Woollam – Variable Angle Spectroscopic Ellipsometer

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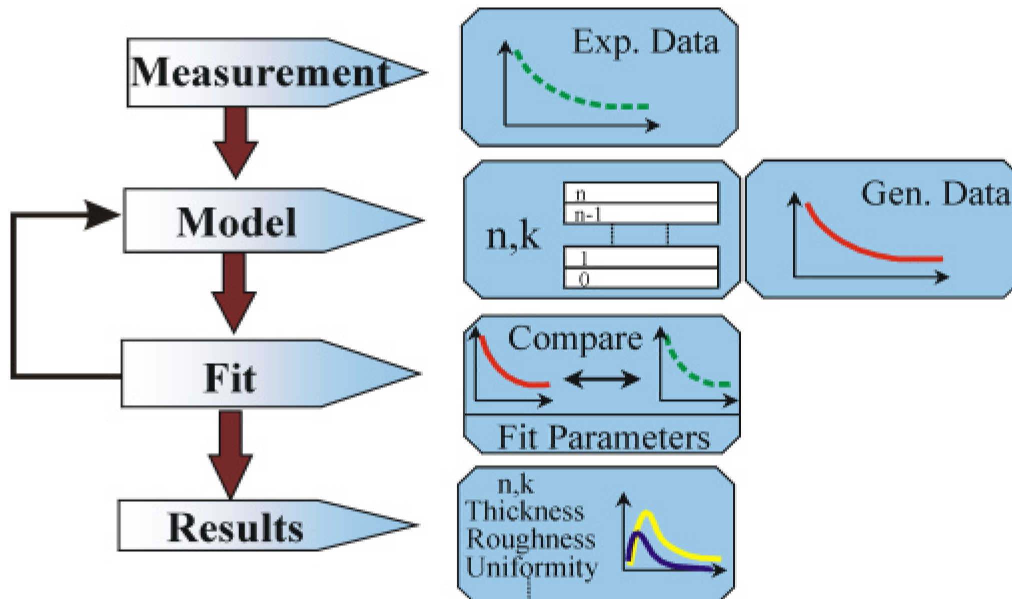
OVERVIEW

Ellipsometry is a noninvasive technique that measures the changes in the polarization state (Ψ and Δ) of light reflecting from a substrate. From these parameters, thickness as well as optical properties of thin films are determined. The figure below illustrates the data analysis flow. First, in the measurement mode, the polarization change is measured. Then a model based on the layered film stack is applied and respective data is generated. Comparison between the experimental and generated data is then made by utilizing fitting functions. Mean squared error (MSE) is employed to quantify the difference between the experimental and model generated data. Minimization of MSE is accomplished through the model and fit phase of the flowchart.

The variable angle spectroscopic ellipsometer in the CNF has the spectral range from 240nm – 1700nm. The automated translation stage has 150mm by 150mm XY mapping capability, with automated angle range from 20-90 degrees. A copy of the WVASE32 manual and software is available in the CNF CAD room for data analysis. Please consult the manual for more advanced features.



QUICK START

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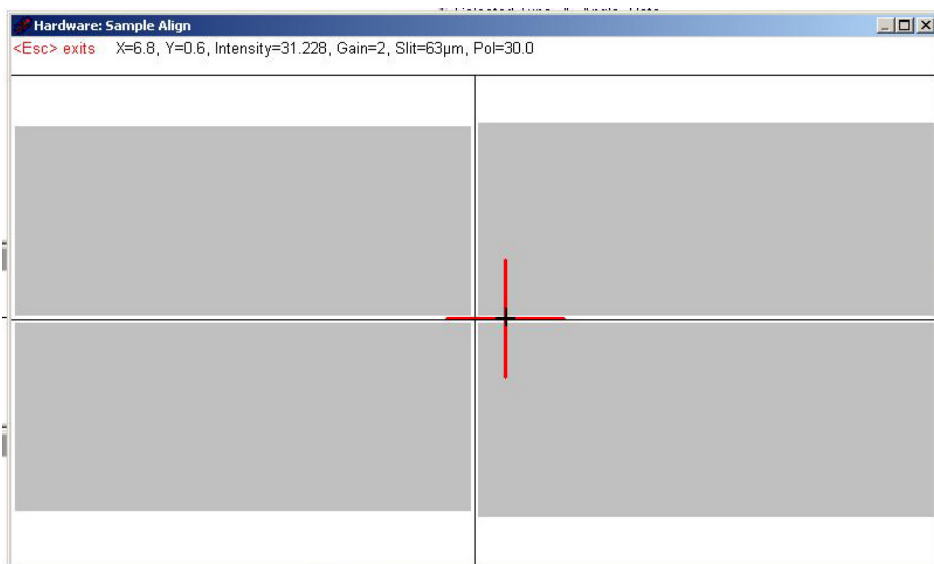
Lamp and monochrometer power should be ON. Ignition switch should also be ON, in case the lamp is off, make sure that the lamp and monochrometer are ON then press the ignition switch.

