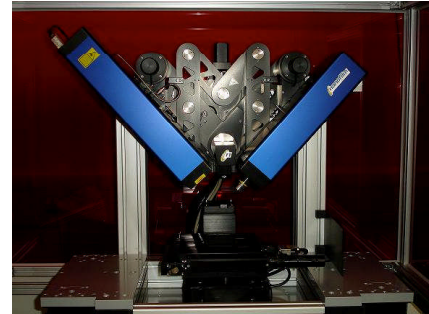


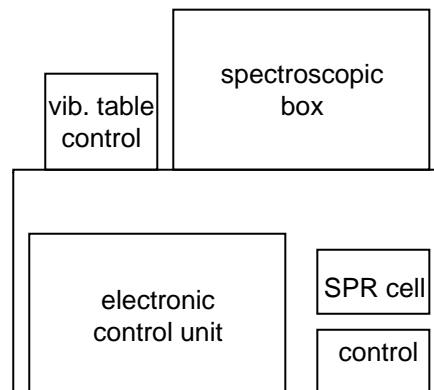
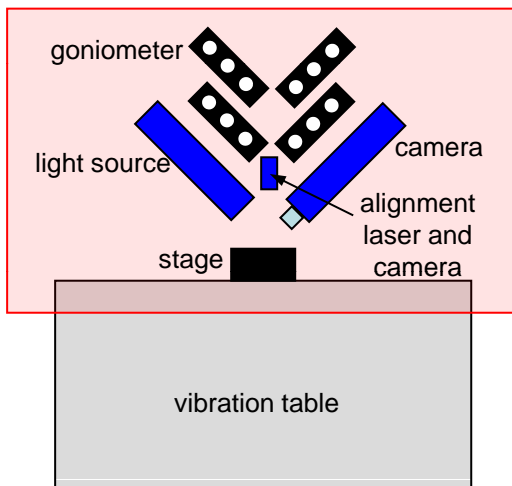
# Ellipsometer user guide

Lab C103a, Door code 3886

Contact: Ben Douglas, A112, x22183



laser safety cabinet



## Contents

1. Switch on
2. Sample setup and imaging
3. Single measurement
4. Angle of incidence scan
5. Wavelength scan
6. Other measurements
7. Modelling
8. Switch off
9. Appendix

# 1. Switch on

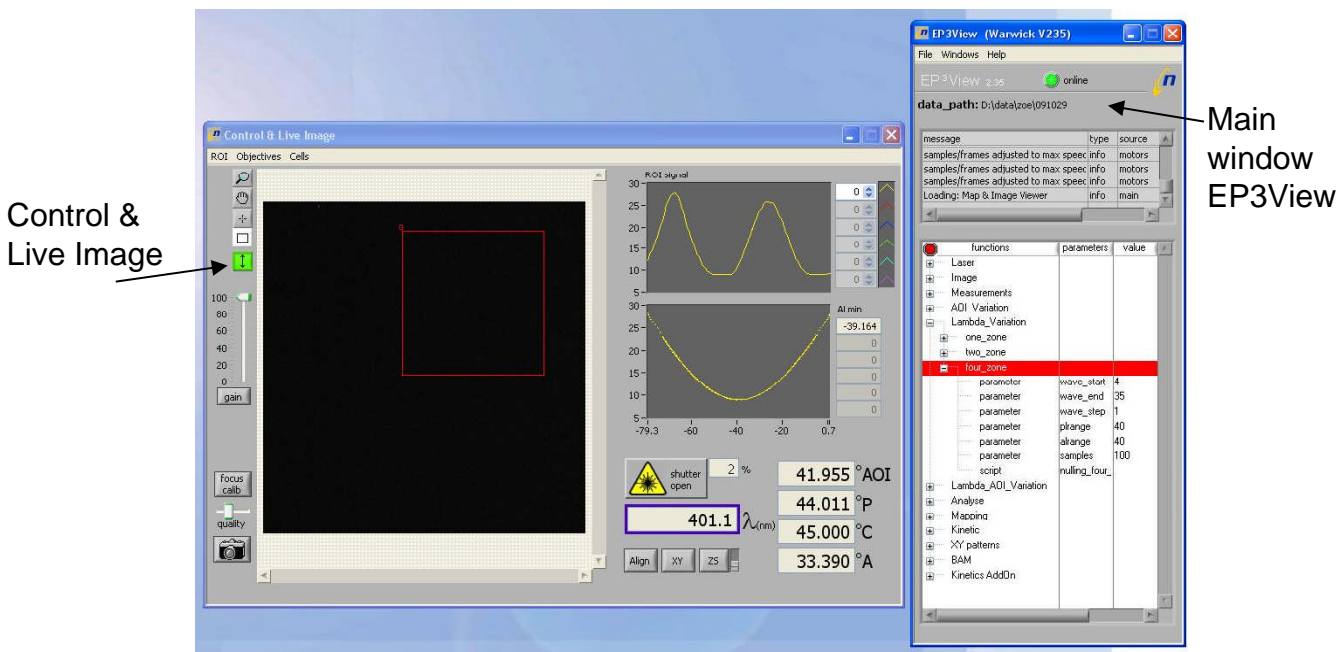
Turn on electronic control unit (using key on front; if blue light does not come on check switch on back).

