For example, a reading of 9,000 meters is very similar to a reading of 5,000 meters.) However at approximately a 20 meter radius, the instrument should read within 5%.
- The 20 meter curved mirror should read within 5% (1 meter) of the certified radius.
- The Flat Mirror should read a larger radius than 3000 meters. *(note: -3000 meters is just as flat as 3000 meters.)*
- The instrument could require cleaning or adjustment if the reflected light intensity is consistently low. Call TOHO Technology Service to schedule the necessary maintenance; *do not* attempt to clean or adjust the instrument yourself. However, before calling TOHO Technology, use the procedures in section 8.3, “Troubleshooting,” to make sure that the low light intensity is not caused by any of the listed reasons.
- The instrument should be calibrated by a TOHO Technology technician once a year. Do not calibrate the instrument yourself; only TOHO Technology Service should calibrate the instrument.

8.3 TROUBLESHOOTING

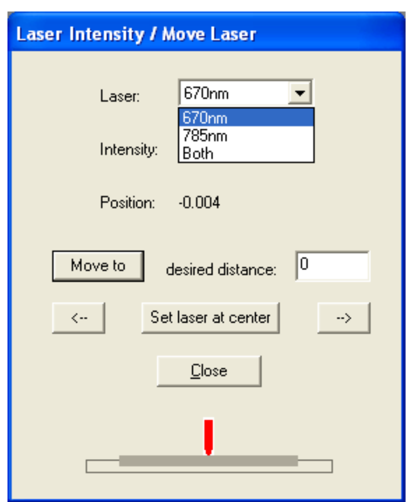
If the measured intensity is zero or low, do the following *before* calling TOHO Technology:

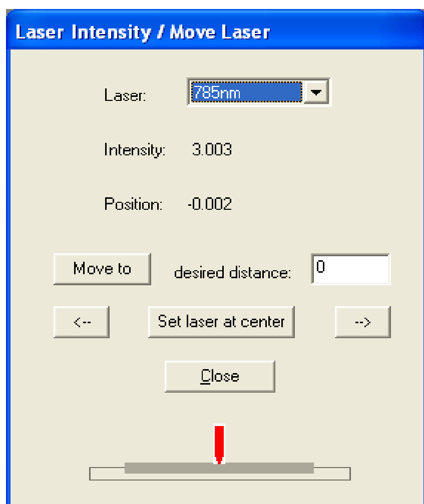
- Make sure the instrument is turned on.
- Make sure a sample is loaded and the sample is reflective.
- Make sure the wafer is sitting flat on the 3 ball bearings.
- Make sure the beam is impinging on the substrate by using the following procedure:

1. Place a bare silicon wafer on the stage.
2. Go to the “Utilities” Menu from the main screen.



3. Select “Laser Intensity/ Move Laser”





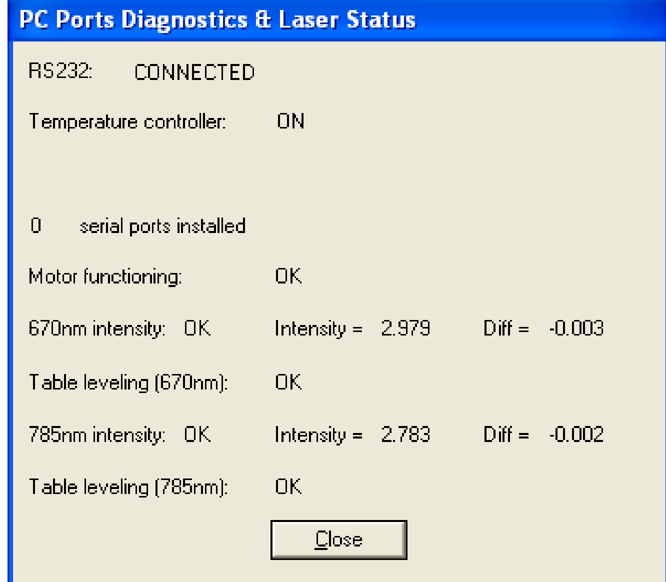
- You can select 670nm, 780nm, or both lasers.
  - The intensity for the 670nm laser (red or vertical) is nominally 3.08, the spec is from 2.58 to 3.58.
  - The intensity for the 780nm laser (yellow or horizontal) is nominally 2.75, the spec is from 2.25 to 3.25.
  - The nominal intensity for both lasers is 3.08 + 2.75 = 5.83.

4. **Position**: Position refers to the position on the detector. The nominal position (DIFF) is 0.000. The tool is in spec from -0.100 to + 0.100.
5. **Set Laser at Center**: When this Utility Menu is opened the tool will automatically move the laser to the center of travel across the wafer. This button is used as a reset in case you've moved the laser.
6. **Move to desired distance**: This field lets you enter a relative distance in terms of millimeters for the laser to move. Negative numbers will move to the left, positive to the right. This is a RELATIVE movement. It is possible to command the laser beyond its stroke and jam the motor. Be very wary of the laser's position before you give it a command! There is a graphic that will indicate where the software believes the laser is pointing.