CALIBRATION

1. Start the WVASE32 software. The hardware window will indicate that the tool is not initialized. If the hardware window does not pop-up during startup, click on **Window** and choose **Hardware**. From the pull-down menu choose **Initialize** this will take approximately 2 minutes. During initialization a *WVASE32 Hardware Log* window will pop-up with *Enter User Name* field already filled in as something, just click **OK**.

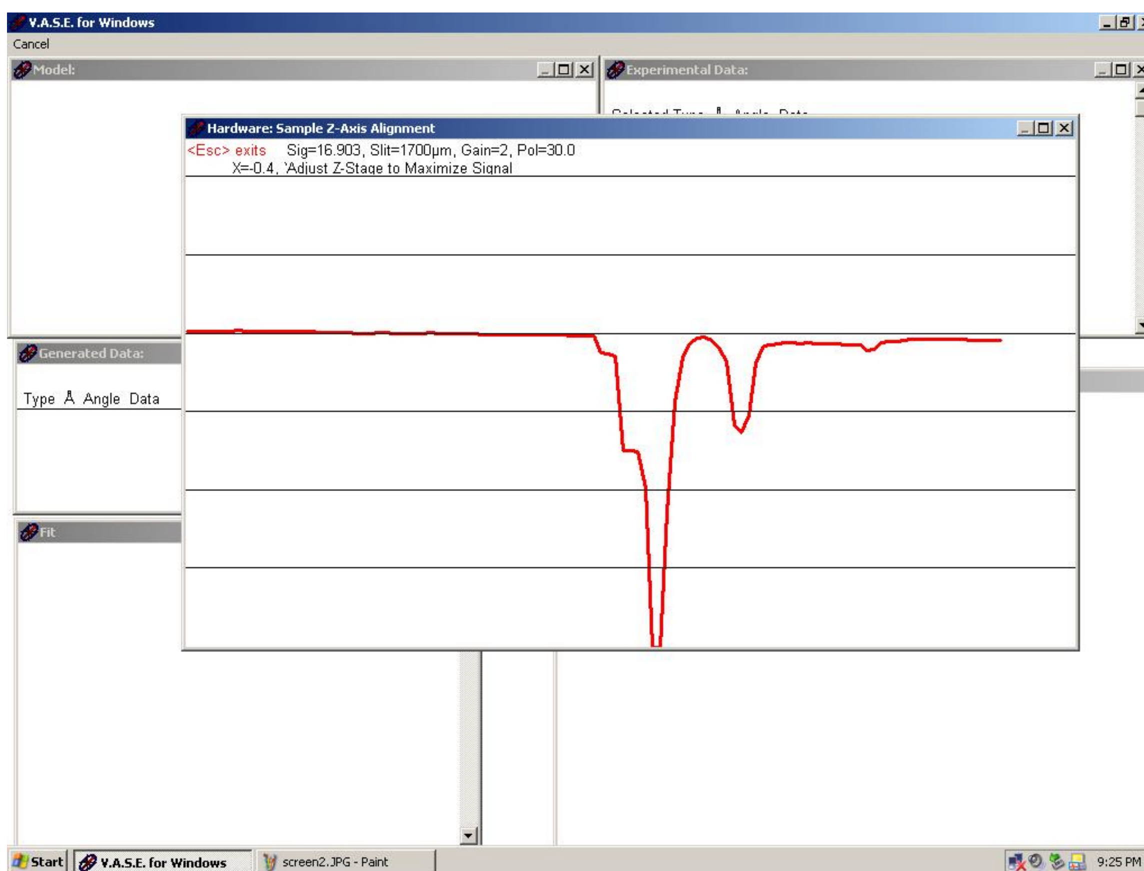
2. Place the calibration sample on stage and apply vacuum. From the menu choose **Acquire Data**, then **Align Sample**. Click **OK**. The detector will rotate and a menu will appear with a red crosshair. Use the two black knobs (X right and Y left) above the wafer to level and align. Make sure that the X and Y values are in the range of –1 to 1 (see figures below). Press the **ESC** key. The detector will rotate back to the home position.



