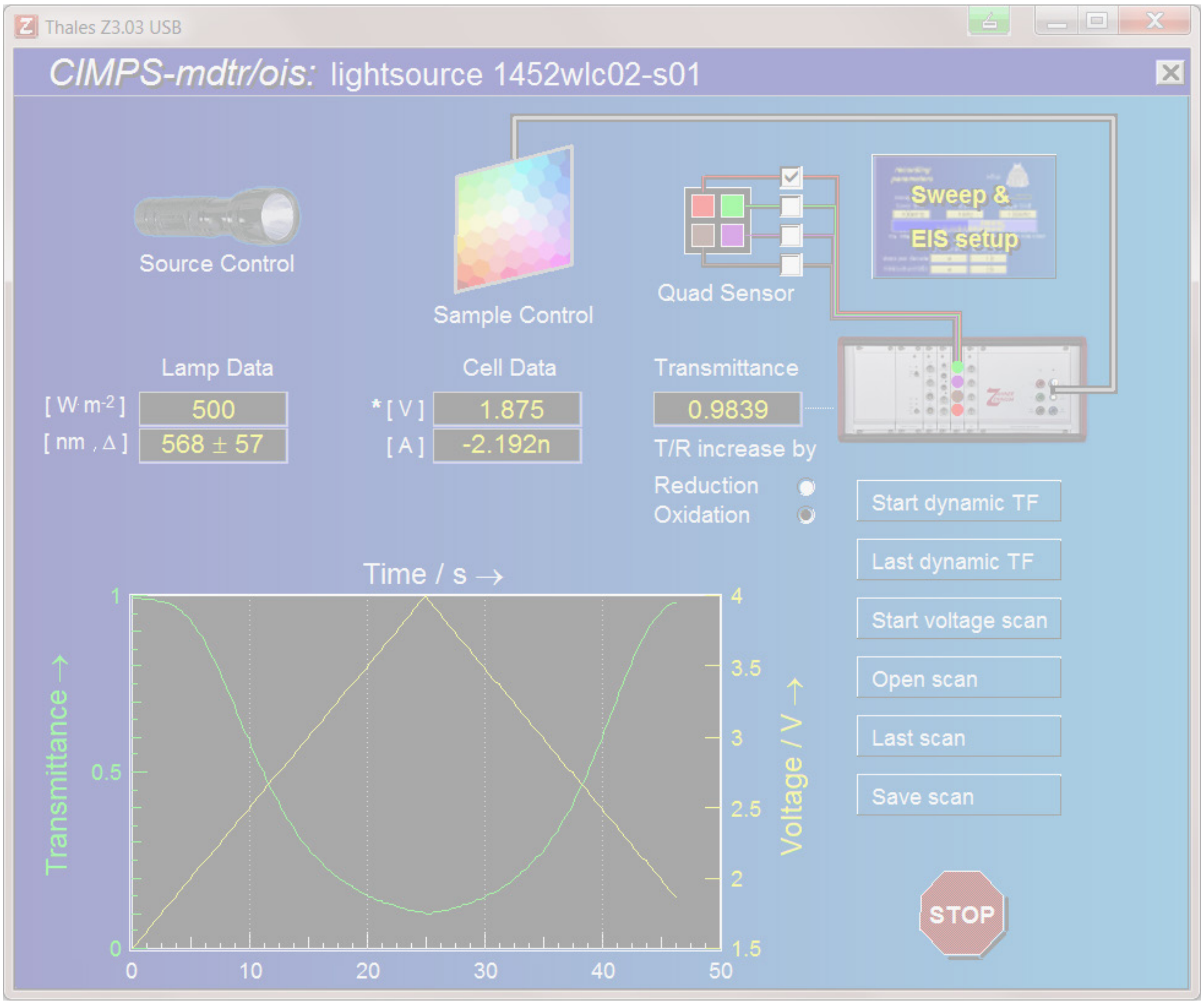
CIMPS-mdtr/ois

Synchronous Multi Spectral Dynamic Transmittance / Reflectance Measurements



1. Introduction

Some physical systems change their optical properties under the influence of an electrical voltage or current applied. Such behavior is of high scientific interest and reached already great economic importance in the fields of electronic displays, smart windows and electronic newspapers, acting as electro-chromic devices.
The electric control of their absorbance may have influence on the spectral properties of such systems. Dependent on the state, color or tone may change, what can be investigated quantitatively by means of CIMPS-abs. For many applications, besides color aspects, the dynamic properties are of high importance as well. The switching time, very important for instance for displays and modulators or the reaction time of smart windows is determined by the kinetic processes of transport- and Redox-reactions or structural re-organization which cause the optical changes.
Dynamic Transmittance Reflectance DTR transfer function analysis follows the ideas popular for instance in Electrochemical Impedance Spectroscopy. The basic transfer function in EIS is given between voltage and current. Like for EIS, in DTR a bias control voltage (or current) applied to the sample is modulated by a small test signal amplitude. Differing from EIS, the sample is illuminated using a certain calibrated static intensity P, and the transmitted or reflected light P^* is recorded and treated as response signal in dependence of the electrical excitation.
The dynamic transfer function DTR is calculated as the quotient between the response modulation signal (the relative intensity change in time $P^*/P = TR^*$) and the excitation signal (Voltage U^* or current I^*, dependent on the selected mode, potentiostatic or galvanostatic).
In the frequency domain, the time dependency of both signals can be cancelled out in the quotient, apart from a characteristic phase shift φ which may depend on the frequency ω.