8.4 DIAGNOSTICS

Use the Diagnostics option to get hardware information such as laser position, and reflected light intensity.

1. **PC Ports Diagnostics & Laser Status**:
   - Select the "**PC Ports Diagnogtics & Laser Status**" selection from the Utilities Menu. This will show the DIFF (position on the detector) and the intensity for both lasers simultaneously.
   - **0 Serial Ports installed:** Tells you the communications with the PC is OK.
   - **Motor functioning:** Tells you the feedback from the motor encoder is OK.
   - **Table Leveling**: Refers to the stage. If this Utility Menu says "CW" (clockwise) or "CCW" (counter-clockwise) it is referring to the thumb screw that used to be adjustable. Toho recommends NOT adjusting the thumb screw. The leveling was done at the factory and is locked in place. This reading in this Utility Menu usually means the wafer isn't sitting flat on the 3 ball bearings.



8.5 CALIBRATION

The TOHO Technology FLX-2320-S should be calibrated once a year. Schedule an appointment with TOHO Technology Service to calibrate the instrument.

CAUTION:	**The following procedures are for verification only. Do not attempt to calibrate the instrument yourself. If your test values fall outside the specified ranges, call TOHO Technology Service. However, before calling TOHO Technology, use the procedures in Section 8.3, "Troubleshooting," to make sure that the low light intensity is not caused by any of the reasons listed.**

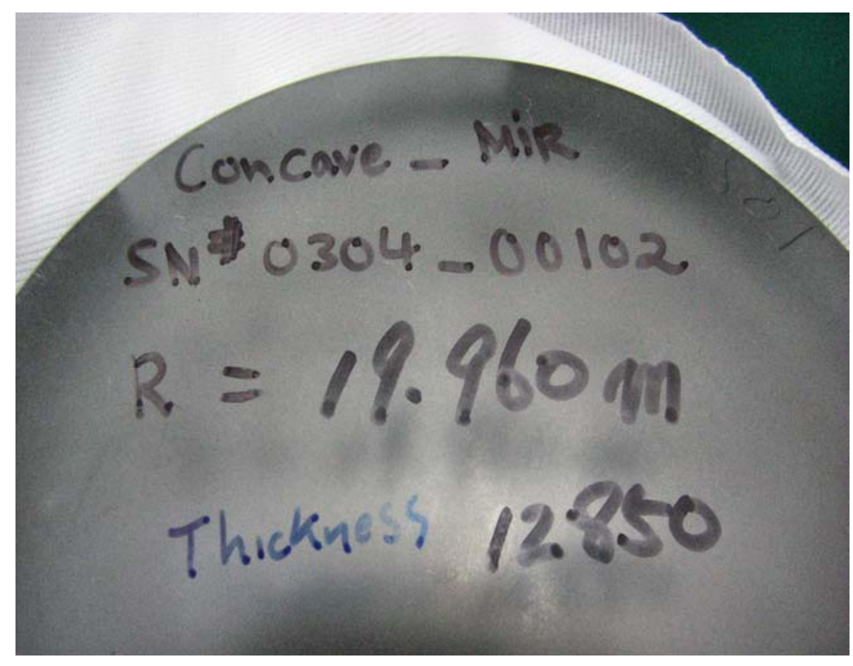
8.6 RADIUS OF CURVATURE VERIFICATION

Note that the following procedure is optional. Before each instrument is shipped, its radius of curvature is verified and a Certification of Accuracy is included with the instrument. This calibration option is only available for the 6-in. and 8-in. wafer instruments.

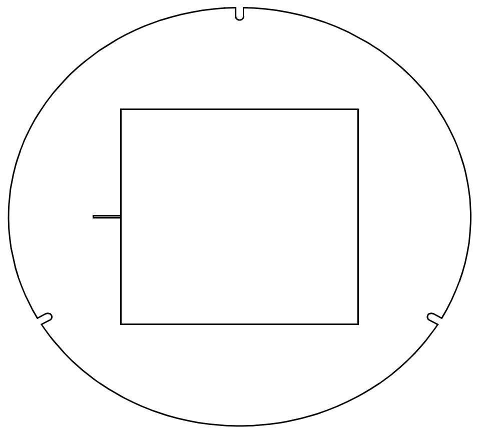
8.6.1 Calibrated Mirror Verification:

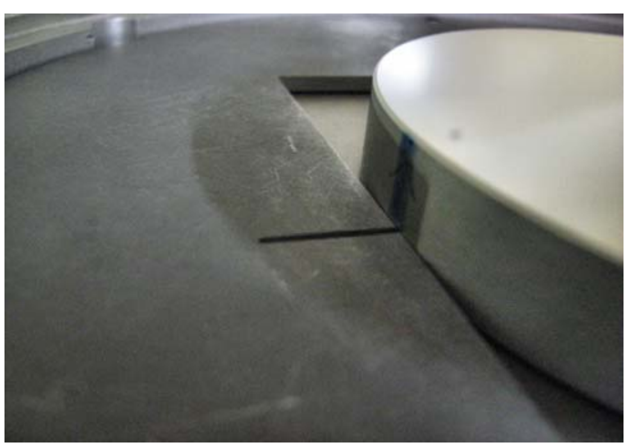
If the user has purchased the optional mirror set, they can set the appropriate Process Programs and measure the mirrors. The mirror set should come with a Certification. The 20meter (approximately 20 meters, spec sheet should specify exact radius e.g. 19.96m) should measure within 5% of the nominal value.

