University of Minnesota Nano Fabrication Center
Standard Operating Procedure

Equipment Name:	Film Stress Measurement System		
Badger Name:	K1 Film Stress FSM 900	**Revision Number:**	2
Model:	FSM 900TC	**Revisionist**:	K. Roberts
Location:	Bay 1	**Date:**	3/27/2020

1 Description

The Film Stress Measurement consists of a quartz-lined chamber which is rapidly heated by high intensity, tungsten-halogen lamps. A wafer loaded into the chamber can be heated to temperatures of 900 deg. C. Most commonly the FSM is used to measure film stress at room temperature, but it can also be used to measure stress at elevated temperatures. To avoid film oxidation effects, the chamber can be pumped to high vacuum via a turbo pump or, alternatively, the chamber can be purged with nitrogen gas. In addition to stress, the FSM will also output a Wafer Bow Height value based on the wafer's radius of curvature. With well characterized substrates, the film's modulus and its coefficient of thermal expansion can also be calculated.

2 Safety

a Do not open chamber unless below 200^{o} C.

b The system uses two laser diodes with a maximum power of 5 mWatts, the system limits the power to 2 mWatts, but these can be cause damage to the human eye if looked into directly, for this reason do not look into the enclosure while running.

3 Restrictions/Requirements

a Must be a qualified user on stresstest-2

b The front door of the system must be closed to perform temperature tests at 450^{o} C or above (i.e. interlocks satisfied). If the interlocks aren't satisfied, the program will simply abort when 450^{o} C is reached.

c The 810 nm laser has a weak signal due to aging effects; use the 750 nm laser.

4 Required Facilities

a Compressed air, 80psi

b Process chilled water, 1.5 GPM

c N2, 25 psi, 20scfh

5 Definitions

a Stoney's Equation:

$$\text{Stress} = \{E/(1-v)\}h^2 / 6R_{eff}\, t$$

or

$$\text{Stress} = Eh^2 / (1-v)6R_{eff}\, t$$

where for NFC's Excel based calculator...

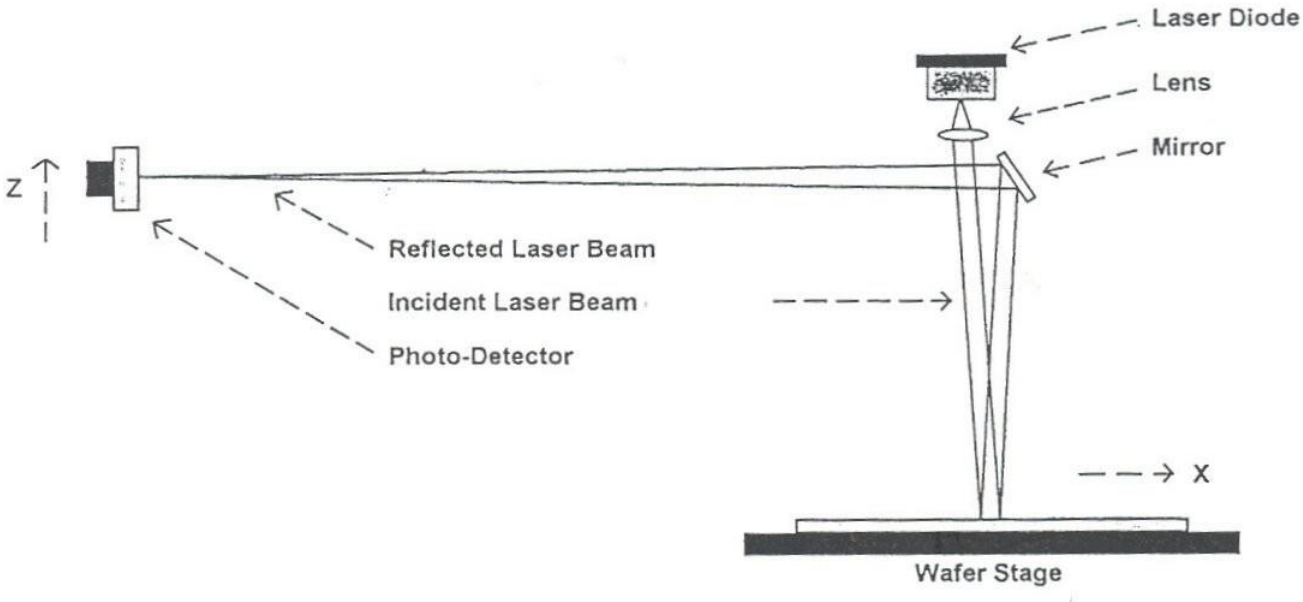
E = Young's Modulus of the substrate. {GPa, 130 for <100> Si}
v = {nu} = Poisson's Ratio of the substrate. {unitless, 0.279 for <100> Si}
E / (1-v) = The biaxial modulus of the substrate. {GPa, 180 for <100>}
h = thickness of the substrate. {mm}
t = film thickness {Å}
R_{eff} = effective radius of curvature. {m, need to measure Ri and Rf}
$R_{eff} = (R_f R_i) / (R_i - R_f)$

