

## Operation Manual of J.A. Woollam Ellipsometer

- 1) Press both the Lamp power and lamp Ignition buttons to turn them on (The buttons are located on the front panel of the bottom control box).
- 2) Put your film sample onto the center of the sample stage (there are two tiny vacuum holes underneath your sample).
- 3) Switch the vacuum on (at the low left side of the tool).
- 4) Open **CompleteEASE** software (if it is not opening).
- 5) Click on the **Measurement** tab at the top left of screen, then, click on the arrow-down sign, the recipe menu showing up, then, choose **Standard**.
- 6) Click on **Measure** tab, then, a Panel shows up. Make sure: a) **Acq. Time** is 4.00; b) **High Accuracy mode** is ticked; c) **Angle Scan**: 55 To 75 By 10.00; d) **Sample tilt Alignment**: Manual; e) **Sample Height Alignment**: Automatic-Quick; f) **Sample Thickness**: type the thickness of your sample substrate, e.g., 0.50 mm; g) **Align At First Angle** is not ticked; h) **Alignment Angle**: 65; i) **Do not Return To Sample Load Position** is ticked; j) Finally, click on **OK** tab at the bottom of the Panel.
- 7) Sample tilt Alignment starts: a) if there is some reflected light signal entering the detector aperture hole, a blue-color section appears on the screen, just adjust the two knobs located at the two sides of the sample stage to center the red cross sign, then, click on **Cancel Alignment** tab at the top left of screen (or just hit the ESC key on the keyboard) to end the alignment (sometimes, one needs to repeat the alignment several times before the measurement starts). b) In some situation, there is no blue-color section appearing on the screen and the red-cross sign jumps all over the screen: this means the detector does not receive any signal reflected from the sample. In such case, what you need to do is looking for a circled white-light spot (weak, but, you can see it) outside the aperture hole, then, adjust the two knobs to make the spot moving toward the aperture hole, as soon as there is some signal light entering the aperture hole, the blue-color section appears on the screen, keep adjusting these two knobs to make the red cross sign to be centered, while the blue-color section becomes larger and larger.
- 8) After the alignment, the measurement starts at the multiple angles. Wait until it is finished: Psi and Delta spectral curves showing up in the Graph section.
- 9) Click on **Analysis** tab at the top left of screen. Then, there are 4 sections appearing in the Analysis screen: Data, Fit, Model, and Graph ones.
- 10) If you want to save the measurement data, click on the **Save** tab in the Data section, choose your file directory, type a file name, and save the data into the file (you can click on **Open** tab in the Data section to open the data file for later-on analyses).

- 11) Click on **Open** tab in the Model section to open a model (you can create a new model or copy some existing model and edit it, including to add or delete layer(s) under **Layer Comments** category, if necessary. Then, click on **Save** tab in the Model section to save it with a different name into your directory). For your reference: 1) using Cauchy model,  $n(\lambda)=A+B/\lambda^2+C/\lambda^4$ , where A, B, C are the Cauchy fitting parameters, for a dielectric film or a photoresist film; 2) using B-Spline model for a thin absorptive metal film (to get a good result, the thickness of the metal film needs to be less than 50 nm); 3) using Si\_JAW for a Si substrate or a single-crystal Si layer in SOI sample structure; 4) using NTVE\_JAW for a very thin oxide layer (turning the fit operation on for the layer thickness) or a native oxide layer with a fixed thickness of 1 nm. **Note: Per suggestion by James Hilfiker from Woollam Co., Inc, from now on, when you fit a data using a Model, you should turn off the fitting of Angle Offset (fixed Angle Offset to 0) in that Model, except fitting the native-oxide data using Model: NTVE\_JAW (you still turn on the fitting of Angle Offset).**
- 12) Click on the **Fit** tab in the Fit section to fit the data with the model chosen. You can set the wavelength range by clicking on **Set Ranges** tab in the Fit section: a panel shows up, then, typing the new low or/and high wavelength limit(s) there (you can also select the data of a certain angle to fit), finally, hitting **OK** tab. **A good fit means a small Mean-Squared-Error (MSE) value.**
- 13) To get the optical constants at a certain wavelength (see Figure 1 below for a reference), before fitting, do the following: click on the red plus sign beside **FIT Options** in the Model section; click on the red plus sign beside **Include derived Parameters=ON** (if it is OFF, just click on **OFF** sign to change to ON) at the bottom; choose Type, and type Layer # and Wavelength in which you are interested. You can add as many Derived Parameters as you want and these derived parameters will show up after the fit.
- 14) To get the optical constant spectra (see Figure 2 below for a reference),  $n(\lambda)$  and  $k(\lambda)$ , after fitting data curves, do the following: click on **Options** tab at the top left of the screen; choose **n&k in Optical Constants** (or **e1&e2**); then, click on **Analysis** tab at the top left of screen; right-mouse-button click on the Model name of the layer, you are interested in getting the optical constants, in the Model section, a menu showing up; choose **Graph Layer Optical Constants**; the  $n(\lambda)$  and  $k(\lambda)$  [or  $e1(\lambda)$ & $e2(\lambda)$ ] spectra show up in the Graph section; right-mouse-button click on at any point within the Graph area, a menu showing up; choose **Copy Data to Clipboard**; open Microsoft Excel file; paste the data into a spreadsheet; save the spreadsheet data into an Excel file.
- 15) If a film is deposited on a double-side-polished substrate, you need to do a correction to reduce the error caused by the backside-reflection (see Figure 3 below for a reference): click on the red plus sign beside **MODEL Options** in the Model section; click on the blue **OFF** sign of **Include Substrate backside Correction=OFF** to turn the correction on (the blue **ON** sign showing up); click on the **Configure Options** at the bottom of the Model section: a frame showing up; choose **Include Depolarization Data** by clicking on the small square empty box (a tick showing up) in the **Available Options** list under **Fit Options**, then, hit **Ok** tab; click on the red plus sign beside **Fit Options** in the Model section; click on the **OFF** sign of **Include Depolarization Data=OFF** to turn the function on (the blue **ON** sign showing up).