1. Set up a Process Program for the mirrors. They are typically 100mm in diameter and 12,700 mm thick (substrate thickness). The picture below is the bottom of a radius 20meter mirror. Its actual radius is 19.960m. Its actual substrate thickness is 12,850mm. It also has a serial number that ties it to its Certification Record. It's recommended practice to write this information on the bottom of the mirrors.

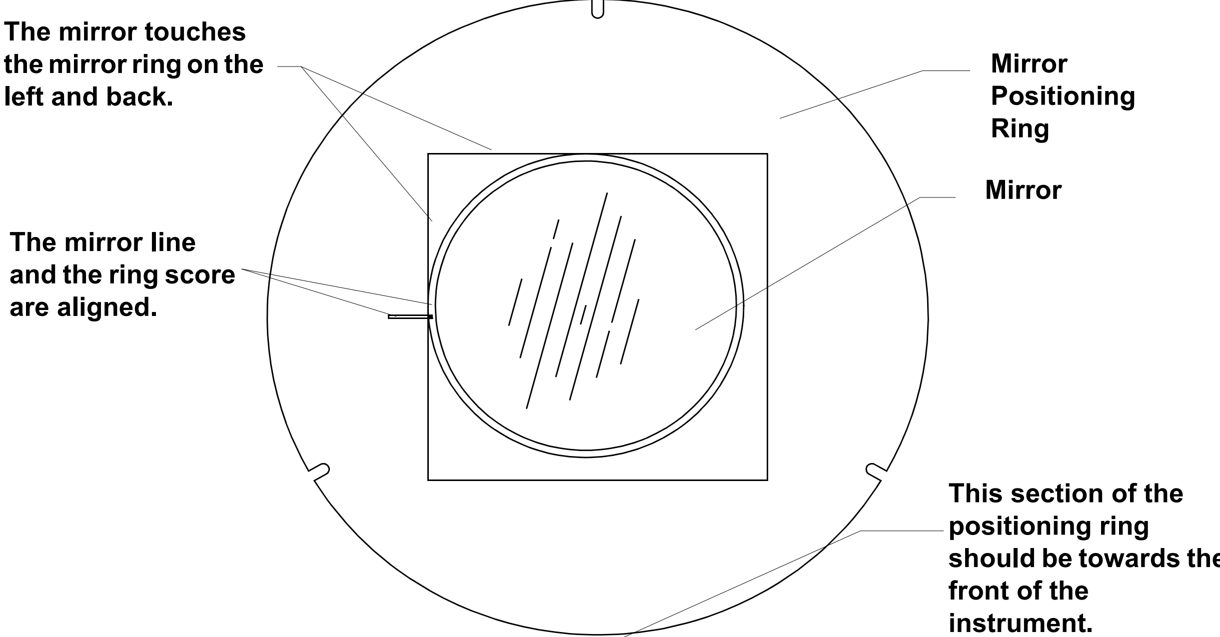


2. Place the Mirror positioning ring on the stage. The mirror positioning ring has a square cutout. There's a hash mark you want to face up. The hash mark will be to the left. This will line up with a hash mark on the side of the mirrors. This is so you always measure the same diameter. Locate the mirror in the corner of the square that is far and to the left of the user.





- The 3 notches will locate to the 3 pegs on the stage.
- Place the flat or concave mirror, face up, into the center of the mirror ring. Position the mirror so that the positioning line on the mirror matches the positioning score on the mirror ring. Also, move the mirror so that it touches the mirror ring on the left and the back.

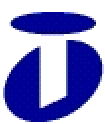


3. Perform a First Measurement:

- See Chapter 3 Section 2 for Process Program setup.
- Be sure the Diameter = 100mm and the Thickness is correct (e.g. 12,850mm).
- Instead of creating another Process Program, you may simply switch mirrors and and re-scan (be careful the Thickness is correct).

- If the thickness of the other mirror is different, simply enter the new thickness in the “Substrate thickness” field and then press the “Measure” button.

The Certification of Accuracy certifies the radius of curvature for the instrument. It includes information such as the customer name, the date the test was done, the type of test done, the reference standards used, and the certified results.



Toho Technology Corporation

Certificate of Accuracy

Customer:

Customer Order No.:

Item Tested: Concave Mirror（Thickness１２． ７ｍｍ）

Part No.: 236349 **Serial No.:** 0408-0115

Type of Test Performed: Optical Lever Cantilever Beam technique

Certified Results

Radius of Curvature ---- 19.960 m

Standard Deviation ---- 0.036 m

Reference Standards Used:

Toho Technology Thin Film Stress Measurement System with Zygo certified 19.532m Radius of Curvature Concave Mirror

Laboratory conditions during the test

Temperature: ２５℃

Toho Technology certifies that the data consist of 10 measurements made under conditions specified producing the results reported. The result reported is the average of these measurements. Although NIST radius traceable standards do not exist, the Zygo Mark IVxp Interferometer with Zygo Axiom 2/20 DMI S/N 87-51-0028 used for certification Toho Technology 19.532m Radius of Curvature Concave Mirror was calibrated using other NIST traceable standards (731/244084-89). Toho Technology Thin Film Measurement System used for the certification was calibrated using 19.532m Radius of Curvature Concave Mirror S/N M0402-0088.