see http://www.nfc.umn.edu for an Excel based calculator which will perform this calculation for you independent of the FSM.

b Wafer Bow Height:
Height = [(Wafer Diam./2)^2] / [2R], where R = radius of curvature.
Note: This is *not* simply 'max - min'.

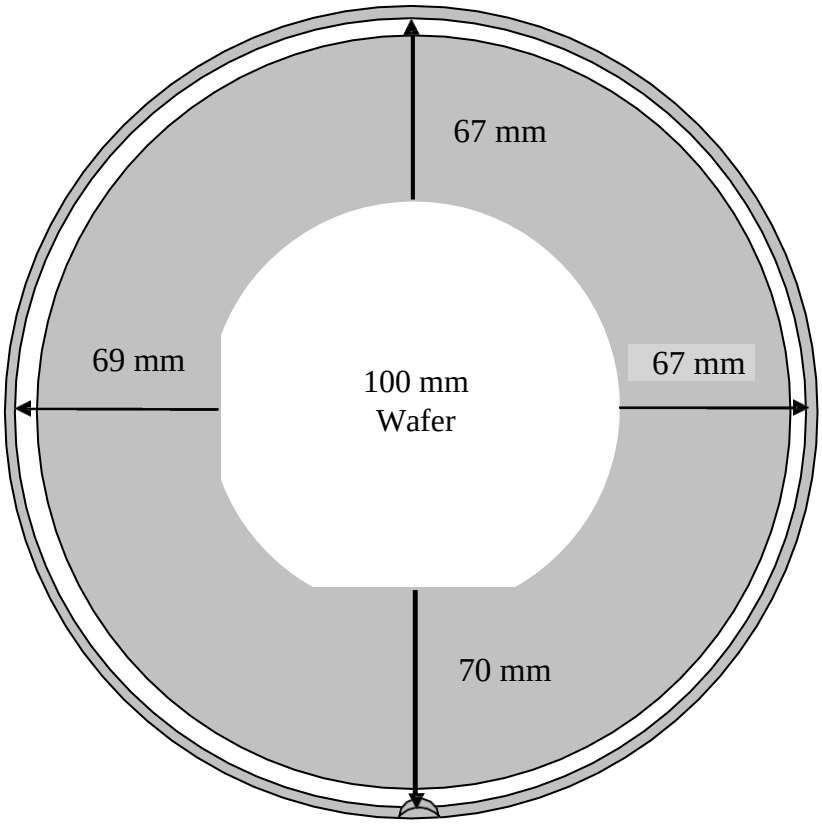
c Theory of Operation:
1) The laser detector path is graphed. This is seen at the top of the screen.
Note: This is *not* the curvature of the wafer, but, of course, is related to it.
2) The slope of the curvature is determined. A 'least squares fit' approximation is made. This slope represents dz/dx–the height adjust of the detector based on the scan travel across the wafer.
3) The 'radius of curvature' is determined. R = C / (dz/dx), where C is a constant. C happens to conveniently be '2 * beam path travel length'.
4) Once R is known, Stress and Bow Height can be calculated as above.

d Figure of Laser Path and Detector:



6 Setup

a Place wafer on the ceramic pins in the center of chamber as shown in the drawing below. This is to ensure wafer placement accuracy from scan to scan, so that the laser beam path is the same both before and after the film is deposited. Try to place wafer within a few millimeters of its original location. Feel free to make use of the steel ruler kept on top of the machine.



