

Woollam M2000 Operation Manual

The Woollam M2000 is a spectroscopic ellipsometer used to characterize optically transparent films. The system has the Near IR upgrade that covers 700 wavelengths from 193nm to 1690nm.

Ellipsometry measures the complex reflectance ratio, which is the change in the amplitude ratio (Ψ) and phase change (Δ) of polarized light reflected from the sample surface. The CompleteEASE software use the measured data and the prebuilt models to extract the thickness and optical parameters of the sample.



The M2000 is an extremely capable system. The extent of its measurement capabilities is beyond the scope of the operating procedure. An electronic copy of the Software Manual is located on the system desktop. More, comprehensive information regarding ellipsometry and the M2000 is available on the JA Woollam web site (www.jawoollam.com).

Training to Become a Qualified User

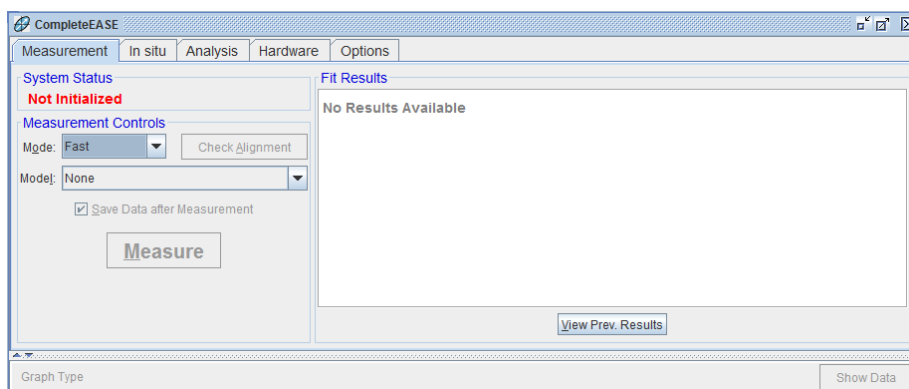
This tool requires a 1-hour training session for qualification.

CompleteEASE Software

The CompleteEASE is Tab-based oriented software for controlling the hardware, collecting and analyzing the data. An analysis involves setting the measurement routine, collecting the data, choosing the appropriate model and then the analysis data.

Tool Start-Up

1. Review Badger for Shutdown, Problems and Comments. Verify there are no lab member reservations for the duration of your measurements and analysis.
2. Enable “Ellipsometer” on Badger.
3. Turn on the lamp by pressing the “Power” button first and then the “Lamp Ignition” button.
4. Place your sample on the chuck. You can use the wafer vacuum, but it is not required.
5. If the CompleteEASE application is open, logon using your own log in ID.
 1. If the CompleteEASE application is not open, click on the Complete EASE icon on the desktop and then log in.
6. Verify the hardware is initialized by going to the Measurement tab. Look at the System Status field. If it shows **Not Initialized**, initialize the hardware by shutting down and reopening the CompleteEASE software. If the hardware is initialized, **Waiting to Acquire Data** will be displayed as the System Status.