$$U^* = \hat{U} \cdot e^{j\omega t}, \quad I^* = \hat{I} \cdot e^{j\omega t}$$ (force signals, amplitudes $\hat{U}, \hat{I}$, j = imaginary unit)

$$\frac{P^*}{P} = TR^* = \hat{TR} \cdot e^{j\omega t+\varphi}$$ (response signal, amplitude $\hat{TR}$)

$$DTR_{pot} = \frac{TR^*}{U^*} = \frac{\hat{TR} \cdot e^{j\omega t+\varphi}}{\hat{U} \cdot e^{j\omega t}} = \frac{\hat{TR}}{\hat{U}} \cdot e^{j\varphi}, \quad \left[DTR_{pot}\right] = V^{-1}$$ (potentiostatic DTR)

$$DTR_{gal} = \frac{TR^*}{I^*} = \frac{\hat{TR} \cdot e^{j\omega t+\varphi}}{\hat{I} \cdot e^{j\omega t}} = \frac{\hat{TR}}{\hat{I}} \cdot e^{j\varphi}, \quad \left[DTR_{gal}\right] = A^{-1}$$ (galvanostatic DTR)

DTR spectra can be understood in principle like EIS. Time constants can be extracted and assigned to certain charge transfer, relaxation and transport processes. Their characteristic phase angle helps to distinguish between them.
It is known, that EIS suffers from the ambiguity of the spectra: different mechanisms may lead to identical dynamic transfer functions. It is an exceptional property of DTR, that the response function can be assigned unequivocally to an occurring colored species. In combination with EIS, DTR may help to cancel out further ambiguities, like it can be done also in combination with IMPS/IMVS data.
DTR can be performed with most calibrated light sources of different spectral properties from the Zahner portfolio. By changing the wavelength, DTR may be extended selectively to the case, when more than one colored species is present.
DTR is a brand-new field. Unlike in EIS or CIMPS, immediate modeling support is not available from Zahner at the moment. The user may profit nevertheless from the stringent treatment of DTR data in Thales, which is orthogonal to the treatment of EIS and CIMPS data. The user is invited to define his own mathematical models via the USR function in SIM for simulation and fitting purposes.
DTR gives valuable dynamic information which belongs to a certain bias within the systems steady state characteristic. Besides, CIMPS-mdtr/ois supports slow, quasi-static scan features determining the steady state characteristics. In order to characterize the static transmittance reflectance behavior

in dependence of the applied voltage, the sample voltage can be swept linearly between two limiting voltages under potentiostatic control. It is save to assume, that mostly not the direct current, but the accumulated charge is more characteristic for the description of an actual quasi-static TR-state of an electro-chromic system under galvanostatic control. Therefore the TR-characteristic in galvanostatic mode is supported in form of a charge scan.
As a new feature, potentiostatic square wave signal excitation was added to CIMPS-mdtr/ois. Here, a set of square wave pulses can be applied within a wide timescale range. The cell voltage switches between two crest potentials, selectable arbitrarily in between the potentiostat set potential range, while the TR course vs. time is recorded. This gives the researcher a direct impression of the sample behavior in the time domain.
Both the quasi-static DC- as well as square wave scan is now fully supported by the new online display window, where you can change the graphical properties arbitrarily during the record time.
Like already in AC CIMPS-mdtr/ois, now up to four traces with different spectral range can be recorded in parallel in quasi-static DC- and square wave scan.

2. Hardware and Installation

CIMPS-mdtr/ois extends the basic CIMPS system by the following components:

- PAD4 four channel synchronous A/D-converter (installed in Zennium/IM6)
- MSS multi spectral sensor with sense amplifier
- four connection cables MSS to PAD4 labeled 1-4

Connect the standard CIMPS components LDA, light source potentiostat and feedback photodiode in the way described for standard CIMPS and route the EPC Channel 1 to the light source potentiostat. Connect the photo-electrochemical cell PECC respectively the sample under test to the Zennium/IM6 potentiostat (sample control potentiostat).
Position the multi spectral sensor MSS behind the sample and connect it to the PAD4 as shown in Fig. 2 right hand side.

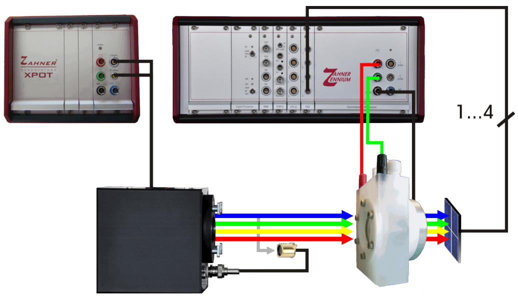


Fig. 1 Connection scheme of CIMPS-mdtr. The four sensor outputs are connected to the PAD4-card.

!	An enclosure covering the complete optical bench is necessary to avoid detrimental effects caused by ambient light during the whole measurement time.