Turn on vibration table.

Turn on spectroscopic box.

Turn on pc; username *electrochemist*, password *dalton*.

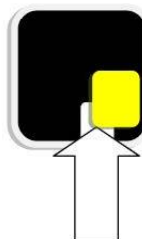
Start EP3 software, click *login*; instrument will initialise. Wait until noises have stopped and a *Control & Live Image* window has opened.



# 2. Sample setup and imaging

Place sample on stage so that sample is under alignment laser dot (red); use a piece of white paper to help if you cannot see the dot on your sample.

Transparent substrates go over the cut-out:



Close cabinet (interlocked to laser shutter).

**PC:** In the main control window *EP3 View* use *File* → *Change data path* to chose the folder where you would like to save your data to, then click on *select current directory*.

## PC: Control & Live Image window

**Align sample** – this process uses the alignment laser and camera to ensure the surface of your sample is level.

Click *Align*; alignment window pops up and view switches to alignment camera.

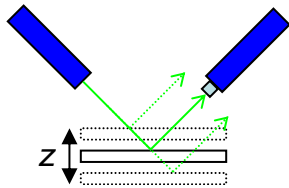
If spot is visible, click *auto align* in pop up window.

(If spot is not visible, drag cross-hairs in alignment window around until it is in view, then click 'auto align'.

If you cannot find the spot, it may be because of your sample. You can align on something else and hope your sample is similarly level!)

Close alignment pop up window.

## Set z height



Click on wavelength box to select laser incident light, then open the shutter.

You can change the z position of the stage (S) or goniometer (G). Start with the stage and use the goniometer if you need more movement. Select ZS or ZG and click on z button. Move up or down (note that the controls are reversed with respect to the real movement) to find the peak intensity of the laser light – watch the ROI trace in the top right graph. This should be quite bright at fairly low laser power (~5% depending on sample) and moderate gain; adjust these if necessary. If you have a transparent sample the peak intensity will not be so obvious.

Repeat the alignment (see above).

## Imaging

Select the *550.2 bright(45)* wavelength by clicking on the wavelength number, choosing it from the list, then closing the window.

Rotate the polariser by clicking on the *P(°)* number, entering a new value (try  $-50^\circ$ ) and closing the pop up window. Change the gain if necessary to find a bright image.

Move in x and y by clicking on the appropriate buttons to find an area of interest to image. Click on 'focus calibration'.

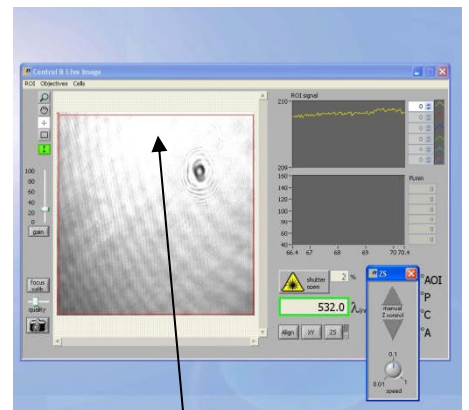
Use the lower slider or up/down cursors whilst in the number box (the digit to the left of the cursor is changed) to focus on something on your sample – a bit of dust for example.