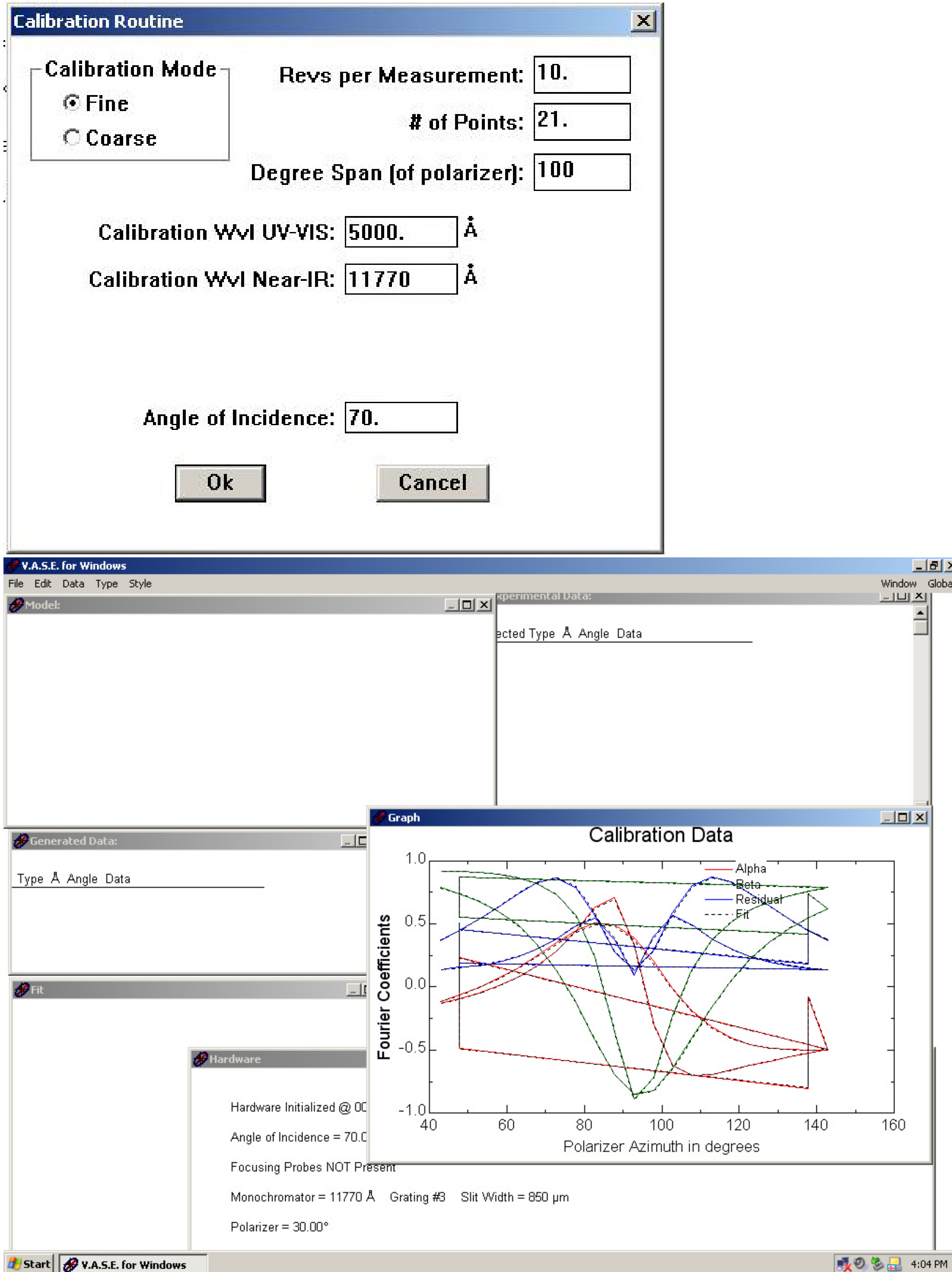
Uncalibrated in the X.