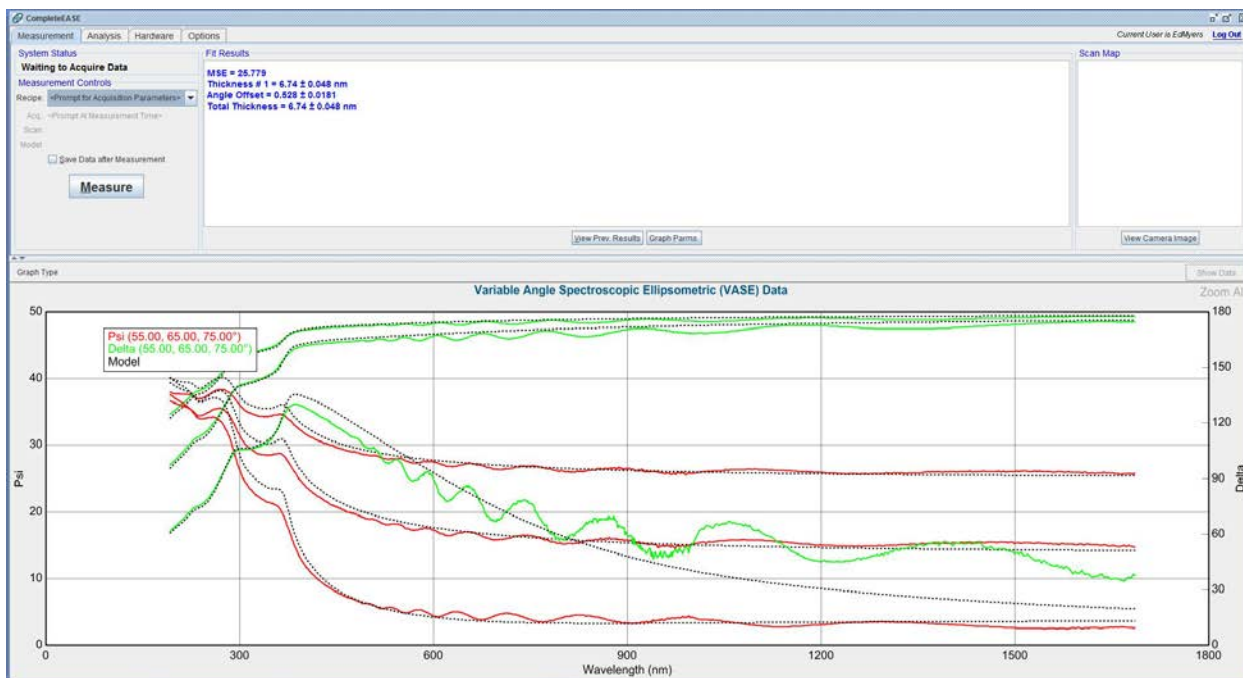


Tool Shut-Down

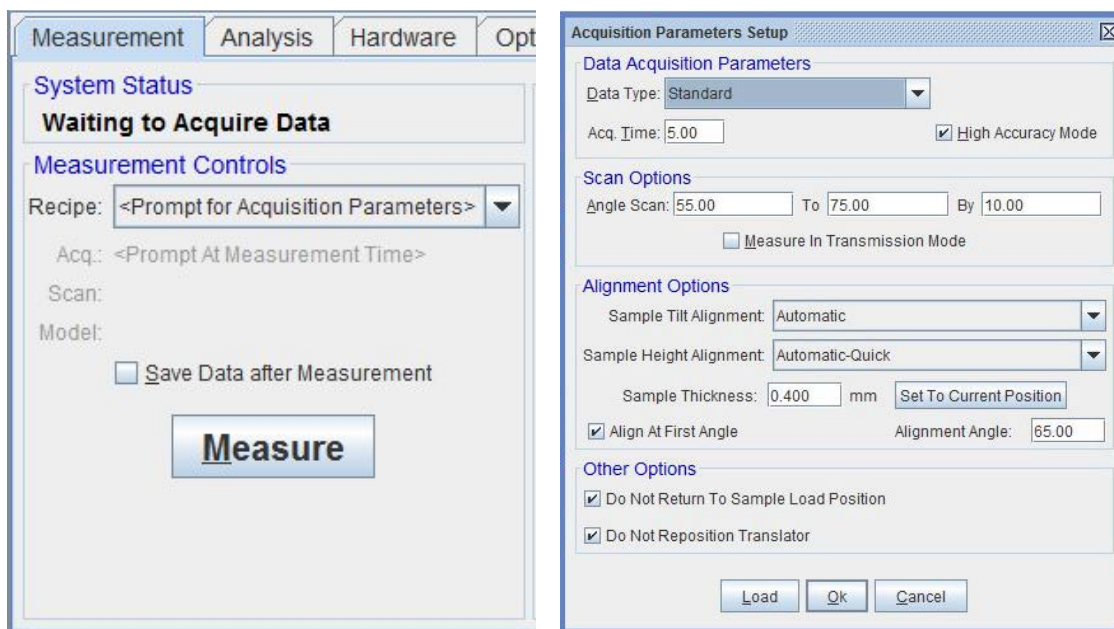
1. Turn off vacuum and remove wafer.
2. Turn off lamp by powering down system, waiting for lights to go off, then turning power back on. Lamp ignition light will remain off.
3. Log out of the CompleteEASE software.
4. Disable “Ellipsometer” on Badger.