Use the upper slider to mark the position of sharp focus in your image.

Close the window.

Click on the camera icon to capture an image. You can alter the resolution using the slider above it. A scan is performed so that the whole of your image will be in focus, using the calibration that you just carried out.

In the *EP3 View* window, go to *Window* → *Map & Image Viewer* to see image. It can be saved from here in various formats (they are not saved automatically).



Peak intensity of laser spot; in this example more z movement is required

### 3. Single measurement

#### **Control & Live Image window**

Chose a region of interest (ROI) by clicking on the box symbol and clicking and dragging to draw a box. For multiple ROIs, hold down shift and then click and drag.

In the *EP3 View* function tree, double click on 'coarse adjust' under 'measurement'. The instrument rotates the polariser and analyser to find an approximate position of null intensity.

Double click on one, two or four zone nulling. There are four positions of the polariser (P), compensator (C) and analyser (A) that give a null value. Four zone finds them all but takes longest.

If you see an error message in red text in the main window 'minimum not found', you may have to try a smaller/more homogeneous ROI, or increase the plrange and/or arange parameters in the function tree.

#### **Log editor**

In the *EP3 View* window go to *Window* → *Log Editor*. Your results appear in a table as values of  $\Delta$  and  $\Psi$  along with Angle of Incidence (AOI), wavelength, P, C, and A values.

### 4. Angle of incidence scan

To collect more data you can do a one, two or four zone nulling at a range of angles. Go to *AOI variation* in the *EP3 View* function tree, and chose one, two or four. Select the angle range and step size you wish to scan – the available range is about 38 to 80° – right-click on the parameter to change it. Double click on one (two or four) zone to run the scan; a graph window opens automatically and displays the data as it is collected. Data can be saved from this window (this is useful to do).

### 5. Wavelength scan

Data analysis on a wavelength scan may be more complicated, because the refractive index of the sample may vary with wavelength.

Go to *Lamda variation* in the *EP3 View* function tree, and chose one, two or four. Select the wavelength range you wish to scan – these are defined by the numbers which are used in the wavelength box in the *Control & Live Image* window – right-click on the parameter to change it. A step size of one will use every wavelength listed in the range. Double click on one (two or four) zone to run the scan as before.

|            |                     |
|------------|---------------------|
| 360.0 (0)  | 659.6 (26)          |
| 370.0 (1)  | 681.1 (27)          |
| 380.7 (2)  | 689.9 (28)          |
| 390.1 (3)  | 711.0 (29)          |
| 401.1 (4)  | 719.8 (30)          |
| 411.6 (5)  | 740.0 (31)          |
| 421.0 (6)  | 761.3 (32)          |
| 431.4 (7)  | 768.8 (33)          |
| 440.2 (8)  | 789.3 (34)          |
| 450.5 (9)  | 811.3 (35)          |
| 460.3 (10) | 829.9 (36)          |
| 471.3 (11) | 849.7 (37)          |
| 480.9 (12) | 870.4 (38)          |
| 491.4 (13) | 881.4 (39)          |
| 500.7 (14) | 906.6 (40)          |
| 510.3 (15) | 921.1 (41)          |
| 521.3 (16) | 952.0 (42)          |
| 531.9 (17) | 969.8 (43)          |
| 546.6 (18) | 1001.1 (44)         |
| 560.1 (19) | ✓ 550.2 bright (45) |
| 571.1 (20) | 1.0 white (46)      |
| 590.8 (21) | 0.0 black (47)      |
| 601.6 (22) | 532.0 532Laser (48) |
| 610.9 (23) |                     |
| 630.1 (24) |                     |
| 640.3 (25) |                     |

## 6. Other measurements

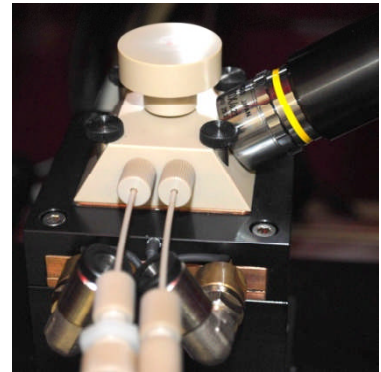
If more data is required a combined AOI/wavelength scan can be carried out. This is accessed through the *EP3 View* function tree as before. The instrument can also be used to measure the Brewster angle of a material, *i.e.* the angle of incidence at which the reflected and refracted light directions are at  $90^\circ$  to each other.