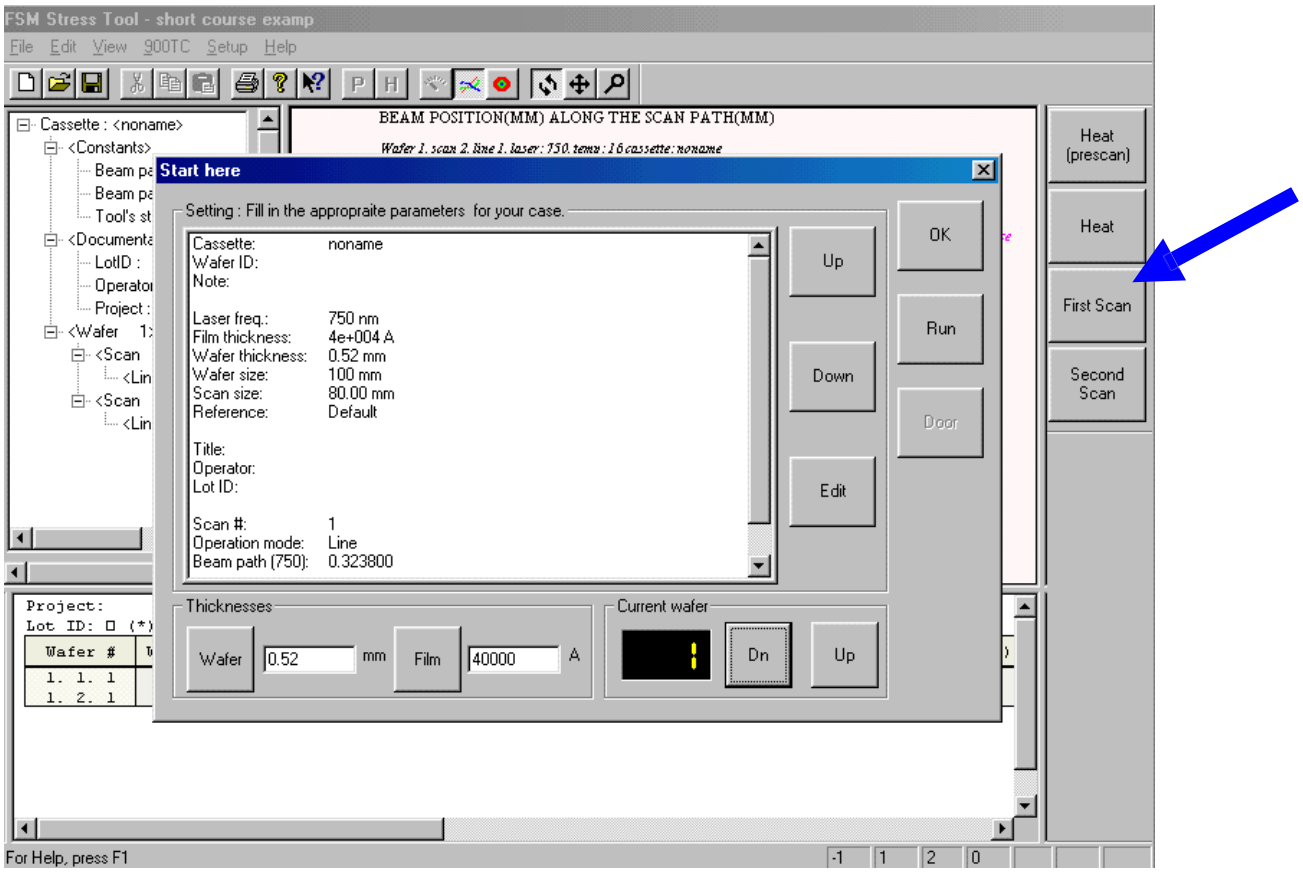
b Close chamber lid prior to scanning. Lid must be all the way closed as shown in the photo below, or at least only one-third of the way open (i.e with the metal clasps around the hooks, though not necessarily 'latched').