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16) Save the data as well as fitting result in a Snapshot file for a later-on analyses: click on the **Save Snapshot** tab at the top right of screen, the Save Snapshot frame showing up; choose your file directory, type a file name, and click on the **Save** tab (you can click on **Open Snapshot** tab to open the snapshot file for later-on analyses).

17) When you done, switch the vacuum off, remove your sample off the stage, and, most importantly, **Turn Lamp Power off** to save the lamp lifetime.

18) Let me know if you have some issues (**Ning Cao, 805-893-4689 or ningcao@ece.ucsb.edu**).

Figure 1 How to get the optical constants at the wavelength(s) you are interested.

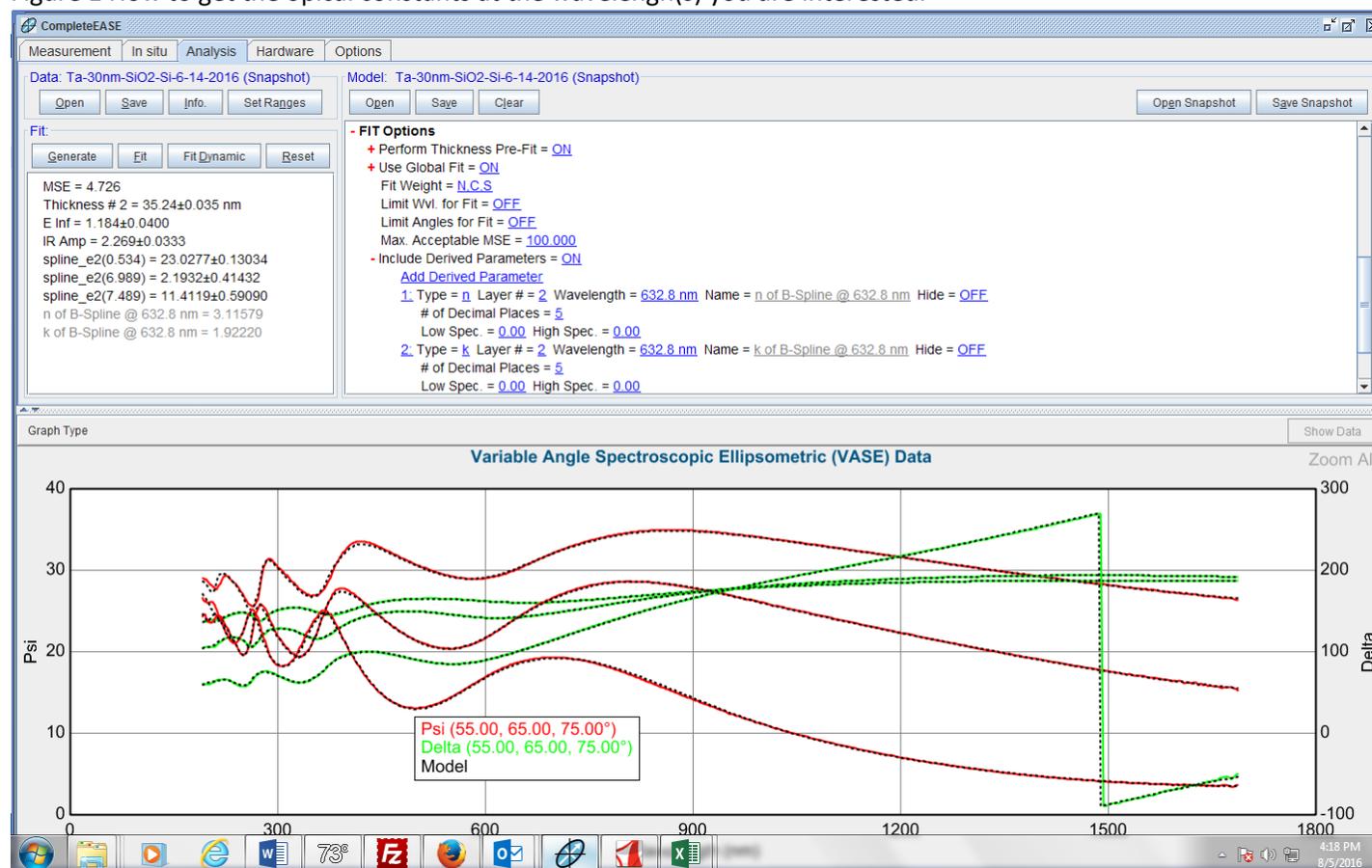


Figure 2 How to get the optical constant spectra  $[n(\lambda)&k(\lambda)$  or  $e_1(\lambda)&e_2(\lambda)]$ .