A solid-liquid cell is available, allowing data to be collected from a surface under a solution.

To use this, select *sl cell 60 degree* in the *Control and Live Image* window.

The sample is aligned before adding the solution (remove the stopper from the top of the cell). The *x-y* position can be found by replacing the stopper and moving the stage so that the alignment laser spot is in the centre of the top of the stopper. Focus should be around 15,000 – 16,000. The *z* position is set as before. The objective is very close to the cell in this measurement, so take care not to make and fast stage movements which could cause a collision.

The cell can then be filled with the solution and the data collection started.



# 7. Modelling

Ellipsometry measures  $\Delta$  and  $\Psi$ , but these are not much use as they are. To obtain information on your sample such as thickness or refractive index, you create a model of your system which the software then fits to your data.

## Open EP4Model

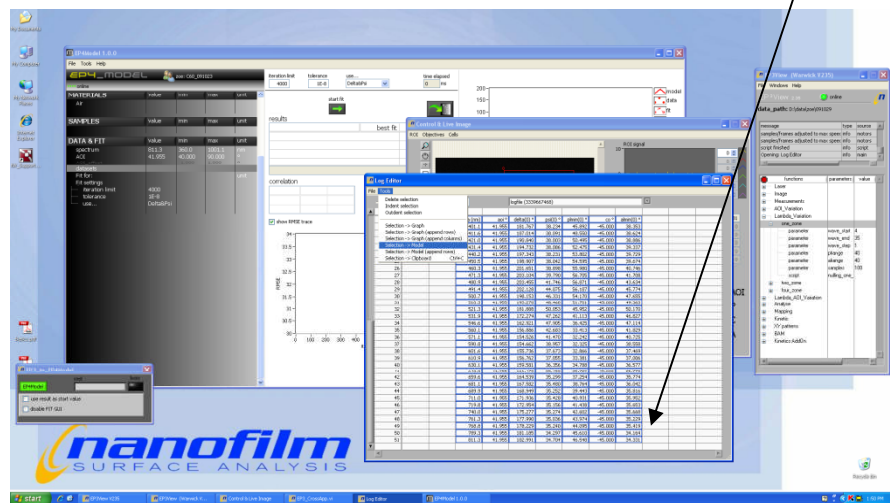
Click on the 'people' icon to choose user and enter a session name. This is where the software will automatically save files.

## Transfer your data to EP4Model

EP3View window, *Window* → *Log Editor*

Select data by clicking on the first cell of your data, holding down shift, then on the final cell.

*Tools* → *Selection* → *Model*



If this does not work, data can be imported from EP4Model using *Tools* → *Data from table*. Select the file that contains your data (e.g. as saved from the graph window during data collection); check the column heading are correct and remove any blank rows before importing.

## EP4Model

This contains three sections: *Materials*, *Samples* and *Data & Fit*.

### Materials

Here you add descriptions of all the components of your sample, which may be predefined dispersion data or functions, e.g. air for ambient or Si for substrate, or may be a substance which is user-defined.

Right-click in the space under *Materials* to *load material* for a pre-defined substance, or *create material* to define your own (you can then right-click to rename it).

### Samples

Here you describe your sample. *Right-click* → *create sample*. You can add extra layers if required. *Right-click* on each component to choose its identity from your *materials* list. Thickness values can be edited by clicking on them.

### Data & Fit

Here you associate data sets with samples, and add or remove parameters from the fit. Right-click on the data set and choose *bind to sample* to associate it with your sample.