WARNING: If chamber lid is all the way open (about 2/3 open), the laser detector will not be able to find the beam due to the light not passing through the quartz window on top of the chamber correctly. If this happens, you will notice the scanner stalling in the back of the chamber. This is an unfortunate situation, as the only way to reset the machine from this state is to perform a soft re-boot of the software (Ctrl-Alt-Delete). If this should happen, and you haven't saved your data file recently, this can be quite costly!

7 Operating Instructions

Note: You will need to scan your wafer both prior to deposition of a film, and after that film's deposition. Also, it is assumed the film exists only on the side of the wafer facing the laser for proper assignment of magnitude and sign of calculated values.

a Click on FSM icon on desktop. The application will open and a new file will be generated. If performing post deposition scans, open your saved file through the File menu heading.
b Click on the **First Scan** box for wafer measurement prior to a film's deposition. Click on **Second Scan** for measurements made after a film is deposited.
c Enter Wafer and Film Thickness at the bottom of the screen. Alternatively, click on the Edit box and change data through the editor screen.
d Make certain the Current Wafer reading in the lower right is at the correct wafer. This number will increment automatically each time the First Scan dialogue box is opened.
e When all data has been updated and is satisfactory, click on the Run box. This will initiate the scan.

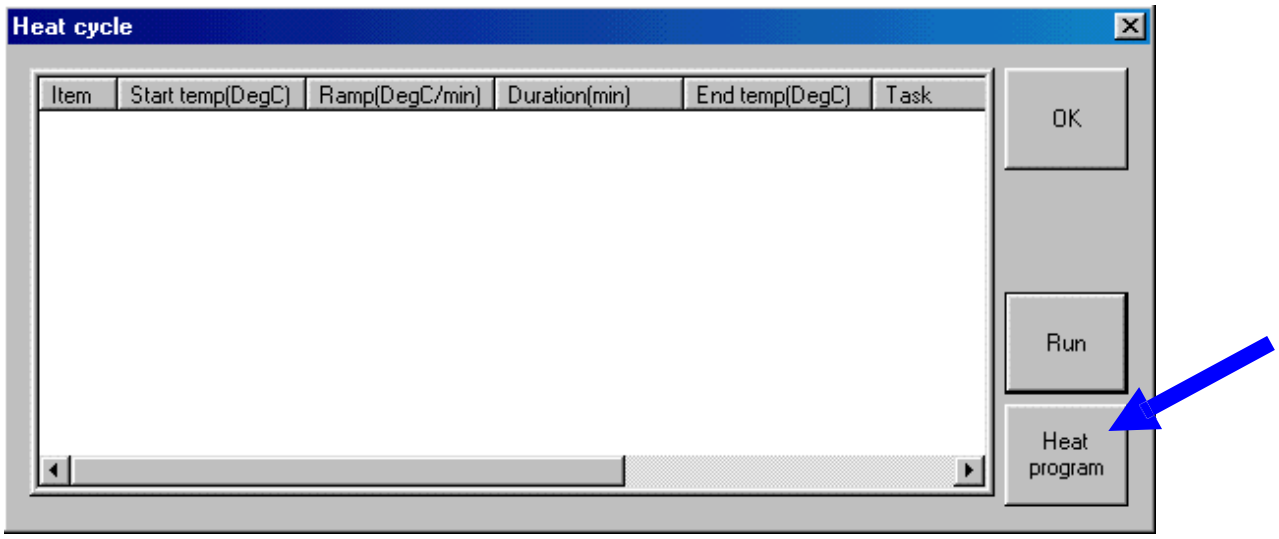


f For heated scans, click on the **Heat (prescan)** box as if it were the First Scan box of a normal scan.

g Enter Wafer and Film Thickness at the bottom of the screen. Alternatively, click on the Edit box and change data through the editor screen.