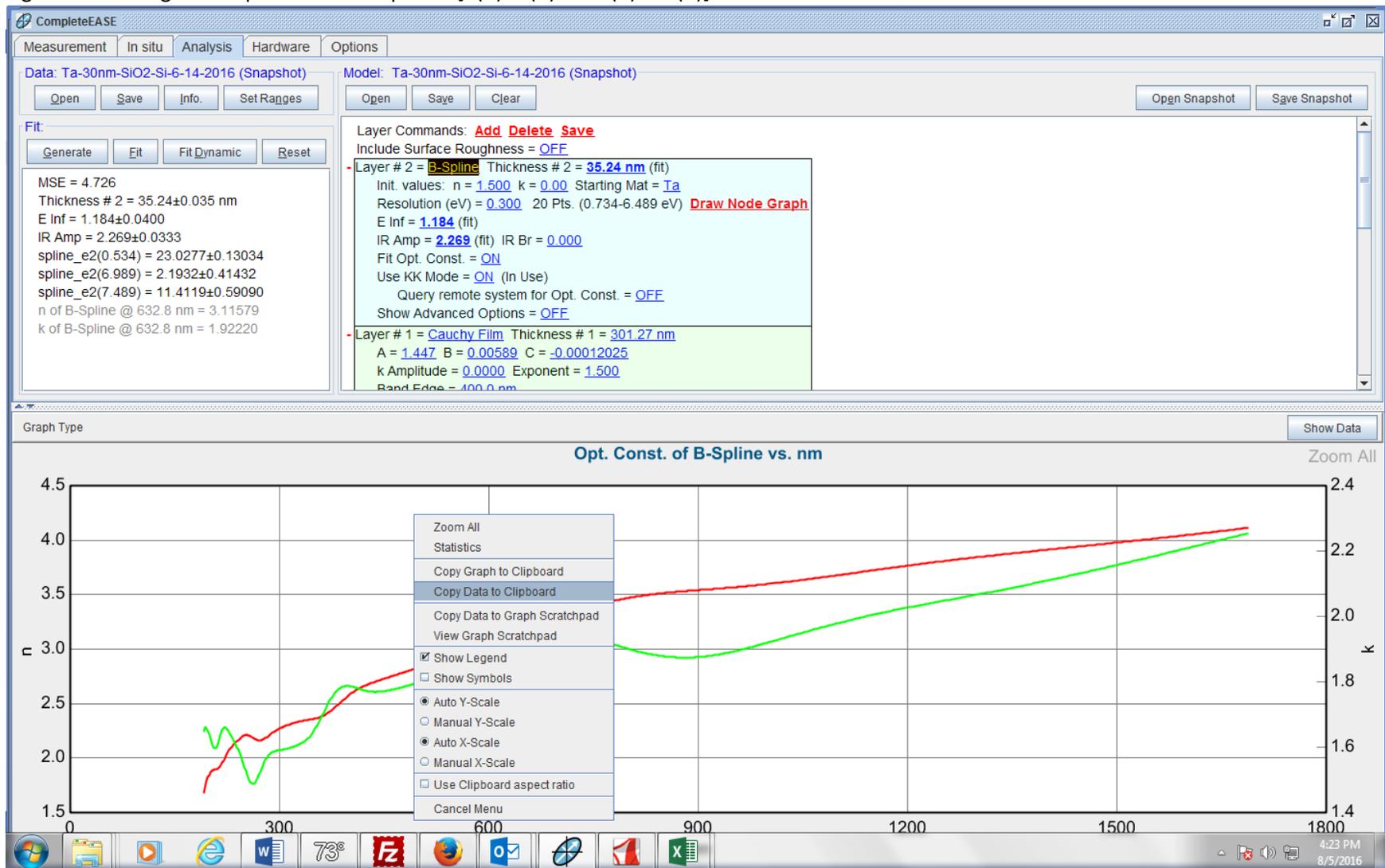
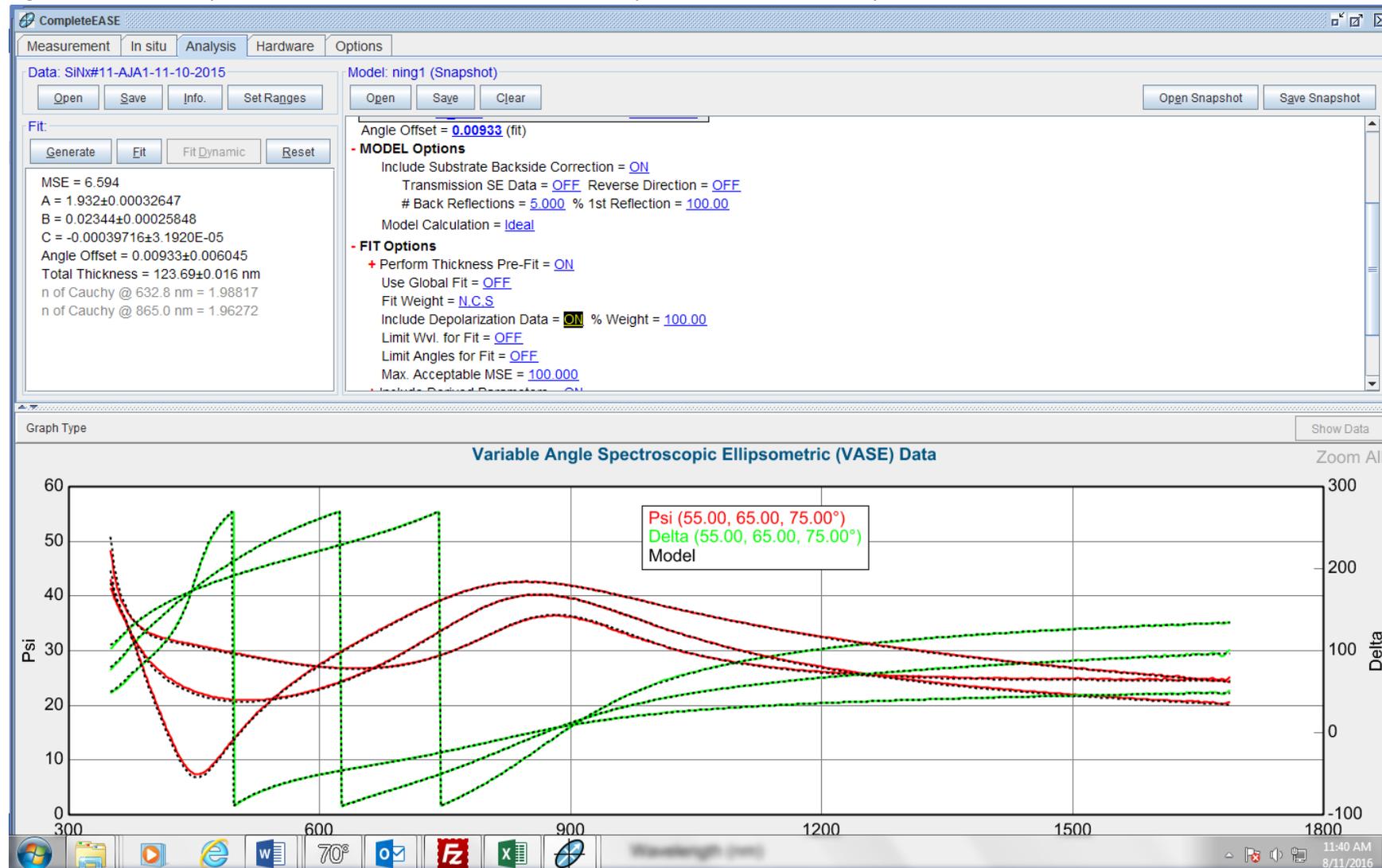