Signed Hidetoshi Suzuki

Title Test Engineer

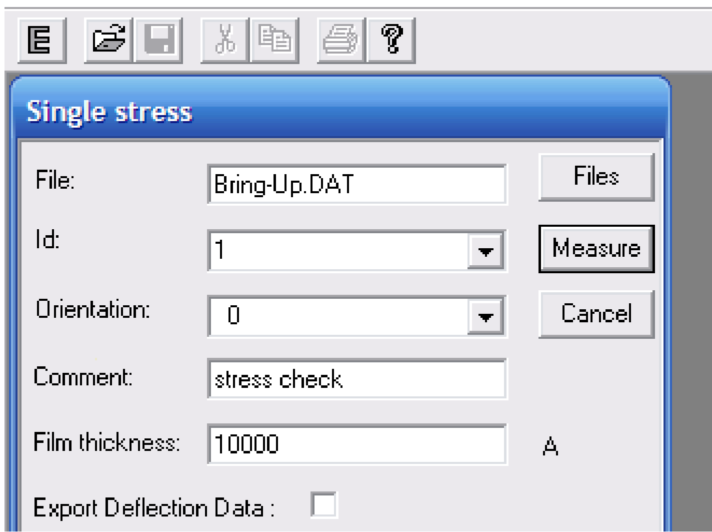
Date Jun 04, 2008

8.7 Stress Accuracy Verification Test

8.7.1 Calibrated Wafer Set

If the user has purchased the optional calibrated wafer set, they can set the appropriate Process Programs and measure the calibrated Stress. The mock Stress should read within 5% of the Certified Stress

1. Set the Process Program up for your Wafer set. be sure to use the thickness and diameter from the Certification.
2. Use Wafer A for the First Scan. Perform scan then close (cancel) the First Scan Window.
3. Exchange Wafer A for Wafer B. Select “Single Scan” from the “Measure” tab. Select the ID from the drop down menu that is the same ID that was used for the First Scan for wafer A.



Enter the film thickness specified on the Certification. Typically it is 10,000 angstroms. (10000 A)

The resulting Stress should be within 5% of the Certified Stress if the tool is in calibration.

Take note that the flat or notch oriented to the right is considered 0 degrees. (Like the origin in Geometry). The flat away from the user is considered 90 degrees (rotating counter clock wise).

Wafer is at 0 degrees

Wafer is at 90 degrees

CERTIFICATION OF ACCURACY
(SET CERTIFIED WAFERS, 200MM DIA)

Item Tested:

Toho P/N	Description	QTY
416070	Set, Certified Wafers, 200 DIA, FLX, consist of	
416053	Wafer Assembly, Bare, Silicon, 200 mm	1
273031	Wafer Assembly, Certified, 200 mm	1

Type of Test Performed:

Given that a single radius measurement can be variable, the best way to ensure long term repeatable correlation or consistent SPC numbers is to use two stable wafers. The best choice is to use a blank silicon wafer marked as ***Wafer A*** and thermal oxide film wafer marked ***Wafer B***. The radius of curvature between these two wafers should be sufficiently different so that the stress calculation will be meaningful (≥150 MPa). The following procedure describes the details.

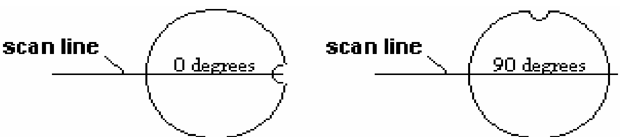
1. Measure Wafer A using the **First** command in the **Measure** menu of the WINFLX software. Enter an appropriate wafer thickness and use the same thickness on every machine.
2. Measure Wafer B using the **Single** command in the **Measure** menu of the WINFLX software. Use the same wafer ID as used for Wafer A, allowing the system to calculate from the difference in wafers A and B. Use a 10,000Å phantom film thickness for Wafer B on all correlation or stability tests.

The system will calculate a phantom stress value from the hypothetical “before” and “after” deposition wafers, which should be repeatable on any system if the same parameters are used. Although the radius measurements may vary from system to system, the phantom “stress” value should be consistent according to Toho specifications (2.5% on the same tool, 5% between systems). The same two wafers should be used regularly for an SPC control of the FLX system stability and also for system matching.

Toho Certified Results:

FLX S/N 1099-4739 WF S/N 0508-0079	*Wafer THK µm	Film THK Å	Reference Radius 0 FLX S/N	Stress Mpa 0 degrees STD DEV	Reference Radius 90	Stress Mpa 90 degrees STD DEV
First Measurement using P/N416053, WaferAssembly, Bare, Silicon, 200 mm	725um	N/A	-171.3	N/A	-186.0	N/A
Stress-Time using P/N273031, WaferAssembly, Certified, 200 mm	725um	10000	63.5	**341.5**	67.5	**319.0**

Note: * Wafer Thickness measured in FLX2320



Wafer Notch position in relation to the Scan direction.