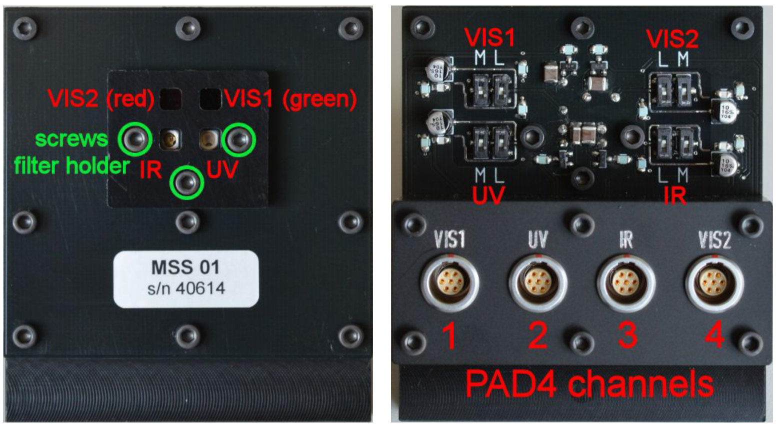


Fig. 2 multi spectral sensor MSS front and reverse side

The MSS has four channels for sensing intensity at different wavelengths simultaneously. Two channels are equipped with dedicated sensors for ultraviolet (UV) and near infrared (IR) light. The sensors VIS1 and VIS2 are equipped with broadband photodiodes for visible light (VIS). Their wavelength response is user selectable by installing suitable color filters. The MSS comes with preinstalled green and red filter foils. After loosening the three screws marked green in Fig. 2, left hand side, the filter holder can be removed and the filter foils replaced.

Each of the four sensors has a dedicated sense amplifier for optimized signal to noise ratio at different light intensities. Sensitivity can be selected separately for each channel with two small slide switches on the MSS (see Fig. 2, right hand side).

Switch positions are given in Table 1. Adjust sensitivity, so the measured voltage of the sensor channels is below 4 V in order to avoid saturation of the sensor amplifiers.

switch M	switch L	relative sensitivity
↑	↑	1
↓	↑	0.1
↑	↓	0.011
↓	↓	0.0099

Table 1: Settings of the sensitivity switches

3. CIMPS-mdtr Software

3.1. Startup

CIMPS-mdtr is easily activated by using the pull down menu as shown in Fig. 3. In order to open the pull down menu, click onto the Z-icon in the title bar of the Thales window.

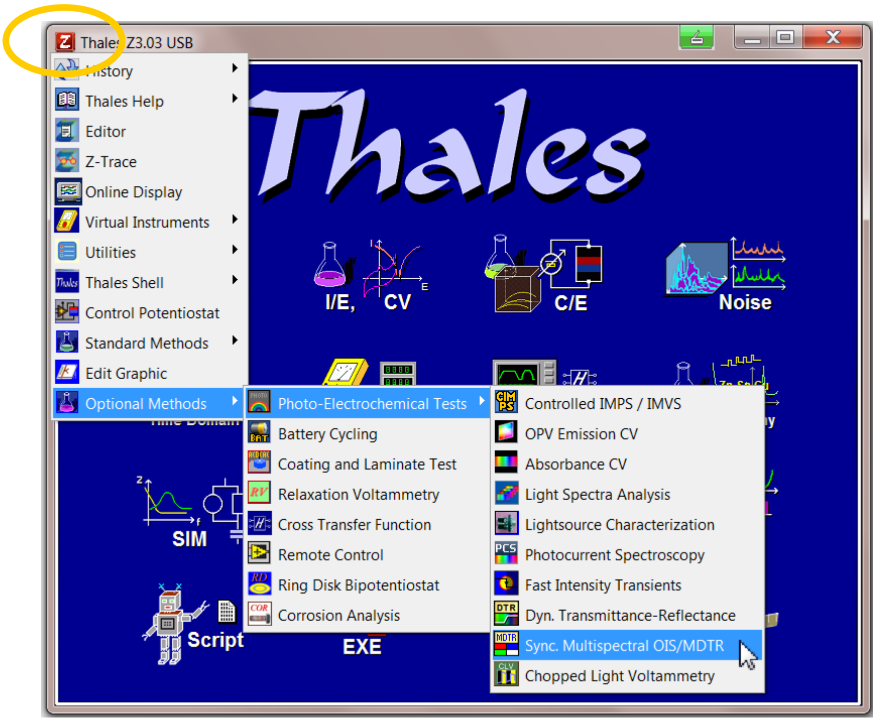


Fig. 3 Start of CIMPS-mdtr using the pull down menu

After initialization of the CIMPS-system, the main window of CIMPS-mdtr is displayed (see Fig. 4).