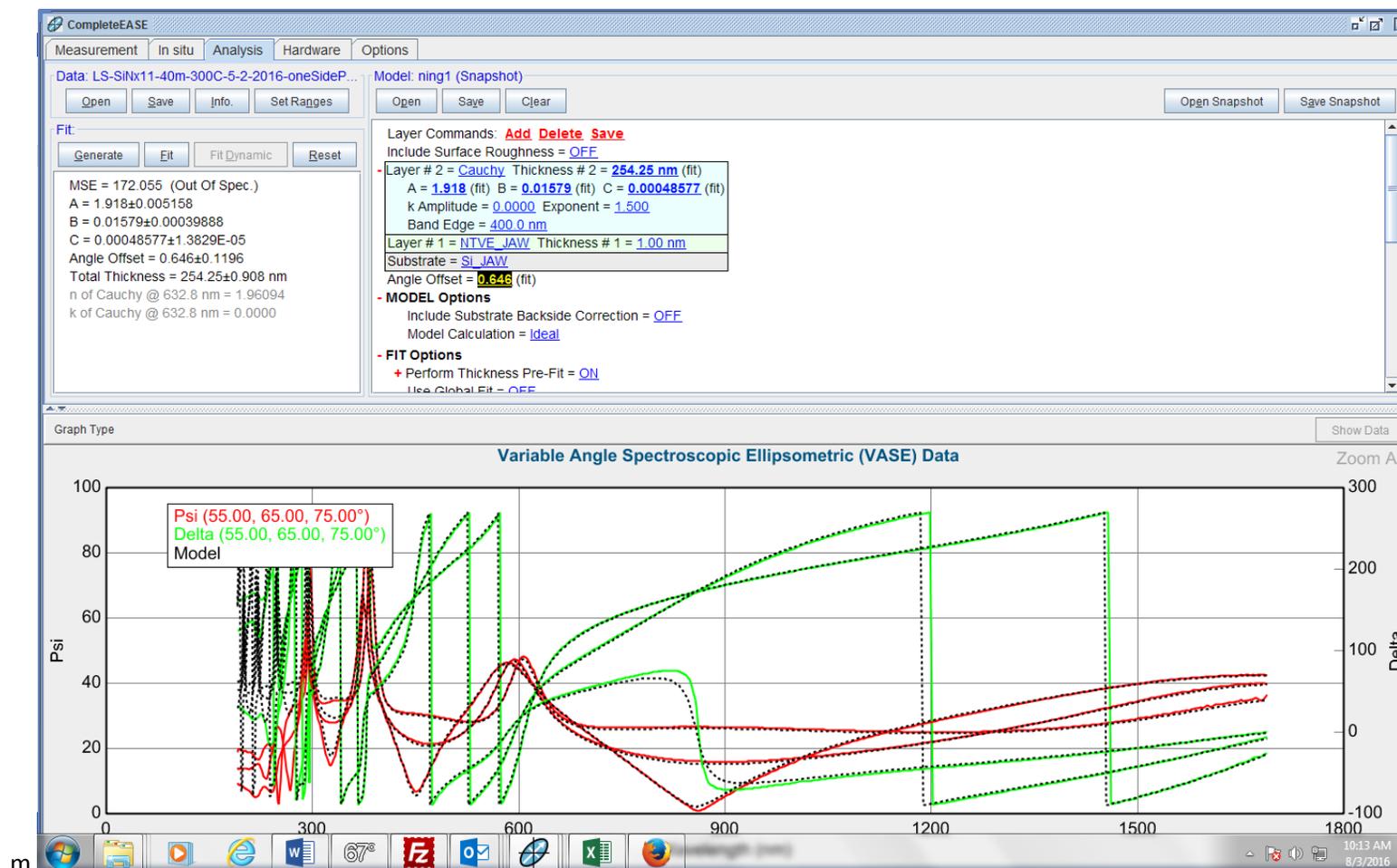
Figure 3 How to set up Backside Reflection Correction for a film deposited on a double-side polished substrate.



### Examples:

**Example A:** a low-stress (LS) SiNx film on a one-side polished Si substrate. Fitting the data using Cauchy mode,  $n(\lambda) = A + B/\lambda^2 + C/\lambda^4$ , where A, B, C as well as film thickness are the fitting parameters.