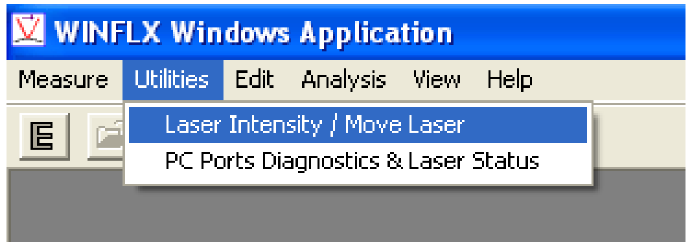
Toho has maintained that the systems of the same model throughout the product line will match to within 5%, for the one particular system to within 2.5%.

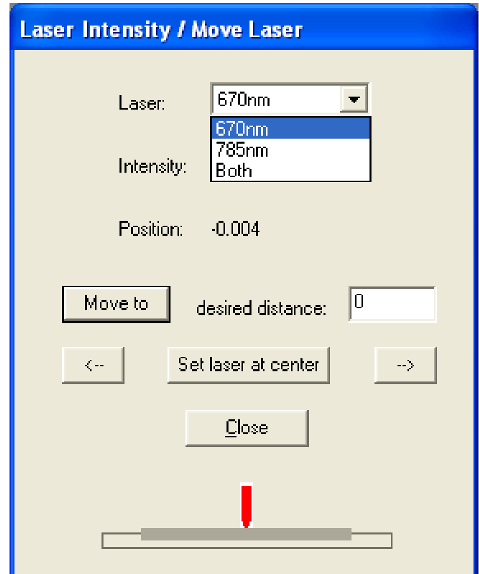
Toho Technology Corporation Date: 12 May 2008
Clean system Division
Manufacturing and Inspection
Equipment System Group

Signature ______________________

8.8 Centered Laser Travel Verification

1. Go to the "Utilities" Menu from the main screen.





2. Select "Laser Intensity/ Move Laser"
3. Select the 670 laser.
4. Place a six inch wafer ring on the stage with no wafer.
5. Open the door.
6. Defeat the trap-door interlock.

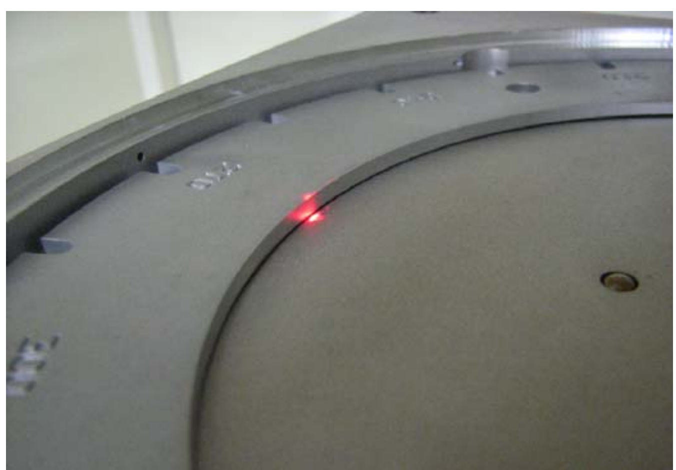
Below the trap door is defeated with a metal scale between the frame and the plunger.

7. With a six inch locating ring, set the “desired distance” to 50 (mm).
8. Then click the “Move To” button.
9. Positive (no sign) “50”(mm) should send the laser to the right 50mm, which will place it on the edge of the 100mm ring.

10. Next, set the “desired” distance to “-50”.

    Press the “Move To” button.

    This will set the laser at the center again.



11. Press the “Move To” button again.

    This will send the laser to the Left edge.

12. Set the laser to the center again. Then nudge the laser to the Left, with the left arrows on the Utility screen.

13. The Laser should hit the top of the left ball bearing. This will verify front to back alignment.

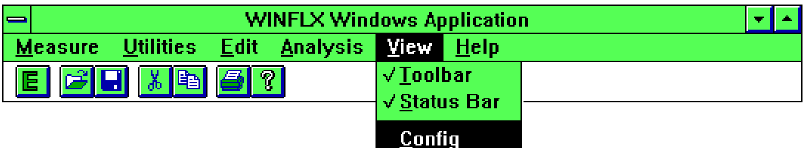
8.9 SYSTEM CONFIGURATION INFORMATION

The Configuration option on the Main menu displays additional system information such as Model Type, Serial number, Max Scan Length, RAM drive, and Motor Speed.