Acquire Data using Spectroscopic Scan.

CompleteEASE allows you to use a predefined measurement routine, define the acquisition parameters, or the recipe components once you initiate the measurement. The approach you chose is based on whether you have an established measurement routine, or if you want to define your model before or after your measurement.



1. Recipe <Prompt for Acquisition Parameters>: Use the pull down menu to select a predefined measurement routine or you can select the option for 'Prompt for Acquisition Parameter'. The 'Prompt for Acquisition Parameter' option will provide a series of configuration questions once you initiate the 'Measurement'. Common Si substrate default values are shown in the Acquisition Parameter Setup window. Increasing the Acq. Time to 40, can help smooth the data.



2. Recipe <Prompt for Recipe Components>: Selecting the Prompt for Recipe Components opens the 'Choose Recipe Components' window, shown below. The available options include the Acquisition

Parameters, Scan Pattern (shown below) and the model. If you have established measurement routines, this option allows for the easy selection of standard recipes.

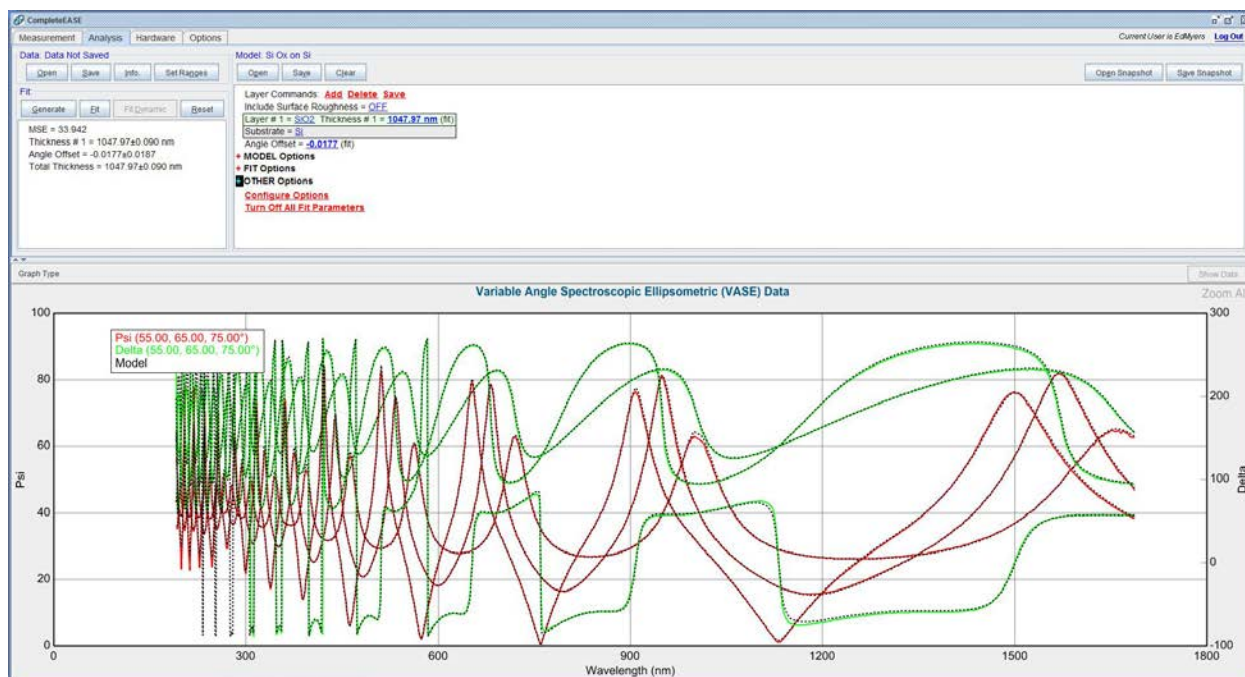
The image displays two screenshots of a software interface. The top screenshot is the 'Choose Recipe Components' dialog box. It has a title bar with a close button. The 'Recipe' section contains three dropdown menus: 'Acq. Params:' with the value '<Select an Acquisition Parameters Set>', 'Scan Pattern:' with the value 'None', and 'Model:' with the value 'None'. Each dropdown has an 'Edit/Create' button to its right. The 'Additional Parameters' section includes a text field for 'Folder for saving acquired data:' with a 'Choose' button, and two checkboxes: 'Save Results Only - No Raw Data' and 'Export measurement results'. At the bottom are 'Load Existing Recipe', 'Ok', and 'Cancel' buttons.