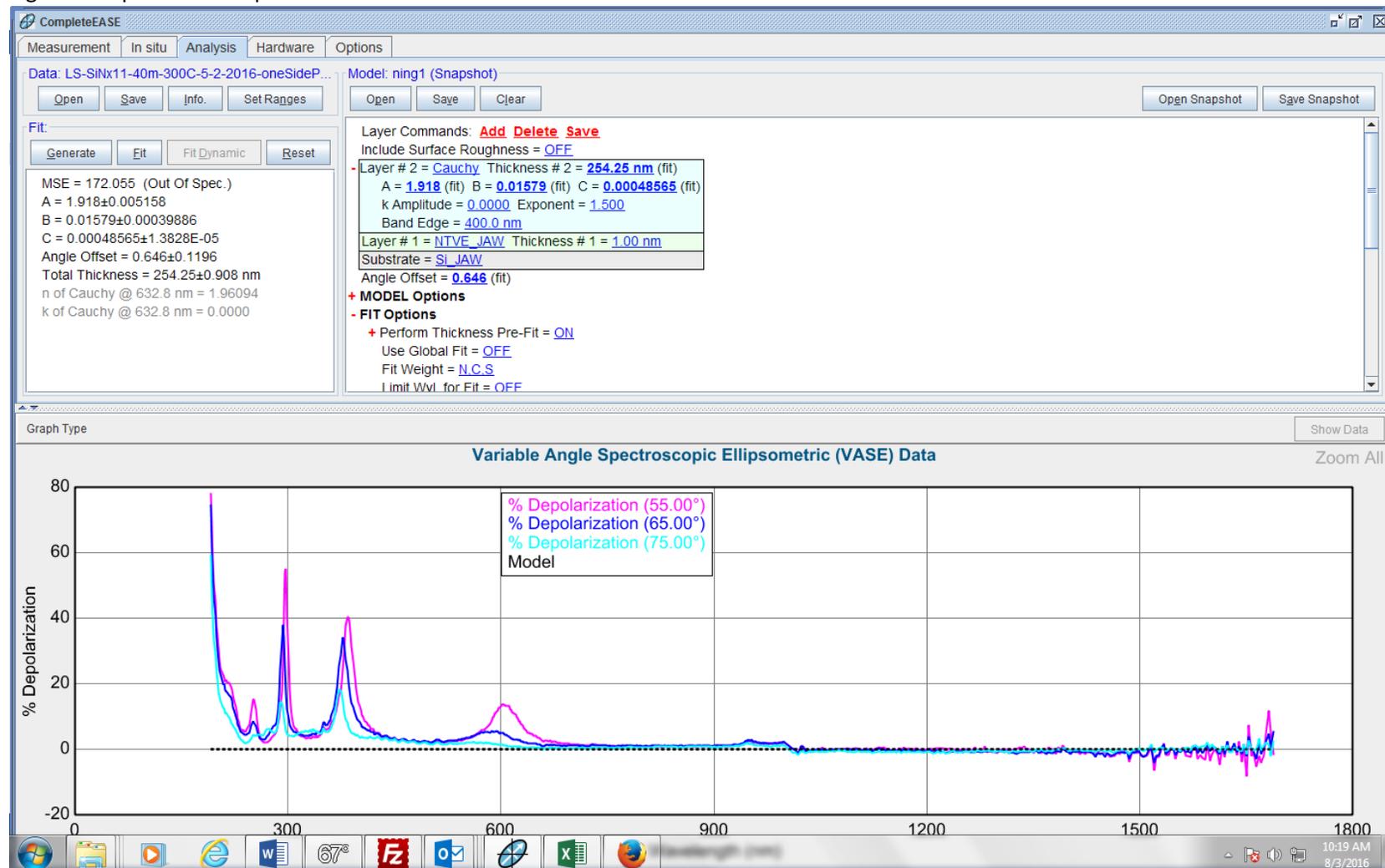
Figure 4 Shows the fit result of the LS SiNx ellipsometry data: film thickness=254.25 nm and MSE= 172.055 with the fit range between 190 and 1688 nm.



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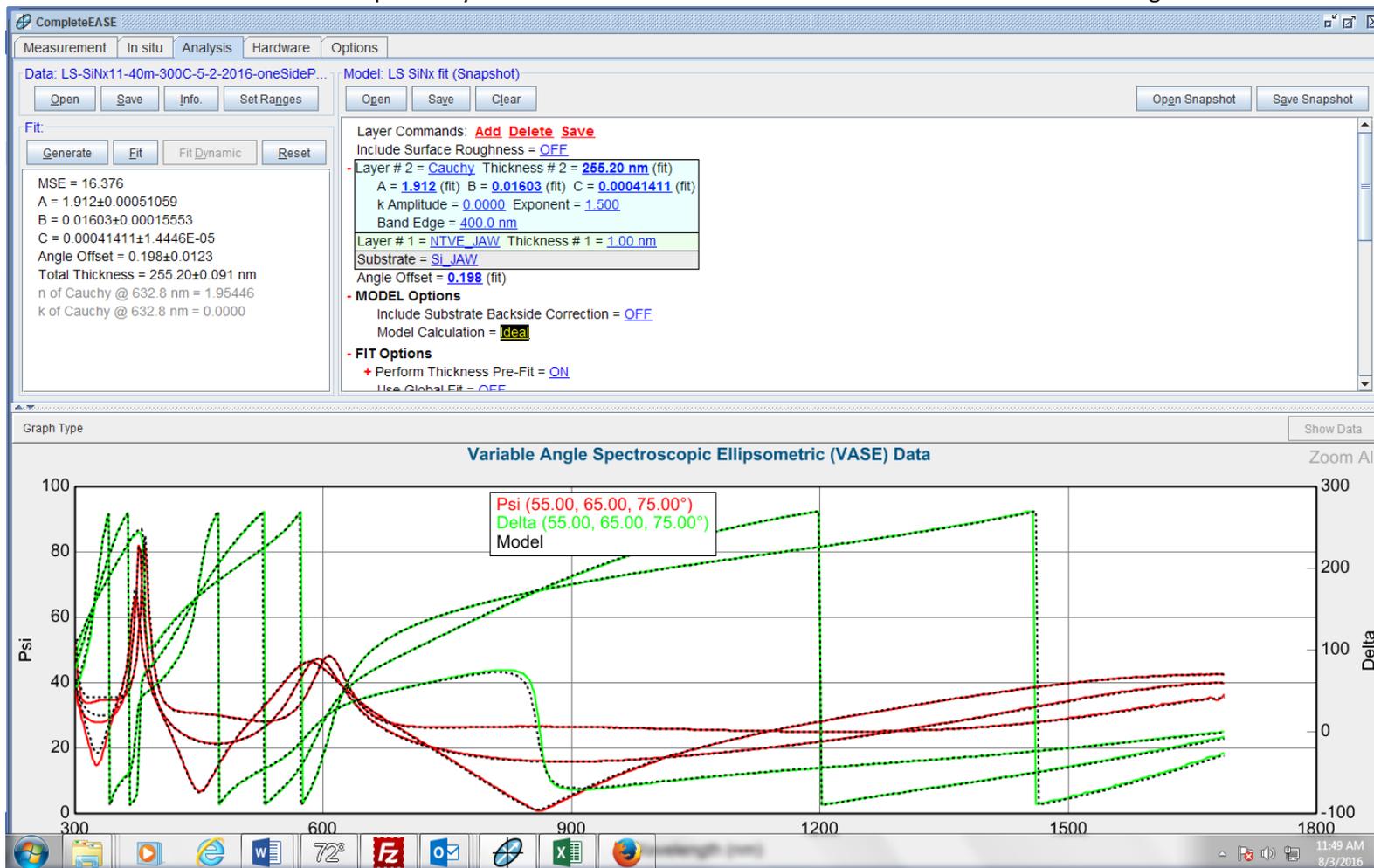
The MSE value (172.055) is too large which is due to the fitting at lower wavelengths is poor. This can be checked out by the Depolarization spectrum [click on **Graph Type** menu in the middle left of screen, then, **Depolarization** (see Figure 5 below)]. The depolarization at low wavelengths is not ideal: there are several peaks, especially, the two big ones below 300 nm.