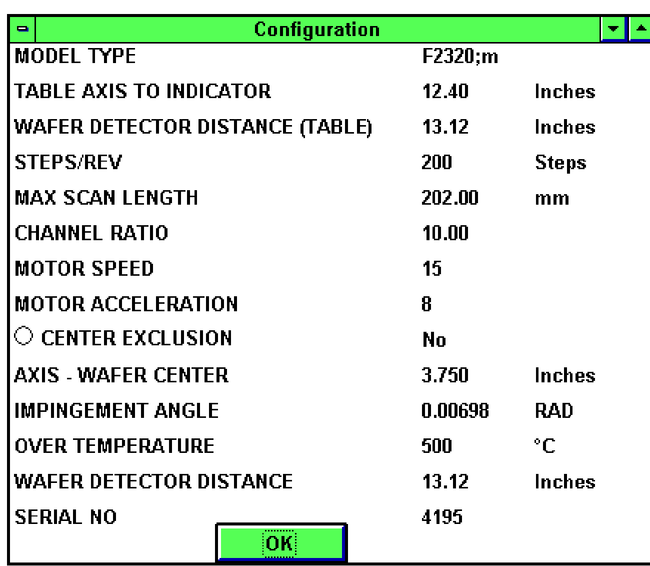
Note that you cannot change any of the information displayed in this window.

To display the Configuration dialog box:

1. Choose Config from the View menu.



The Configuration dialog box displays:



2. When you have finished reading the information, choose OK to return to the Main menu.

9 THEORY OF OPERATION

This chapter describes the theory of operation of the FLX-2320-S, and the equations used to calculate the diffusion, expansion, and elastic coefficients.

The FLX-2320-S measures the changes in the radius of curvature of a substrate caused by deposition of a stressed thin film. The stress in the thin film is calculated from the radius of curvature of the substrate using the following equation:

$$\sigma = \frac{Eh^2}{(1-v)6Rt}$$

where

$\frac{E}{(1-v)}$ is the biaxial elastic modulus of the substrate (1.805E11 Pa for 100 silicon wafers)

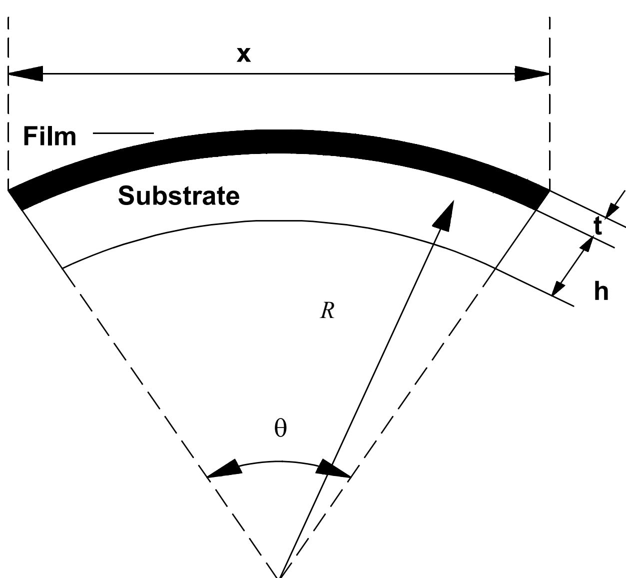
h is the substrate thickness (m)

t is the film thickness (m)

R is the substrate radius of curvature (m)

σ is the average film stress (Pa)

The following picture is a schematic drawing of substrate deformed to radius R by the deposition of a film. In this case, the film is under compression deforming the substrate.



To illustrate the stress calculation, suppose that a 100 mm silicon wafer, 525 μm thick, is deformed to a radius of 30 m by the deposition of a surface film of thickness 7500Å. Since the biaxial elastic modulus of 100 silicon is 1.802 x 10^{11} Pa, the stress calculated according to Equation 1 is

$$\sigma = \frac{1.805 \times 10^{11} \times (525 \times 10^{-6})^2}{(6 \times 30 \times 7500 \times 10^{-10})} = 3.69 \times 10^8 Pa = 369 MPa$$

The average radius R_1 of the bare substrate is obtained by measuring θ as a function of x and performing a linear regression. $\frac{1}{R_1}$ equals half the slope obtained from the linear regression. After the film is deposited, the substrate deforms to a new radius R_2. Since the stress is proportional to $\frac{1}{R}$, it follows that

$$\frac{1}{R} = \frac{1}{R_2} - \frac{1}{R_1}$$

or

$$R = \frac{1}{\left(\frac{1}{R_2} - \frac{1}{R_1}\right)} = \frac{(R_1 R_2)}{(R_1 - R_2)}$$

The thin film stress is now determined by using the effective radius *R* in the equation described above. To calculate the stress, the substrate radius must be measured 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.

DIFFUSION COEFFICIENT CALCULATION

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

$$\sigma = \sigma_0 - \Delta\sigma\left[1 - \left(\frac{8}{\pi^2}\right)\sum_{1}^{\infty}\left(\frac{1}{(2n-1)}\right)^2 \exp-\left(\frac{(1-2n)^2}{4L^2}\pi^2 Dt\right)\right]$$

where
σ is the stress at time t
σ_0 is the initial stress
$\Delta\sigma$ is the total stress change after completion
n is a running index from 1 to infinity
L is the film thickness
D is the diffusion coefficient
t is the time

For details on using this option, see Section 6.3, “Displaying Graphs.”