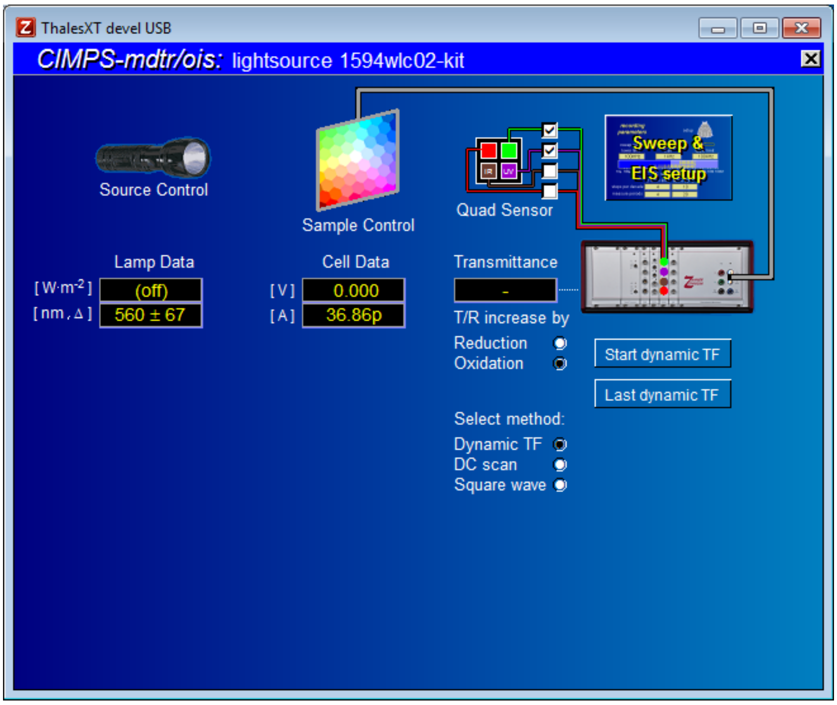


Fig. 4 Main window of CIMPS-mdtr after startup

3.2. Light Source Control

All functions necessary for controlling the light source are easily accessible by the light source control icon. Differing from standard CIMPS, access is established through an intermediate dialog menu.

Fig. 5 Icon of the light source control in default (left hand side) and active state (right hand side).

3.2.1. Light Source Calibration

Light sources delivered by Zahner are calibrated allowing the direct input of light intensity in W/m². Most of the light sources are automatically detected and Thales opens calibration automatically. In case the light source can not be detected or the calibration file was not found in the folder c:\thales\cimps, the file can be opened manually.

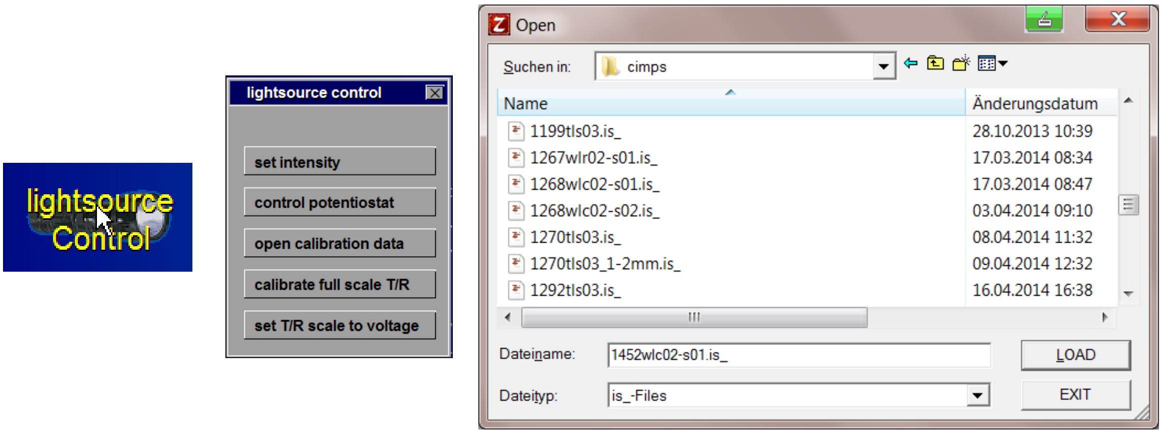


Fig. 6 Loading light source calibration data.

Click the light source control icon (Fig. 6, left hand side) to open the light source control dialog. In the light source control dialog (Fig. 6, middle) select open calibration data. Now the file dialog for choosing the light source calibration file opens (Fig. 6, right hand side). In the file dialog select the file corresponding to the light source. After installation of the calibration data CD, light source calibration files are located in c:\thales\cimps. The name of the calibration file consists of the serial number and the ordering code of the light source, e.g. 1452wlc02-s01 for the white light source WLC02 with serial number 1452 with sensor S01.

3.2.2. Intensity Control

The intensity of the light source is set by clicking the light source control icon (Fig. 7, left hand side). In the light source control dialog (Fig. 7, middle) select “set intensity” to open the intensity dialog (Fig. 7, right hand side). Enter the desired intensity here and confirm by either hitting the enter key or clicking the green button top right. After setting a new intensity value, check the measured voltage of the multi spectral sensor is below 4 V. Otherwise change setting of the slide switches on the MSS (see chapter 2).

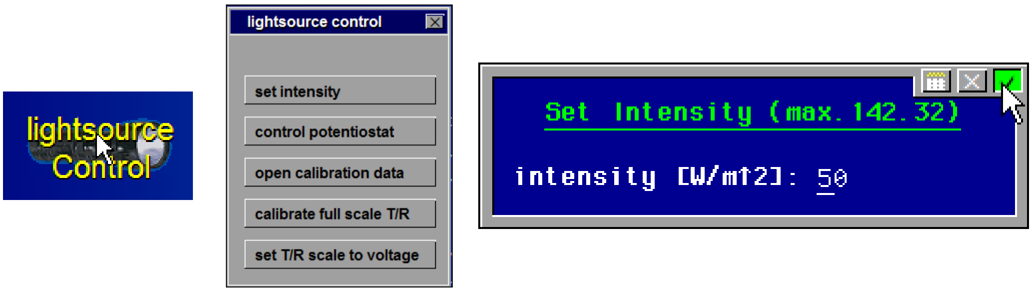


Fig. 7 Setting the intensity of the light source

By setting an intensity of 0 W/m² the light source is switched off. Here the confirmation dialog (Fig. 8) offers two options. In case of "yes" the light source potentiostat is switched off so the current-carrying leads are floating. In case of "no" the light source potentiostat stays on but is set to 0V.