Figure 5 Depolarization spectrum of the LS SiNx film.



What you can do to get a better fit with a much smaller MSE value is to reset the fit wavelength range: in this case, to reset the range to between 300 and 1688 nm (see the result in Figure 6 below), then, fit the data curves again. The new fit result is much better with a MSE value of 16.376.

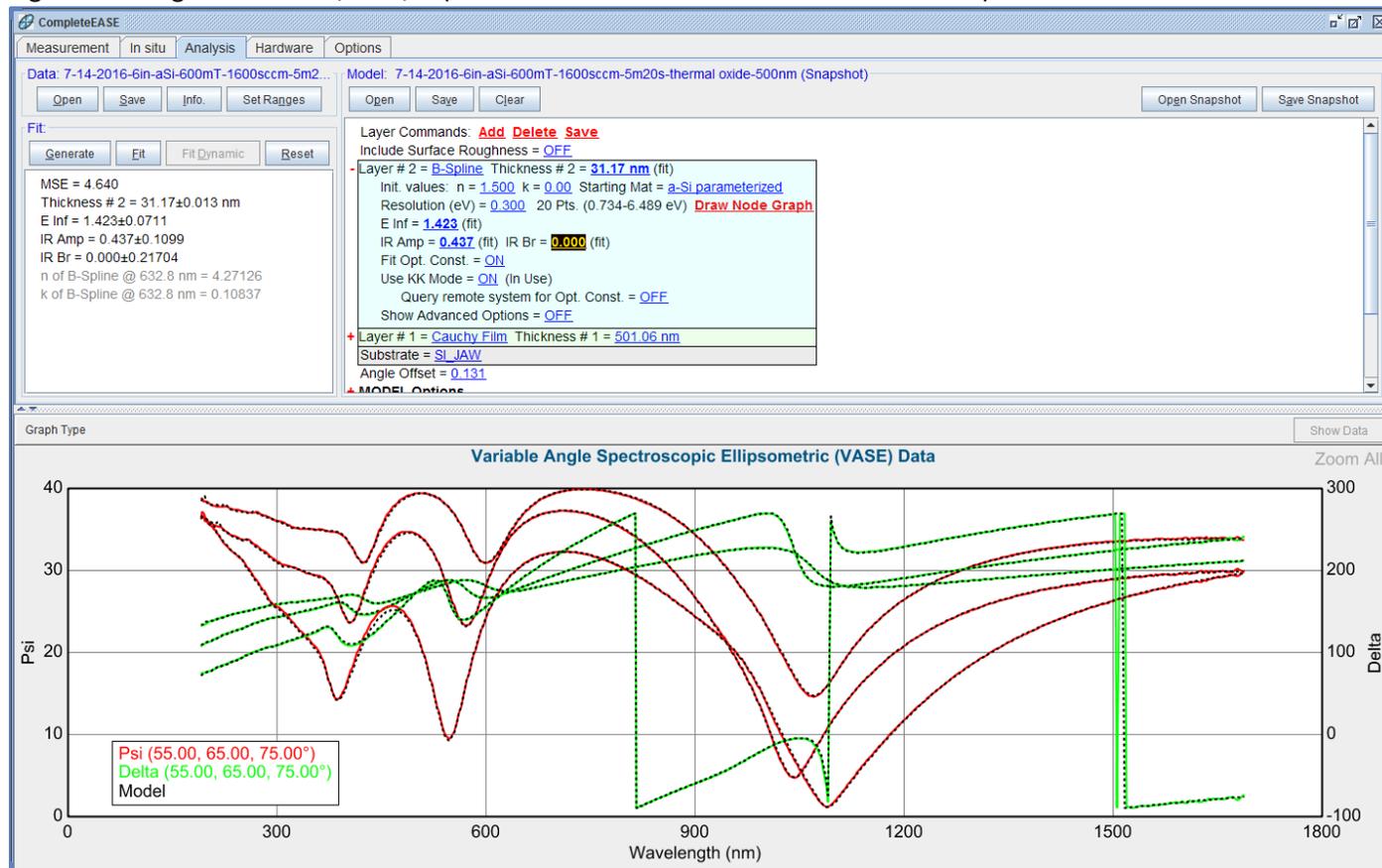
Figure 6 Shows the fit result of the LS SiNx ellipsometry data: film thickness=255.20 nm and MSE= 16.376 with the fit range between 300 and



1688 nm.