Fully calibrated with X = 0.2 and Y = -0.7

3. Click **OK** in the *Sample Z-axis Alignment* popup window and maximize the signal with the micrometer below the wafer stage (see figure below). Press the **ESC** key.



4. With the **Hardware** window enabled, from the pull down menu click **Acquire Data**, then **Calibrate System**. Make sure that the values match the ones in the figure below and that the **Fine Calibration** mode is enabled. Click **OK**. This will take approximately 2 minutes. Calibration data will appear in the *Graph* window (see bottom most figure).

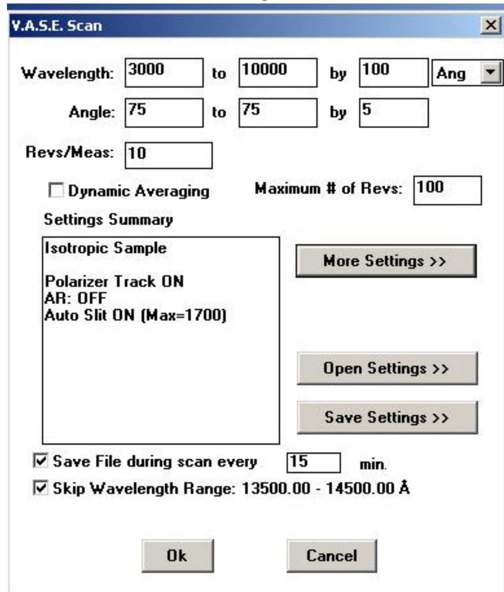


Example illustrating calibration data.

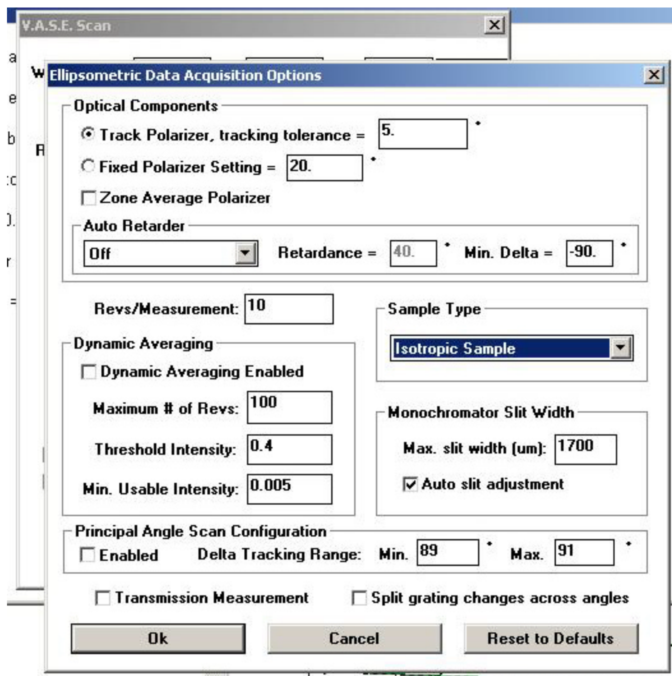
ACQUIRING DATA

Place the sample on the stage and align the optics by repeating steps 2 and 3 from the calibration section. In the following, example a silicon wafer with 500nm thermal oxide is measured.