The bottom screenshot is the 'Scan Pattern Editor: (not saved)' window. It features a 'Substrate Dimensions' section with a 'Circle' dropdown, a 'Dia. (cm):' field set to '20.00000', and a 'Draw Wafer Notch' checkbox. A 'Point List (cm)' table is on the left, and a 'Grid Fill' section with buttons for 'Grid Fill', 'R-T Grid Fill', 'Line Fill', and 'Point Commands' (Add Point, Edit Point, Move Up, Move Down, Delete Point, Delete All, Paste From Clipboard) is in the center. A large circular diagram is on the right. The 'Alignment Position' section has 'X: 0.00000', 'Y: 0.00000', and an 'Align at this position only' dropdown. The 'Pattern Offset' section has 'X: 0.00000', 'Y: 0.00000', 'Theta (°): 0.0000', and a 'Use Initial Position' checkbox. The 'Deskew Points' section has checkboxes for 'Do Deskew' and 'Record Image At Each Point', and fields for 'X1: 0.00000', 'Y1: 0.00000', 'X2: 0.00000', 'Y2: 0.00000', and an 'Image Zoom: 1x' dropdown. The 'Transmission Intensity Baseline' section has a 'Use Point For Transmission Baseline' checkbox and fields for 'X: 0.00000' and 'Y: 0.00000'. The 'Pad (Measurement Point) Alignment' section has a 'Do Pad Alignment' checkbox. At the bottom are 'Load', 'Save', 'Close', 'Show Translator Dialog', and 'Test Scan' buttons.

3. Begin the measurement by clicking on the 'Measure' icon. The hardware will automatically adjust for the stage tilt and sample height before collecting the spectroscopic data.

Data Analysis

The CompleteEASE software uses a standard, iterative, non-linear regression algorithm (the Levenberg-Marquardt method) to converge to the minimum MSE by adjusting the lab member defined fit parameters of the model, typically the layer(s) thicknesses and optical properties of the layer(s). Make the model and the solution are physical and valid. For example, if the optical constants determined from a model fit are outside acceptable bounds for the material (e.g., $k < 0$ or $n > 10$), the results are unphysical and should be considered invalid. The Analysis screen is comprised of the 'Fit', 'Model' and Spectroscopic Data' windows.

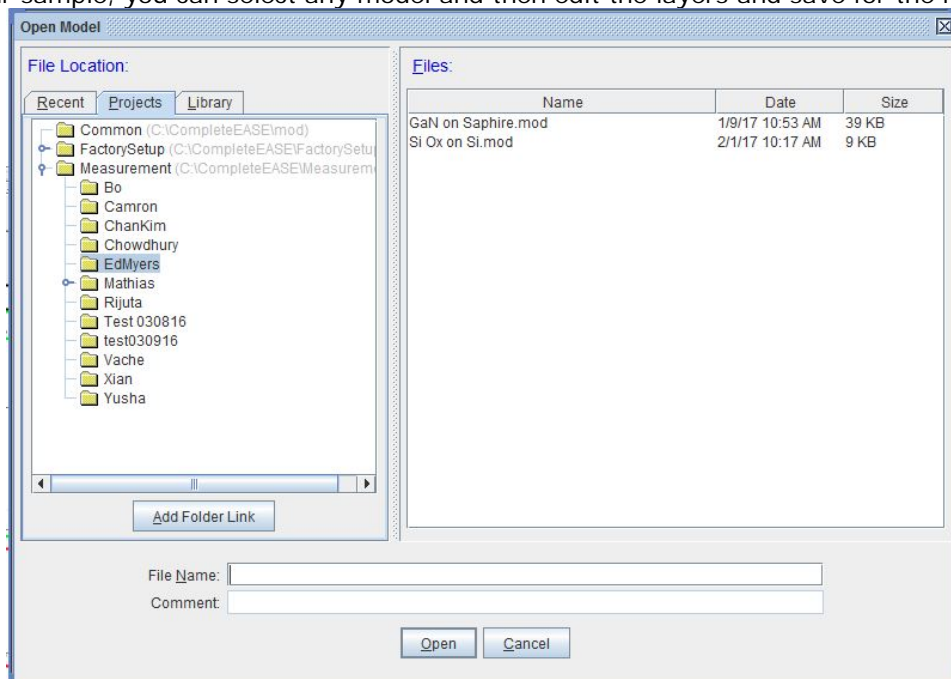


Variable Angle Spectroscopic Ellipsometric (VASE) Data window: Displays the active data used for the analysis. Default settings for graph are Ψ and Δ on the y-axes and nm on the x. Right clicking on the graph will display the options for changing the data that is graphed and the axes.