ELASTIC AND EXPANSION COEFFICIENT CALCULATION

The stress change with temperature in the elastic range is governed by the following equation:

$$\frac{d\sigma}{dT} = \left(\frac{E}{1-\nu}\right)_f(\alpha_s - \alpha_f)$$

where
$\frac{d\sigma}{dT}$ is the derivative of stress versus temperature
$\left(\frac{E}{1-\nu}\right)_f$ is the biaxial modulus of the film
α_s is the substrate thermal expansion coefficient
α_f is the film thermal expansion coefficient

The above equation has two unknowns—α_f and $\left(\frac{E}{1-\nu}\right)_f$. To solve these, two temperature cycles are done with two different substrates and the software solves two equations. For details on using this option, see Section 7.3, “Elastic and Expansion Coefficient Calculation.”

GLOSSARY

Autoscan. A scan in which the start and end scan positions are defined as 10% in from the edge of the wafer.

Elastic Modulus. The biaxial elastic modulus of the substrate to be used in stress calculations.

First (No Film) Measurement. A single scan performed on a wafer before deposition and used as a reference for subsequent scans.

Hole Diameter. The diameter of the center region of the substrate to be skipped.

Intrinsic Stress. The stress of a film at the deposition temperature.

Process Program. A set of parameters specifying information, such as the wafer diameter for measurement, elastic modulus, and substrate thickness.

Ramp Value. The rate of change of temperature in degrees Celsius (°C) per minute during a heating or cooling cycle.

Recipe. A recipe contains data that the instrument uses to automatically take a temperature measurement. The information in a recipe determines the setting of a stress-temperature measurement, the target temperature, and the number of ramping readings for each measurement.

Record Comparison. A comparison of the deflection curves of the first stress and single stress measurements. Record Comparison also allows you to do stress and stress uniformity calculations as well as view intensity curves. This feature is only available on measurements where scan data has been saved.

Scan. Action performed when the Toho FLX-2320 optical system and measurement stage are used to inspect wafers.

Single Stress Measurement. A single scan, performed on a wafer after film deposition, used to measure the induced stress.

Stress-Temperature Measurement. A scan used to measure stress as a function of temperature on a wafer after deposition. The instrument uses temperature cycling to reveal stress changes. Temperature cycling causes stress changes due to thermal expansion, mismatch, volume changes, and plastic deformations.

Stress-Time Measurement. Scans used in measuring the stress over a specified period of time, on a wafer after deposition. This type of measurement reveals the kinetics, such as wafer absorption in oxides, densification, phase transformations, and stress relaxation, of a wafer.

Temperature Controller. Instrument that displays the temperature heating and cooling cycle. The controller is located on the front panel of the measurement unit.

Thermal Stress. The film stress change between the deposition temperature and the measurement temperature.

Wafer Diameter. The diameter of the wafer in millimeters (mm).

APPENDIX A – SPECIFICATIONS

PERFORMANCE SPECIFICATIONS

Substrate Diameter

100-mm (4-in.), 125-mm (5-in.), 150-mm (6-in.), and 200-mm (8-in.) wafers.

Measurement

Speed: 5 sec. for 150-mm wafer
Range: 1 x 10^7 to 4 x 10^{10} dyne/cm^2 (stress upper limit increases with shorter scan length)
RMS Noise: 0.0001 m^{-1} (radius=10,000 meters) at room temperature
Resolution: 0.00003 m^{-1} (33 kilometers)
Minimum Scan Step: 0.02 mm
Maximum Points Per Scan: 1250
Minimum Radius: 2.0 m (for 80 mm scan length)

Temperature Range

Standard: Room temperature to 500° C
Optional: -65° C to 500° C. (Factory installed only)

Repeatability

The main source of the repeatability error is the replacement accuracy of wafers. The typical TOHO Technology 1σ error in $\frac{1}{R}$ is 1x10^7 dynes/cm^2 for a 1-µm film on a 525-µm silicon substrate. Thicker films and thinner substrates result in smaller errors and thinner films and thicker substrates result in larger errors. The following table lists stress errors for different film and silicon substrate combinations.

Substrate Thickness	Film Thickness (Å)			
	100,000	10,000	1,000	100
375 µm	0.5x10^6	0.5 x 10^7	0.5 x 10^8	0.5 x 10^9
525 µm	1.0x10^6	1.0 x 10^7	1.0 x 10^8	1.0 x 10^9
625 µm	1.4x10^6	1.4 x 10^7	1.0 x 10^8	1.4 x 10^9
675 µm	1.7x10^6	1.7 x 10^7	1.7 x 10^8	1.7 x 10^9

OPERATING SPECIFICATIONS

Light Source

Two lasers: 4-mW solid state (GaAlAs) laser with wavelength 670 nm and 4-mW solid state (GaAlAs) laser with wavelength 780 nm.