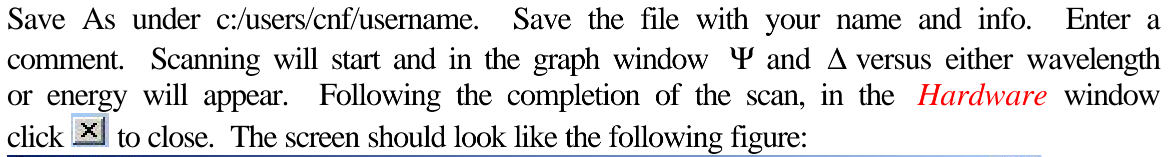
1. With the **Hardware** window enabled, from the pull down menu click **Acquire Data**, then **Spectroscopic Scan**. Click on **More Settings** to choose scan parameters and then click **OK** (see figures below).



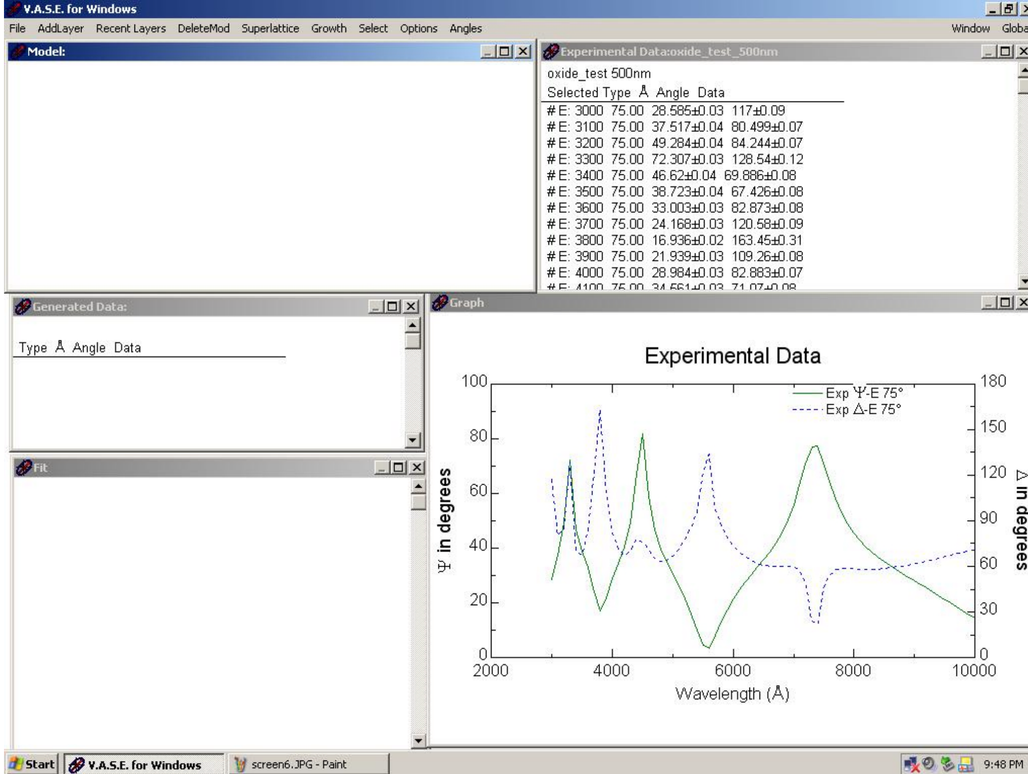
Spectroscopic scan menu.



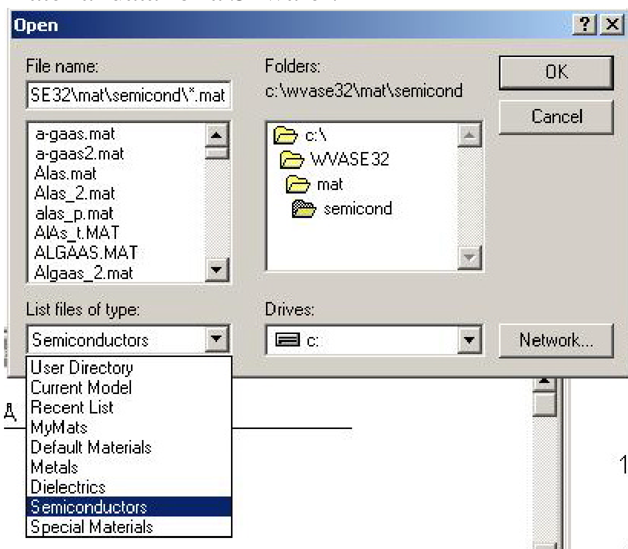
More settings menu.