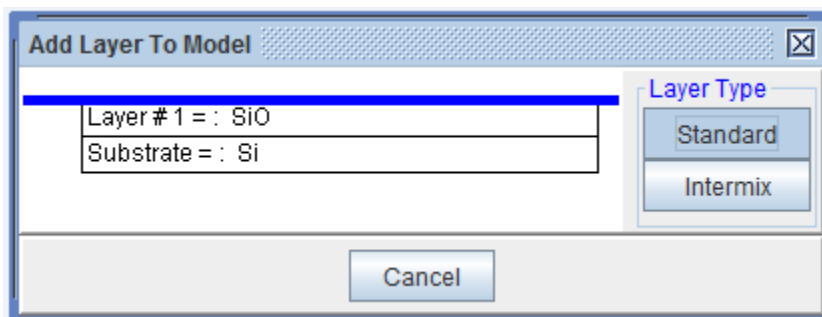
1. Model window: The model defines the layers, which comprise the analysis sample, material layers and how the data will be "fit" by CompleteEASE. Models can be stored and recalled for future use.
2. Fit: Displays the 'Fit' results for the selected model. If no model is selected the window will be blank.
 1. 'Generate' graphs the mathematical solution to the model you defined. It does not do any type of fitting. It will show how representative your model is to the actual sample.
 2. 'Fit' initiates the regression analysis using the material stack(s) [model] defined in the 'Model' window.

3. Creating the analysis model: An analysis model can be relatively simple or can be very complex depending on your sample. The following description should cover most of your analysis requirements. If you have any questions, or would like help with your analysis please contact the CNM2 staff and/or refer to the CompleteEASE Manual.

1. Open: Opens the link to saved models. Models use the .mod file suffix. If no model matches your sample, you can select any model and then edit the layers and save for the next use.



2. Editing the model: You can add a layer by clicking on the 'Add' button. The Add Layer to Model window will pop up. The blue line indicates where the new layer will be placed. You can change the insertion location by clicking below, between or above an existing layer. Most 'Layer Type' will be Standard. There is a wide range of options available to apply to any model, but most are not required.



4. Fitting a Model Fit: Once the measurement is complete and model built, you can fit the data. The 'Generate' button plots the defined model without any fitting. This can provide an insight as to how close your model matches the data. The 'Fit' button initiates the regression analysis. This

software will modify the thickness and / or optical properties of your fit layers to best match your model layers to the data.

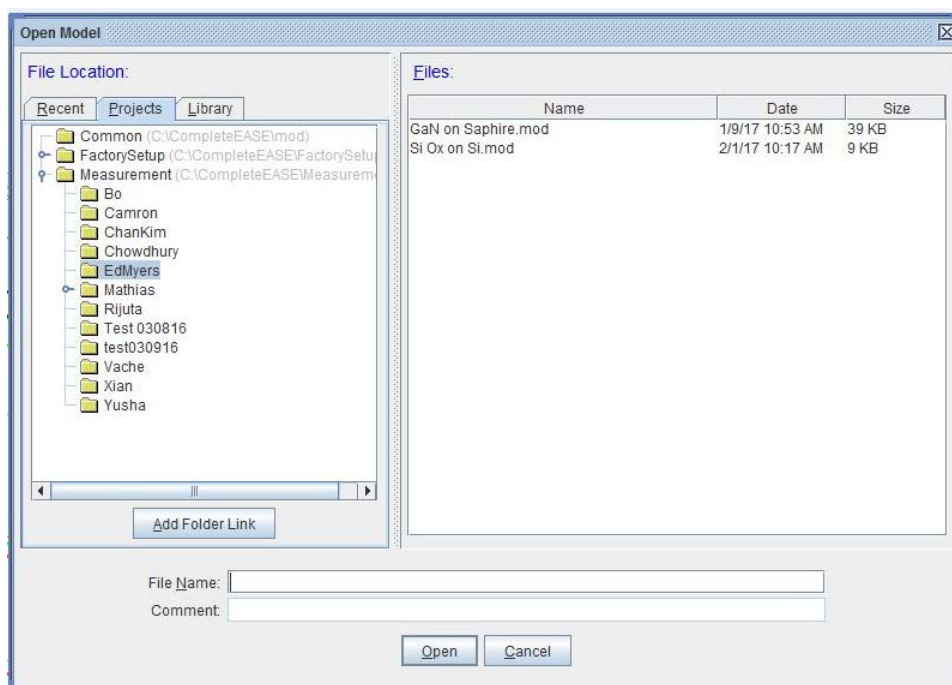
WARNING: The results are only as good as your model. You must include all relevant layers and in the correct order in your model to get a valid answer.