## Modelling procedure

You need to choose which dispersion function to use to describe your material if it has not been loaded from the software's database, and which parameters to fit. *Materials* → *Right-click* on material to describe → *add term* and choose a model (see appendix).

*Data & Fit* → *Right-click* on fit parameters to choose what to include in the fitting process. If they are not included they will be fixed at the values displayed in the *Materials* or *Samples* tables.

You can observe the effect of changing a parameter by clicking on it and using the slider.

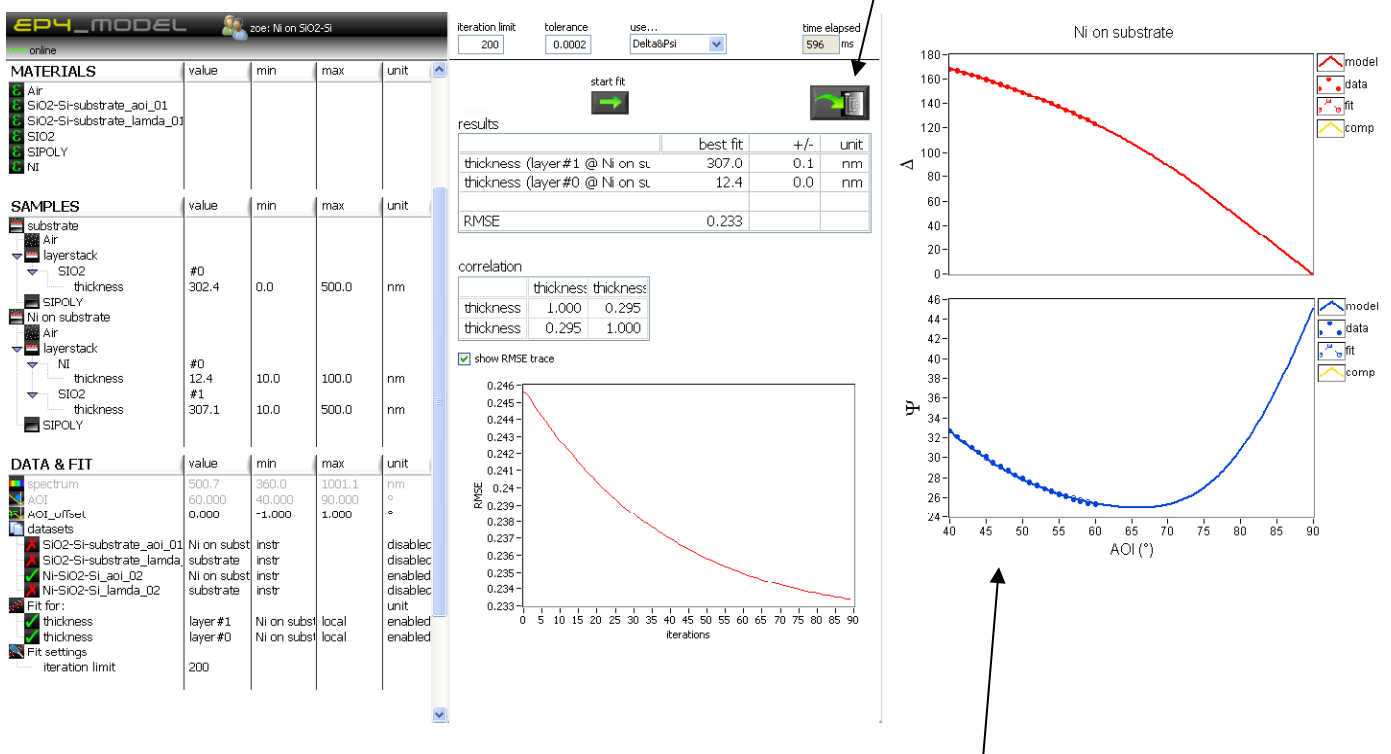
Here you can also set a value and change the limits.

Click on start fit. If the process is successful, values and errors are displayed below, along with a correlation table and a RMSE (route mean square error) plot (< 3 is considered good).

Your session should be saved in your folder (worth checking!). You can also save a screenshot as you go.