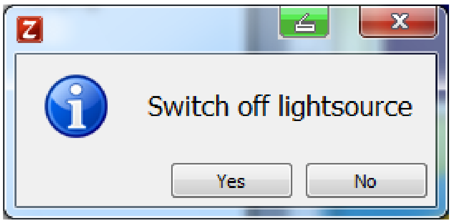


Fig. 8 Options for switching off the light source

3.2.3. Control Potentiostat

The test sampling screen of the light source potentiostat can easily be reached by selecting "control potentiostat" (Fig. 9). The potential displayed here is not the voltage applied to the LED but has a special meaning. It is the response signal of the feedback sensor at the cell site. Control voltages are automatically calculated by the set intensity function (refer to chapter 3.2.2) so setting a voltage here is not necessary.

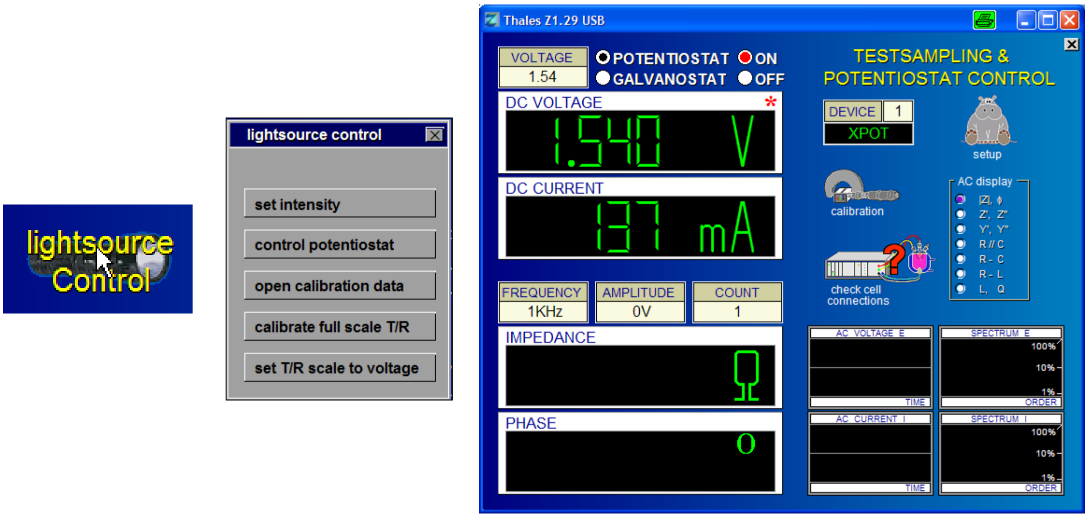


Fig. 9 Entering test sampling of the light source potentiostat

3.2.4. Full Scale Transmittance / Reflection Calibration

The absolute intensity measured by the MSS depends on the preset intensity of the light source, the optical aperture of the experimental setup and the state of the sample investigated. Therefore a reference measurement considered as maximum transmittance has to be done. This is accomplished by selecting "calibrate full scale T/R" in the light source control (Fig. 10 left hand side and middle).

Now adjust the experimental setup and the sample cell state for maximum transmittance and acknowledge the dialog of Fig. 10 right hand side by clicking it.

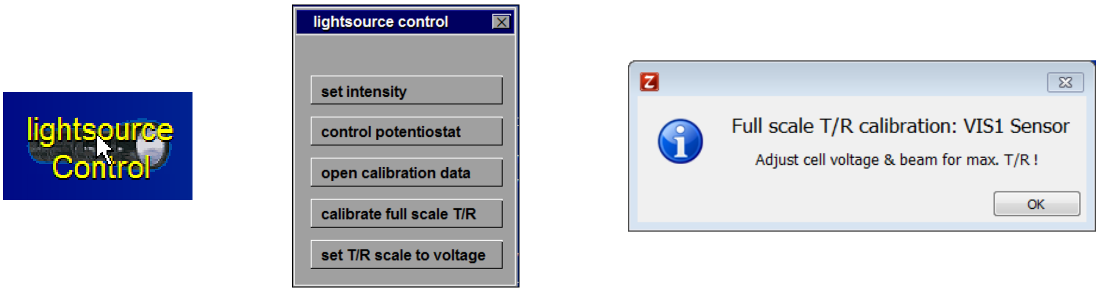


Fig. 10 Procedure for full scale transmittance / reflection calibration

Transmittance / Reflectance calibration automatically switches from voltage scale (0-4 V) to transmittance scale (0-1) and sets transmittance to 1 for all activated channels.
In analytical applications it may happen, that the sample state for maximum transmittance is different for different spectral ranges (colors). This is usual, if different colored species appear or vanish dependent on the potential, for instance acting as a red-ox couple.
Example: A P3HT-film (for Smart Window, OLED or OSC applications) absorbs in the blue-green spectral range at low (negative) potential (reduced state), while it absorbs in the near IR range at high (positive) potential (oxidized state). During a scan from negative to positive potential, the green transmission will increase, while the IR transmission will decrease. Here it makes sense to calibrate the full scale T/R individually for the individual sensors.
In our example this means: set the sample into oxidized condition, activate only the IR sensor and perform the “calibrate the full scale T/R” operation. Then set the sample into reduced condition, activate only the green sensor and perform the “calibrate the full scale T/R” operation again. Then activate both sensors and perform your measurements.