Save As under c:/users/cnf/username. Save the file with your name and info. Enter a comment. Scanning will start and in the graph window Ψ and Δ versus either wavelength or energy will appear. Following the completion of the scan, in the *Hardware* window click [X] to close. The screen should look like the following figure:

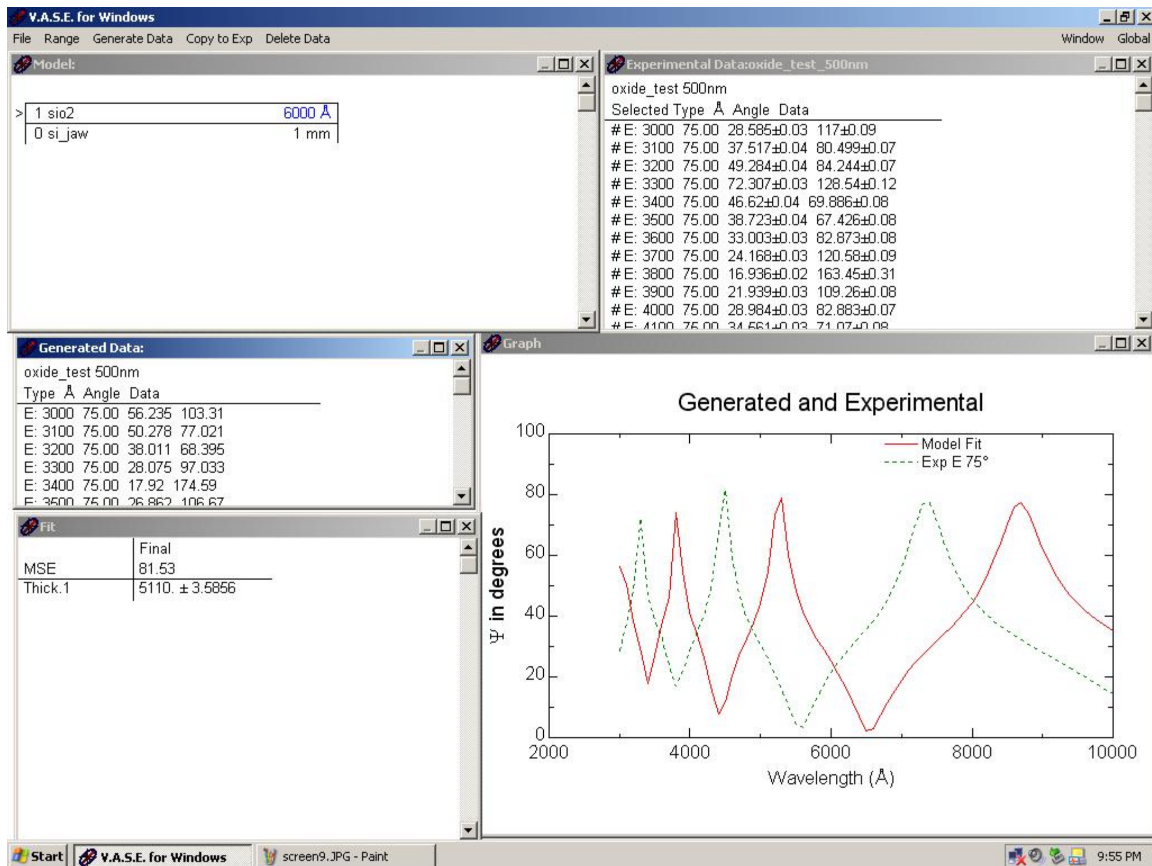


2. Click anywhere in the *Model* window to activate. From the pull down menu click **Add Layer**, choose **Semiconductors** then choose **si_jaw.mat**. This is the J. A. Woollam material data for a Si wafer.