### Example of Ni film on SiO<sub>2</sub>/Si substrate:

Click here to update values in model with the fit results



Data are shown as solid points

The open points and dashed line represent the results of the fit

The solid line represents current settings of the fitted parameters

## Measuring data on a blank substrate

It is possible to collect data from your substrate and use this in the modelling procedure. This may be useful if you are doing wavelength scans, where the  $n$  and  $k$  values of the substrate are not constant, and you are using a non-standard material.

Collect a data set from the substrate covering a wide wavelength range. Import the data into *EP4Model*, then use *Tools* → *Open vi*. Browse to `program\tools\Covert_DeltaPsi_to_effectiveSubstrate.vi` and open. Click on *run* (arrow icon), then select your data set and click *convert now*. You must save the resulting file in `C:\Program Files\Accurion\EP4Model\Dispersions` (should be the default folder) in order to use it – include your initials/name in the file name to avoid overwriting any of the existing files.

Measure data from your sample, and you can use your substrate file by right-clicking in the *Materials* section and using *load material*.

## 8. Switch off

Remember to copy any files you want to take away with you.

Exit software and shut down computer.

Turn off boxes in reverse order to switch on: spectroscopic box, vibration table, electronic control unit.

Remove sample and close cabinet doors.



## 9. Appendix

### Dispersion functions

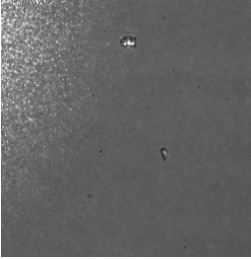
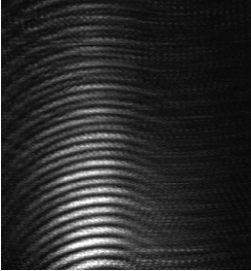

Useful reference: 'Handbook of Ellipsometry', H. G. Tompkins and E. A. Irene Eds., p 252 (available in the library or copy in A112).

|                     |  |
|---------------------|--|
| n_k_fix             | Fixed values of $n$ and $k$ , for AOI scans  |
| eps_fix             | Fixed $\varepsilon$ (equivalent to above)  |
| Cauchy              | For polymers, glasses, organics, etc $k = 0$ , $n = A + B/\lambda^2 + C/\lambda^4 + \dots$                           |
| Cauchy_Urbach       |  |
| Sellmeier           | Development of Cauchy function   |
| Lorentz             | Original oscillator function, $k > 0$  |
| Tauc_Lorentz        | Amorphous materials  |
| Tauc_Lorentz_Urbach |  |
| Cody_Lorentz_Urbach |  |
| Fourrhi_Bloomer     | Amorphous materials, $k > 0$   |
| Drude               | Metals   |
| Blending            |  |
| EM_linear           | 'Effective medium': models the layer as a host-guest system, %guest can be fitted. Assumes homogeneous distribution. |
| EM_Lorentz_Lorentz  |  |
| EM_Bruggmann        |  |
| EM_Maxwell_Garnett  |  |
| EM_linear_(3)       |  |

### Abbreviations and acronyms

|     |   |
|-----|---|
| AOI | Angle of incidence                              |
| ROI | Region of interest                              |
| P   | Polariser                                       |
| C   | Compensator                                     |
| A   | Analyser  |
| NaN | Not a number (error, probably dividing by zero) |

## Troubleshooting

| Problem   | Solution   |
|---|--|
| <p>Light patch in image</p>                              | <p>Turn off alignment lamp in function tree → laser</p>  |
| <p>Sample not visible, interference seen with laser</p>  | <p>Sample z-position is probably way off. Try moving a long way in z while watching for collision with camera.</p>                         |
| <p>Data not transferring to EP4Model</p>  | <p>Save data from the graph window when collection has finished. This can be imported into the modelling software ('data from table').</p> |
| <p>Captured image not in focus throughout</p>   | <p>Check the Objectives menu in the Control and Live Image window- it should be set to x10.</p>  |
| <p>Objective incorrectly located (may be a result of a collision with sample stage)</p>   | <p>Can be repositioned – ask for assistance.</p>      |