3.2.5. Switching between voltage and transmittance scale

Light intensity is sensed by the PAD4 card as voltage which is automatically converted to transmittance, once full scale transmittance calibration (see chapter 3.2.4) is done. In order to revert to the voltage display, select “set T/R scale to voltage.” When changing the experimental set up this can be used to check the voltage is still below the 4 V maximum input voltage of the PAD4 card.

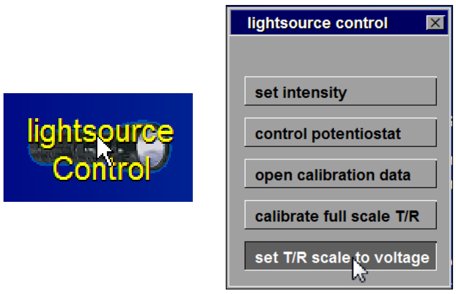


Fig. 11 Switching between transmittance and voltage display

3.3. Channel Selection

The active channels of the MSS can be set arbitrarily by clicking the corresponding check boxes. In Fig. 12 VIS1 (green) is active. In case all channels are deactivated, the software automatically activates channel VIS1 (green).

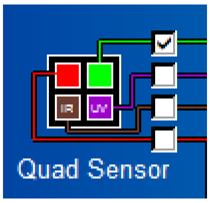


Fig. 12 Channel selection

The immediate transmittance display in the Thales screen (Fig. 12 bottom) always refers to the first selected channel in the order VIS1 (green), UV (violet), IR (brown) and VIS2 (red). The same priority is used when recording static transfer functions as described in chapter 3.4. If the Online display function is activated in parallel, all active channels may be visualized on selection.

3.4. Method Selection

The different measuring methods are chosen by means of the method selector switch. Use “Dynamic TF” for the AC method “Dynamic transmission / reflection - OIS” (Fig. 13).
Use “DC scan” for the quasi-steady-state method “Potentiostatic voltage scan” (Fig. 14) and “Galvanostatic charge scan” (Fig. 15). Choose between these two methods by setting the sample control to “Galvanostat”, see chapter 3.6.
Use “Square wave”, if you want to examine your sample with the method “Square Wave Excitation” in the time domain (Fig. 16).