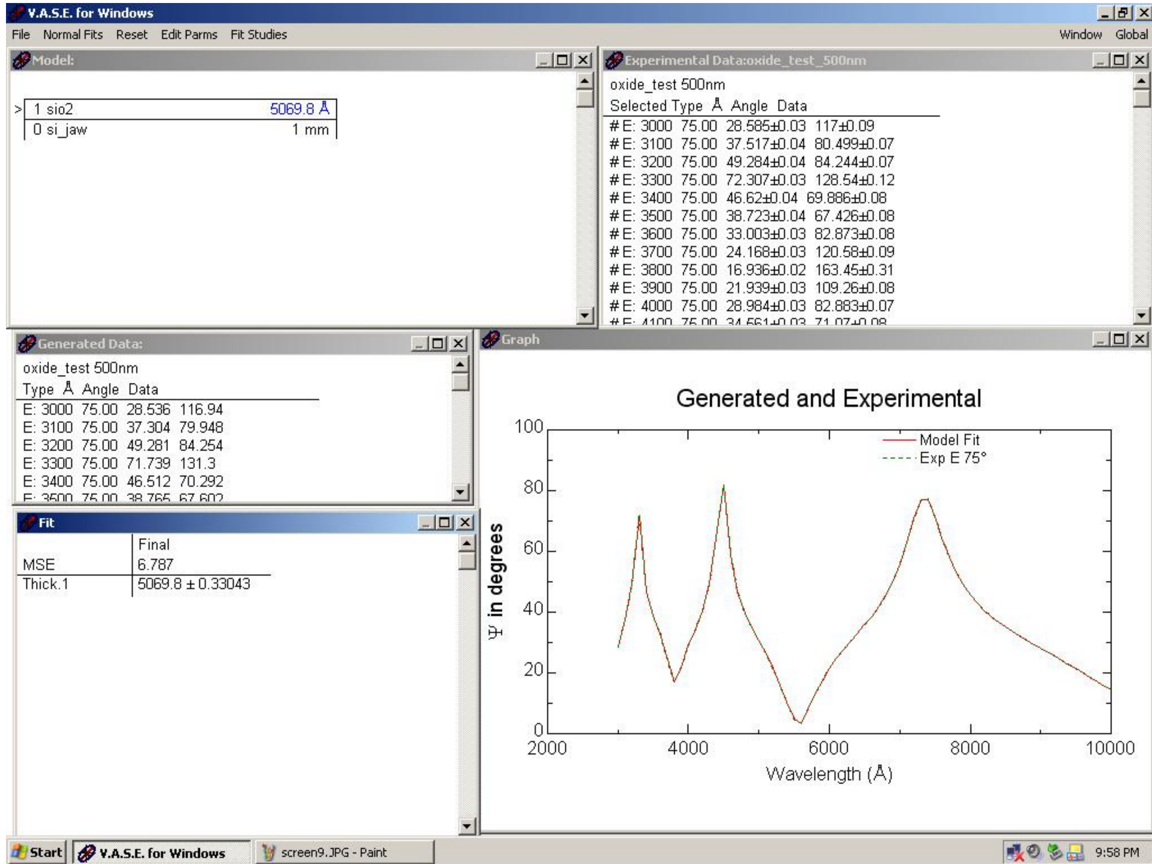
Click **Add Layer**, then choose **Dielectrics**, then choose **SiO2.MAT**. In the popup window, for the thickness place a value of **6000A**. Right click in the *Graph* window, choose **Style**, then **2D**, and **Disable Double Y-Axis**. This is extremely useful when viewing multi-angle Ψ and Δ data.

3. Click anywhere in the *Generated Data* window to activate. From the pull down menu click **Generate Data**. Data from the chosen model is then plotted in the *Graph* window and labeled as **Model Fit** (see figure below).