5. Verify the Results: First and foremost, do the results make sense. There are many parameters, which can be included in the regression analysis, which can lead to a better MSE fit number but may not make practical sense. For example, do not include optical constants for well-established films such as silicon or thermal oxide. It is more likely you may have forgotten a thin layer, or a graded layer, which is common in some growth technologies. MSE values are important, but the goal of your analysis should not be to achieve the minimum MSE fit value, it is to correctly represent your sample.

Creating or Modifying a Model

Each layer in your model has a multitude of parameters that can be used to fit the data. It is best to start with a basic model that contains the material layers and their thickness. This helps to keep the model physical and lets you a good idea of how successful you were in defining the layers. The easiest way to create a model is by opening an existing model and modifying it to match your sample.

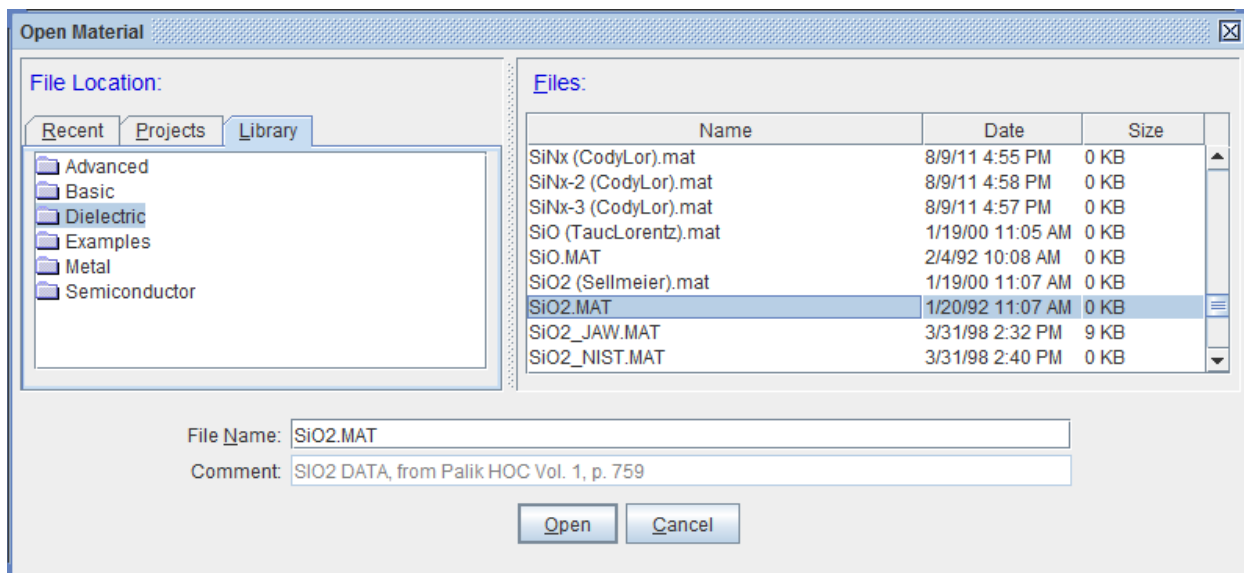
1. Open a Model: Under the 'Analysis' tab, click on the 'Open' icon under the Model: window. This will open the directory with the existing models. Look through the "Recent", 'Projects' and 'Library' directories for a representative starting model. Once you have the correct model opened (.mod extension) click on the 'Open' icon.