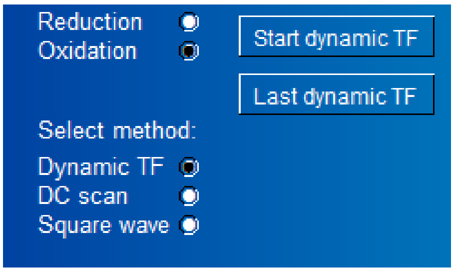


Fig. 13 Method selection set for Dynamic Transmission / Reflection – OIS

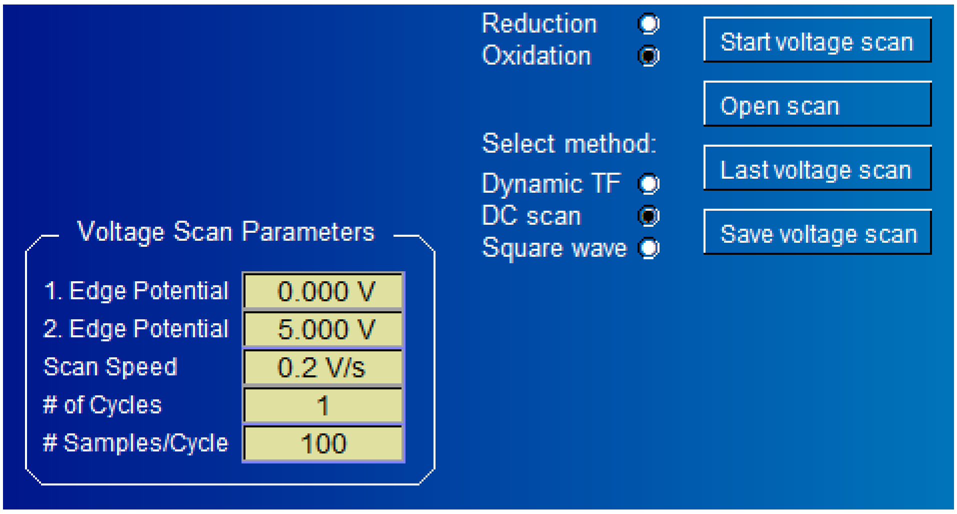


Fig. 14 Method selection set for potentiostatic voltage scan

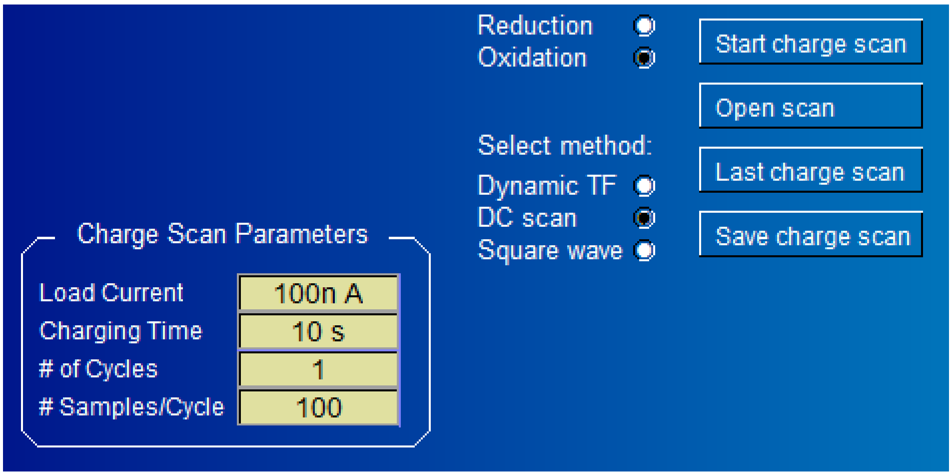


Fig. 15 Method selection set for galvanostatic charge scan

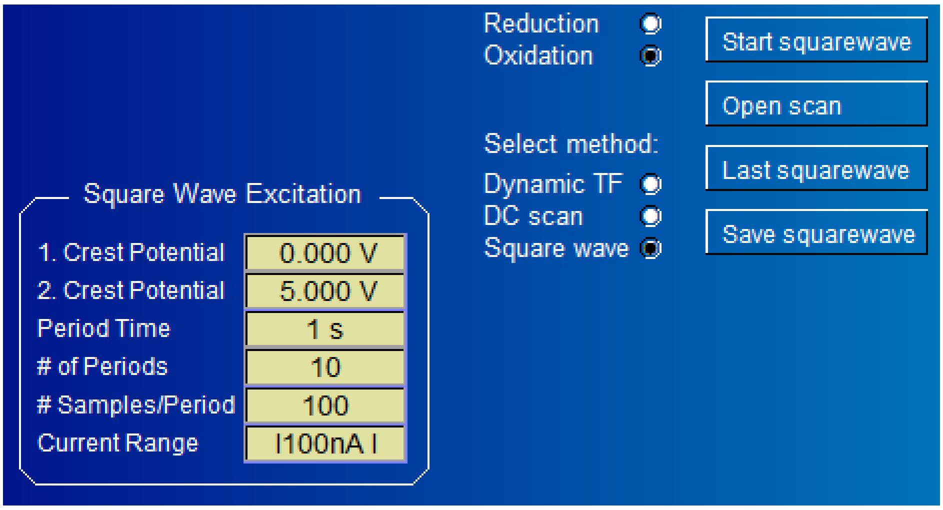


Fig. 16 Method selection set for square wave excitation

3.5. Dynamic Transfer Functions

After the light source has been activated and a transmittance full scale calibration has been performed (refer to chapter 3.2) dynamic transmittance measurements can be done.

3.5.1. Sample Control

In order to record dynamic transfer functions the state of the sample and the excitation signal have to be set. Therefore click the sample control icon (Fig. 17 left hand side and middle) to enter testsampling and potentiostat control (Fig. 17 right hand side). Here choose either potentiostatic or galvanostatic mode, set a DC bias and amplitude. Now return to the CIMPS-mdtr main screen by pressing the middle mouse button or by clicking the x button at the top right.

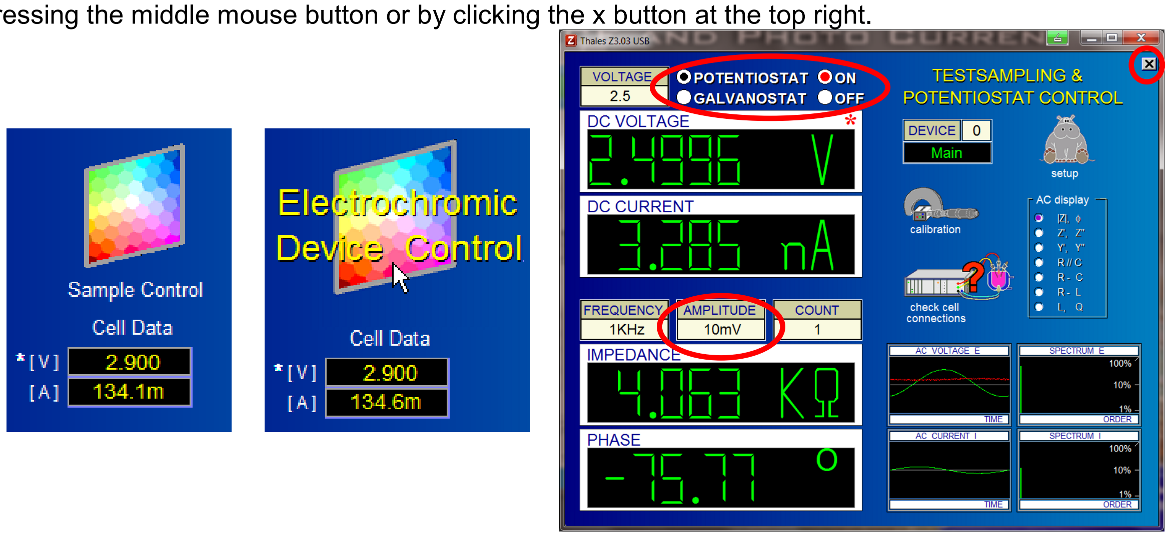


Fig. 17 Sample control icon and potentiostat control screen

The actual potential and current of the sample are displayed in the CIMPS-dtr main screen. The controlled quantity (potential for potentiostatic mode and current for galvanostatic mode) is marked with an asterisk (see Fig. 17 left hand side and middle).