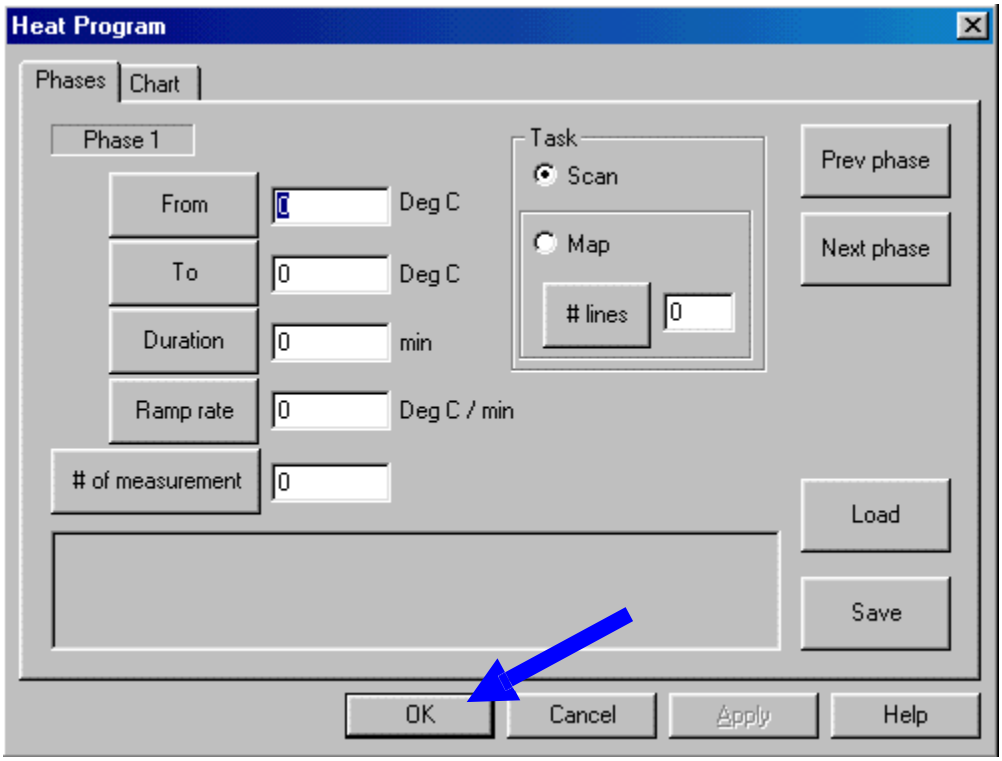
h When all data has been updated and is satisfactory, click on the **Run** box. This will initiate the room temperature scan.

i For the heated scans, click on the **Heat** box. The following window will come up.



j Click on **Heat program** box to open the window shown on the next page which will allow you to programm the temperatures, their ramp rates, and the number of scans you wish to perform.

k When finished programming the temperature and scan data, click on the **Okay** box.



l To run the heat cycle that has just been programmed, click on the **Run** box in the Heat Cycle window.

8 Problems/Troubleshooting

a Problem: Scanner stalling in the back of the chamber.
Solution: May be due to lid not being closed enough. Scanner will stay in locked-up position. Re-start computer with **Ctrl-Alt-Del**.

b Problem: Scanner stalls a lot during course of scanning.
Solution: Wafer not reflective enough over entire surface; detector is losing signal.

c Problem: Database shows incorrect wafer thickness on one, or both, First and Second scans.
Solution: Right click mouse on 'folder view' of scans on left-side of screen. Use option for changing wafer thickness. Note that this changes both the the First and Second Scan wafer thickness values.

d Problem: Database shows incorrect film thickness on one, or both, First and Second scans.
Solution: Right click mouse on 'folder view' of scans on left-side of screen. Use option for changing film thickness. Note that this changes both the First and Second Scan wafer film values--usually not very practical for room temperature stress measurement involving 'with' and 'without' film scenarios. Might be useful for temperature scans though.

Other alternatives to changing a film thickness include... if an earlier version of the file was saved, one could close/open the current file and scan the data again. Or, one can re-name the wafer with a new wafer number, and do the First Scan and the Second Scan over again.

9 Appendix

Data Export — One can export the data to a floppy disk or a 100MB Zip disk by right-clicking the mouse on the data table in the lower portion of the screen. This is useful for making stress calculations in other software applications, and cross-checking assumptions made by the FSM, especially with regards to which scan is being compared to which.