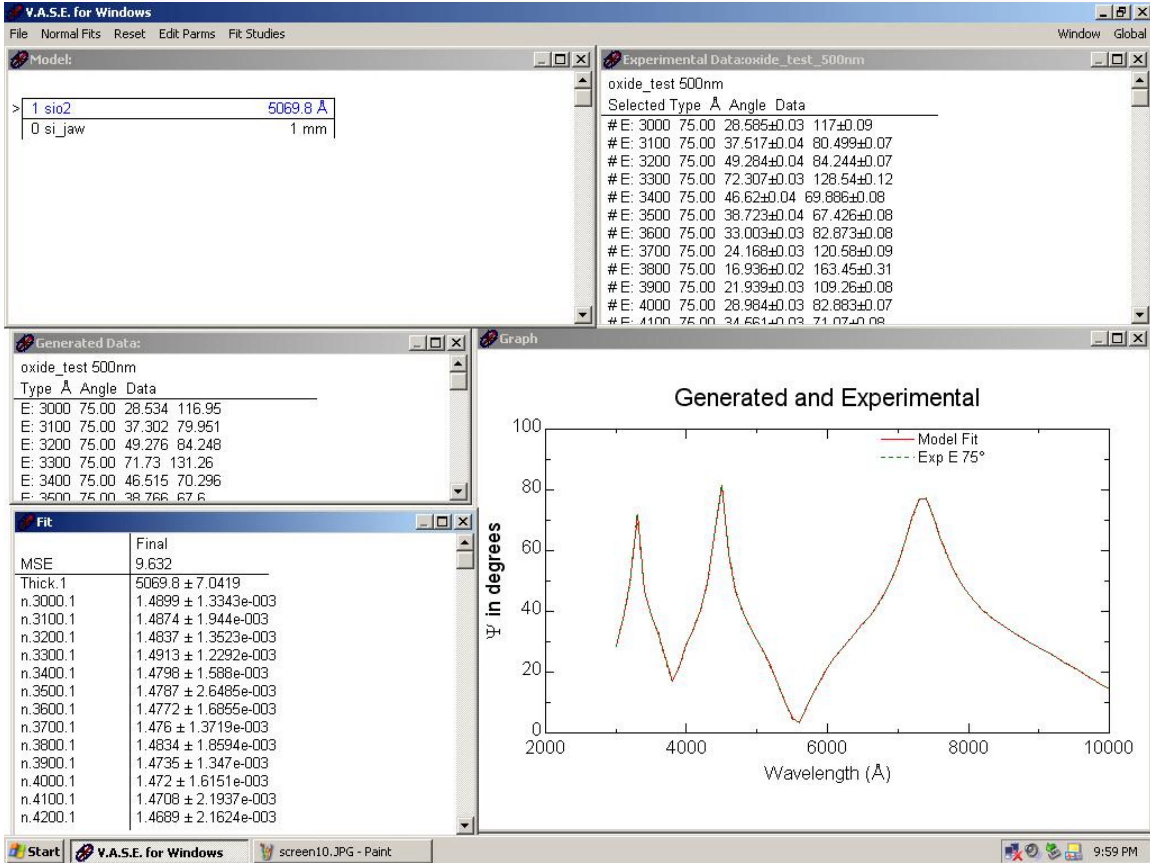


The mean squared error is 81.52 and the thickness of the silicon dioxide layer is approximately 511nm.

4. Since the model data fit is not coinciding with the experimental data(MSE is large), click anywhere in the *Fit* window to activate, then choose **Normal Fits** from the pull down menu. The figure below shows that the MSE is 6.787 indicating a good agreement between the measured and modeled data, and the SiO2 thickness as 506.98nm.



In order to acquire refractive index information, click on the **SiO2** layer in the *Model* window and enable n. Repeat the fitting algorithm and the resulting figure illustrates the refractive index result in the *Fit* window.



When finished, from the pull-down menu click **File**, then click **Exit** then **YES**.

EXAMPLE

Below is an example of a three-angle measurement of a 100nm polycrystalline silicon film on top of a 240nm thermal oxide film on a silicon substrate. In this model, roughness was incorporated in order to minimize the MSE.