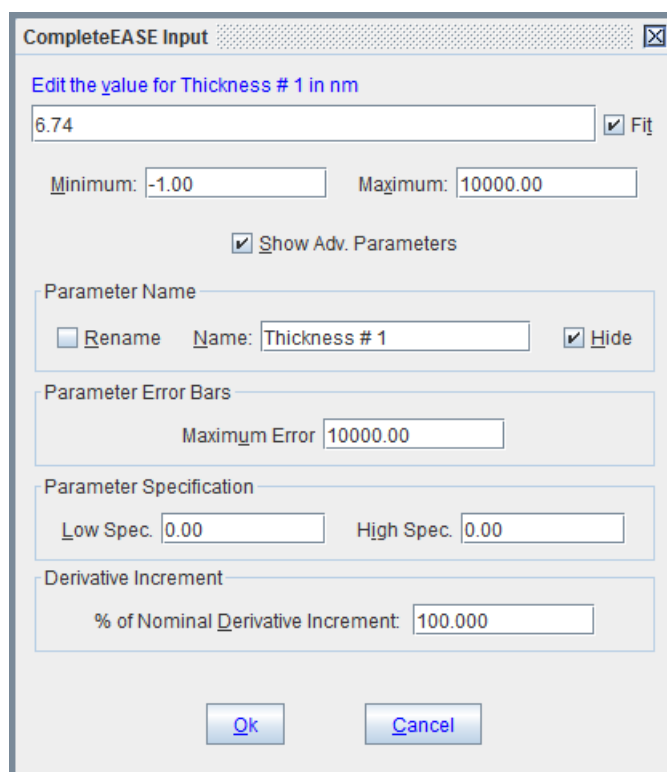
Change a Layer Material: You can change any parameter by selecting the any blue, underlined text.
For example the substrate (Si) or Layer #2 (SiO₂) in the following picture.



Clicking on the 'Layer' material, it opens the Material files. Navigate through the directories until you find the material (.mat extension) that matches your sample.



Turning on the 'Fit' option: Click on the blue, underlined parameter you want to fit (6.74 nm in this example). This will open up the following dialogue box. Click on the Fit either to fit or to turn off fitting for this parameter. You can define the range to fit the thickness as well as other parameters.



MODEL Options, FIT Options and OTHER Options: These options are used infrequently.

1. MODEL Options: Used to include substrate backside corrections.

2. FIT Option: Limit wavelength and limit angles option is useful. Limiting the analysis angle to one angle, instead of multiples increases the regression time. Likewise limiting the wavelength is used to limit wavelengths that don't follow index and absorption book values. Examples such as Plasma Enhanced Chemical Vapor Deposition (PECVD) films often are much more absorptive in short wavelengths than high temperature films. Eliminating the absorptive part of the spectra allows for solving for the film thickness prior to determining the optical constants. The Global Fit option, is used when there are multiple layers and not a good understanding of the individual layer thickness.
3. OTHER Options: Are not commonly used.

Additional Information

Some options (more frequently used options - many more exist and please feel free to document any helpful procedures that might be useful to lab members!):

1. Select angle(s) for measurement. In order to reduce the polarization shifts from the substrate it is best to choose angles near the Brewster Angle for your substrate. (Typical selection for Si is 65-75 degrees).
2. Select angle step size for measurement. More angles will give you more data and improve confidence in the results, but will also take more time. (Typical selection for a single thin film on silicon is 3 angles, so the angle step size would be 5 to measure at 65, 70, and 75 degrees).
3. Select revs/measurement. The default setting is 5. More revs/measurement will decrease the amount of noise in the data collection but will also take longer. (Typical value is 40 revs/measurement)
4. Transmission Scan instead of Spectroscopic Scan. Transmission scans require that the wafer be set perpendicular to the chuck. CNM2 does not have a jig available for lab members but many users fashion their own out of lab-approved materials.
5. Some films will not have the optical constants in any of the tool databases. Modeling of the films as Cauchy layers, EMA layers or GENOSC layers can be done as well. Please contact staff for training if you need help.