PHYSICAL DIMENSIONS

FLX-2320-S Instrument	46 cm (18 in.) x 46 cm (18 in.) x 56 cm (22 in.) plus computer

WEIGHT

System	45.5 kg (100 lb)
Shipping Weight	190 kg (420 lb)

OPERATING ENVIRONMENT

Temperature	18–22° C (64–72° F)
Air Quality	Clean room Class 100 or better
Gas Connections (Optional)	Inert gas flow rate: 2–10 CFH(3L/min=6.4CFH); Cooling gas (typically CDA or N2) flow rate: Up to 500 CFH (236L/min=500CFH); pressure not to exceed 40 psi (.3 MPa= 43.5psi)
System Power	15 amp. at 230 V, 50/60 Hz

COMPUTER AND PERIPHERALS

Computer	Windows
Hard Disk	320 GB
Monitor	Flat Panel
DVD-RW	DVD, CDR, etc..
Floppy Diskette Drive	3.5-in. high density (1.44 MB)
Printer	Hewlett-Packard, recommended
Comm Port	Serial cable
USB Ports	USB mouse

APPENDIX B – CONSTANTS AND CONVERSIONS

This appendix lists selected constants and conversions.

1 MPa = 10^7 dynes/cm^2

1 GPa = 10^{10} dynes/cm^2

1 angstrom (A) = 0.0000001 mm

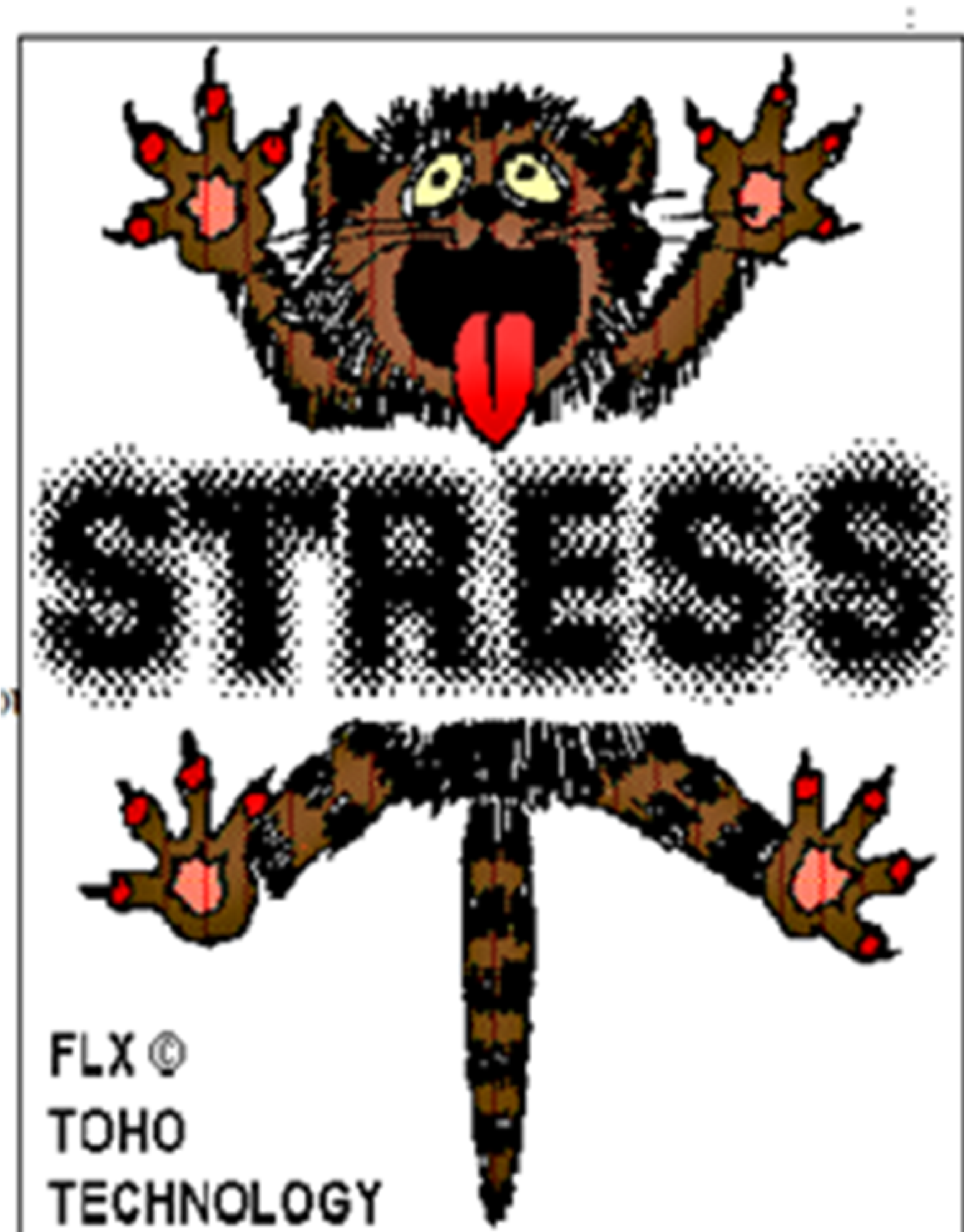
1 nanometer (nm) = .000001 mm

1 micron (mm) = .001 mm

Silicon Biaxial Moduli[1]:

(100) 1.805 x 10^{11} Pa

(111) 2.290 x 10^{11} Pa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