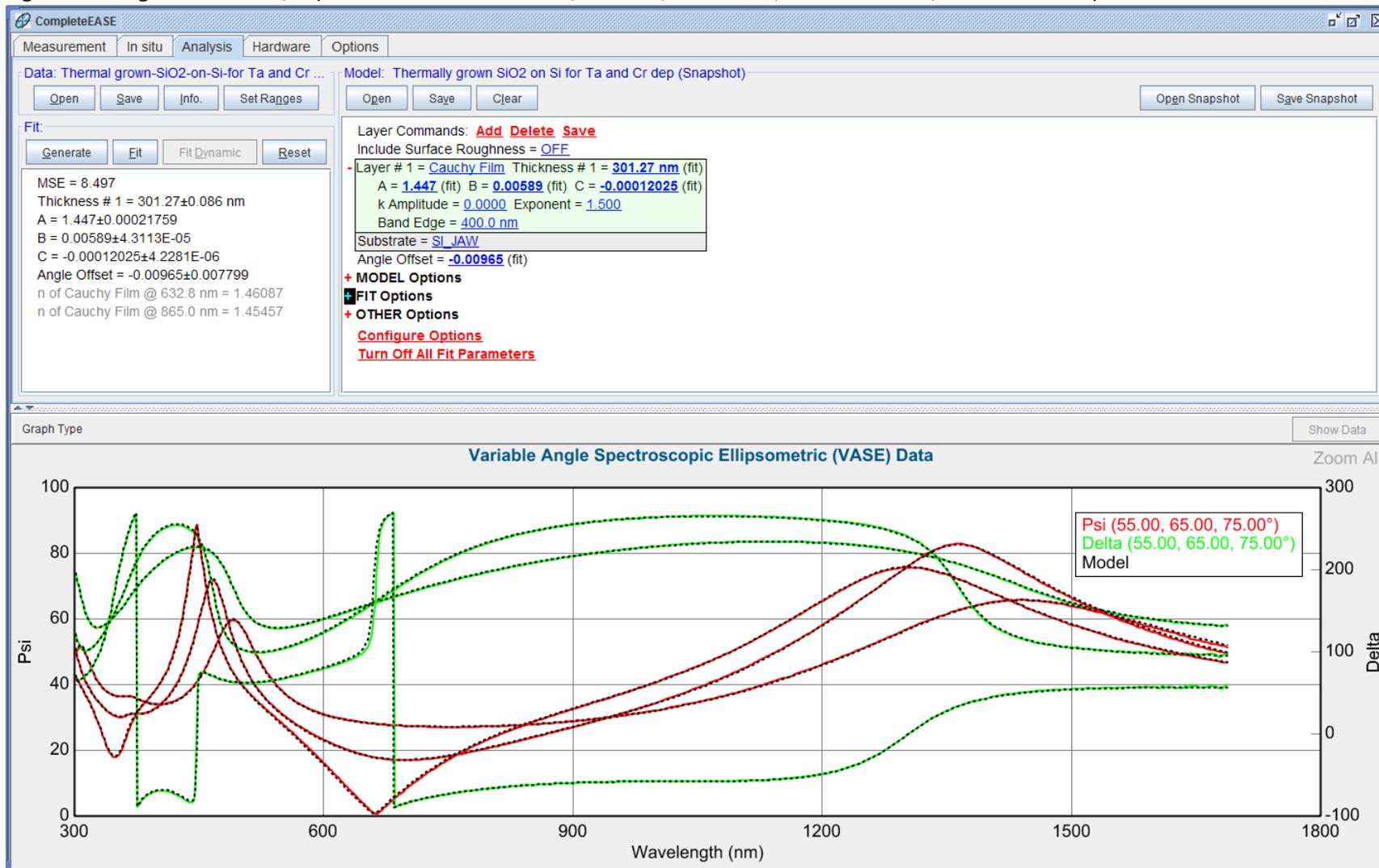
**Example B:** Amorphous Si film, deposited using PECVD#2, on a 500-nm thermal SiO<sub>2</sub> (just called SiO<sub>2</sub> below)/one-side polished Si substrate: 1) Taking the measurement of SiO<sub>2</sub>/Si, fitting the data using Cauchy model, and saving it into a Snapshot file; 2) Depositing a-Si film on the SiO<sub>2</sub>/Si substrate and measuring the Psi and Delta spectra of a-Si/SiO<sub>2</sub>/Si, and save into a SE file; 3) opening the Snapshot file of SiO<sub>2</sub>/Si, fixing all the fitting parameters of the first SiO<sub>2</sub> layer as well as Angle Offset value in the model, and **opening the SE data file of a-Si/SiO<sub>2</sub>/Si**; 4) Adding the second layer with B-Spline model for a-Si to the model; 5) loading the **a-Si Parameterized** file from Semiconductor directory into the Starting Mat and turning **Use KK Mode** on ; 6) Fitting the a-Si/SiO<sub>2</sub>/Si data with this modified model to get the result (see Figure 7 below): a-Si film thickness of 31.17 nm (MSE=4.460).

Figure 7 Fitting result of a-Si/SiO<sub>2</sub>/Si (a-Si film thickness =31.17 nm and MSE=4.640).



**Example C:** Cr/Ta/thermal SiO<sub>2</sub> (just called SiO<sub>2</sub> below) on one-side polished Si substrate: 1) Taking the measurement of SiO<sub>2</sub>/Si, fitting the data using Cauchy model (see Figure 8), and saving it into a Snapshot file.

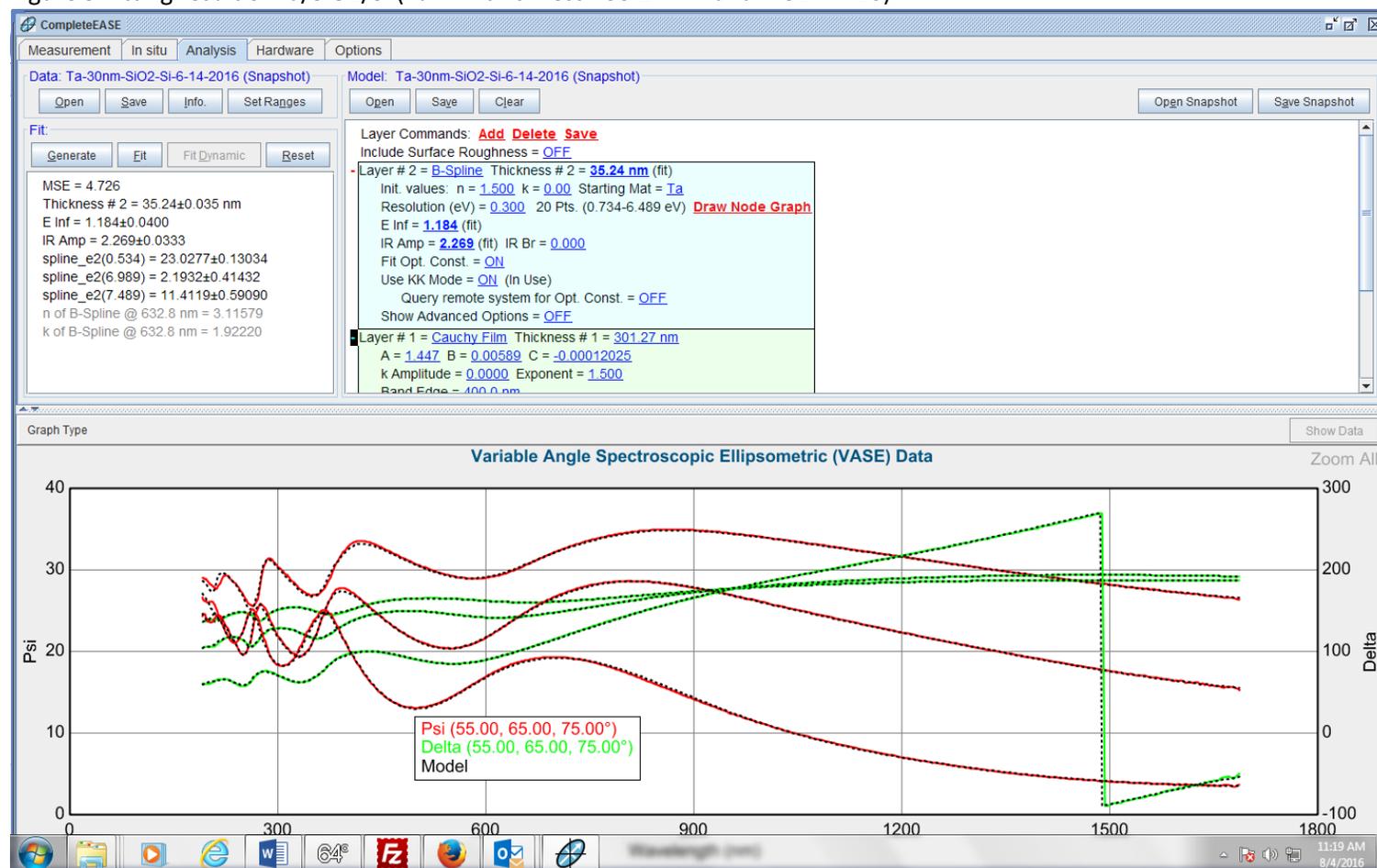
Figure 8 Fitting result of SiO<sub>2</sub>/Si (film thickness =301.27 nm, A=1.447, B=0.00589, C=-0.00012025, and MSE=8.497).



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2) Depositing a thin Ta film (the target film thickness is 30 nm) onto the SiO<sub>2</sub>/Si substrate. Then, taking the ellipsometry measurement of Ta/SiO<sub>2</sub>/Si and saving the data into a SE data file. Then, opening the previous Snapshot file of SiO<sub>2</sub>/Si with the SiO<sub>2</sub>/Si data curves, and **opening the Ta/SiO<sub>2</sub>/Si SE data file**. Then, editing the model by adding the second layer with a B-Spline model for the Ta film, loading the **Ta** file from the metal directory into Starting Mat and turning **Use KK Mode** on, fixing the fitting parameters of the first layer (SiO<sub>2</sub>) as well as the Angle Offset value. Finally, fitting the Ta/SiO<sub>2</sub>/Si data curves using this modified model, and saving it into another Snapshot (see Figure 9 below).

Figure 9 Fitting result of Ta/SiO<sub>2</sub>/Si (Ta film thickness =35.24 nm and MSE=4.726).



3) Depositing a thin Cr film (the target film thickness is 30 nm) onto the Ta/SiO<sub>2</sub>/Si substrate. Then, taking the ellipsometry measurement of Cr/Ta/SiO<sub>2</sub>/Si and saving the data into a data file. Then, opening the previous Snapshot file of Ta/SiO<sub>2</sub>/Si with the Ta/SiO<sub>2</sub>/Si data curves, and **opening the Cr/Ta/SiO<sub>2</sub>/Si data file**. Then, editing the model by adding the third layer with a B-Spline model for the Cr film, loading the **Cr (Lorentz)** file from the metal directory into Starting Mat and turning **Use KK Mode** on, fixing the fitting parameters of the second layers (Ta). Finally, fitting the Cr/Ta/SiO<sub>2</sub> data curves using this modified model, and saving it into a Snapshot (see Figure 10 below).

Figure 10 Fitting result of Cr/Ta/SiO<sub>2</sub>/Si (Cr film thickness =34.85 nm and MSE=2.310).