3.5.2. Sweep and EIS-Setup

The frequency range and the parameters of the dynamic measurement are set in the sweep and EIS setup. Pease consider, that electro-chromic processes often appear at slow timescales. Using high test frequencies under these circumstances will only reflect artifacts due to the break-down of the response signal to zero.

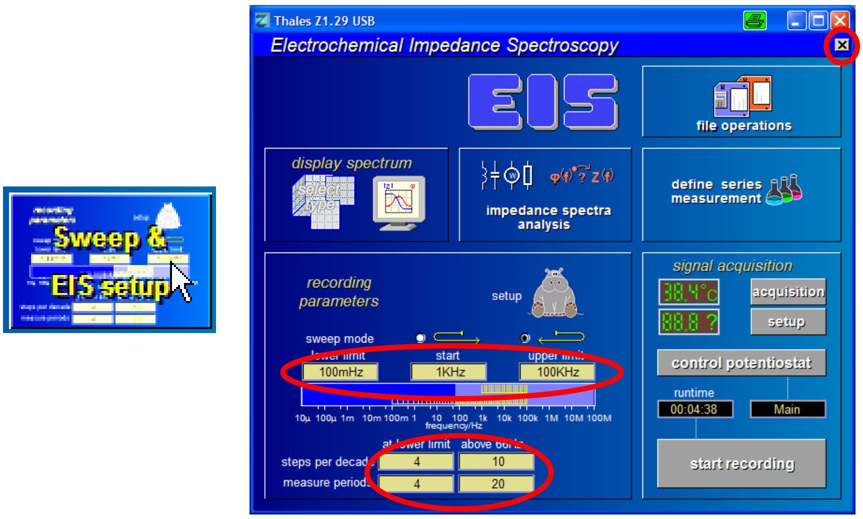


Fig. 18 Setting up frequency range and parameters for dynamic measurements

For details regarding the function of the recording parameters refer to the EIS manual. When finished return to the CIMPS-mdtr main screen with the middle mouse button or by clicking the x button at the top right.

3.5.3. Sign of response

The response of a sample to an excitation can be divided into two general cases. Either transmittance can increase with oxidation at the working electrode, i.e. when driving potential more positive. Or transmittance can increase with reduction at the working electrode, i.e. when driving potential more negative. These two cases differ in a phase shift of 180° in the force response relationship. In order to get minimum phase spectra the type of sample can be set by the radio buttons shown in Fig. 19.

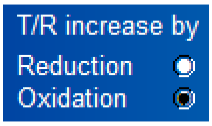


Fig. 19 Setting the sign of response

In case the sign of response is set to the wrong direction phase will be shifted by 180°.

3.5.4. Recording Dynamic Transmittance Spectra

After all settings are done, the measurement can be started by clicking the “Start dynamic TF” button (Fig. 20 left hand side). During measurement the spectrum and most recent data are displayed online (Fig. 20 right hand side). Concerning details of this screen also refer to the EIS manual.

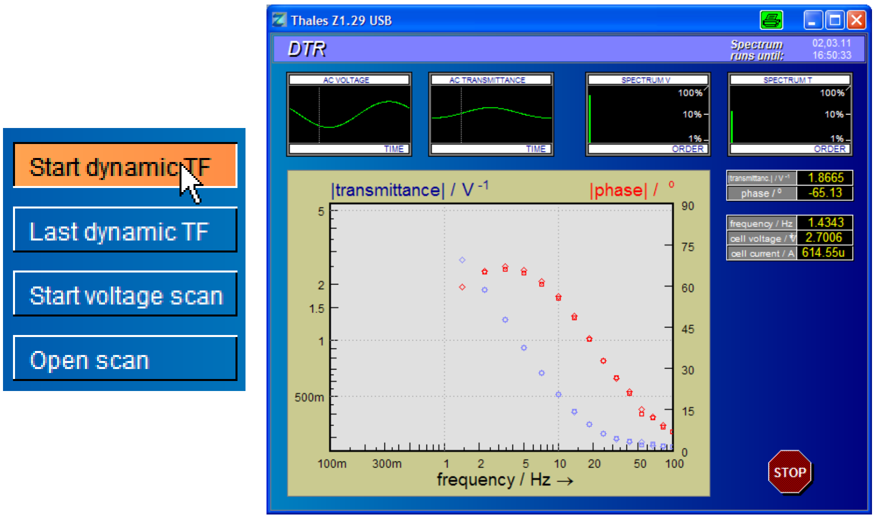


Fig. 20 Starting and recording dynamic measurements

After measurement has finished, the spectrum is displayed for review and saving in different formats (Fig. 21 left hand side). For a first quick investigation of the spectrum click the graph to activate the crosshair mode (Fig. 21 right hand side).

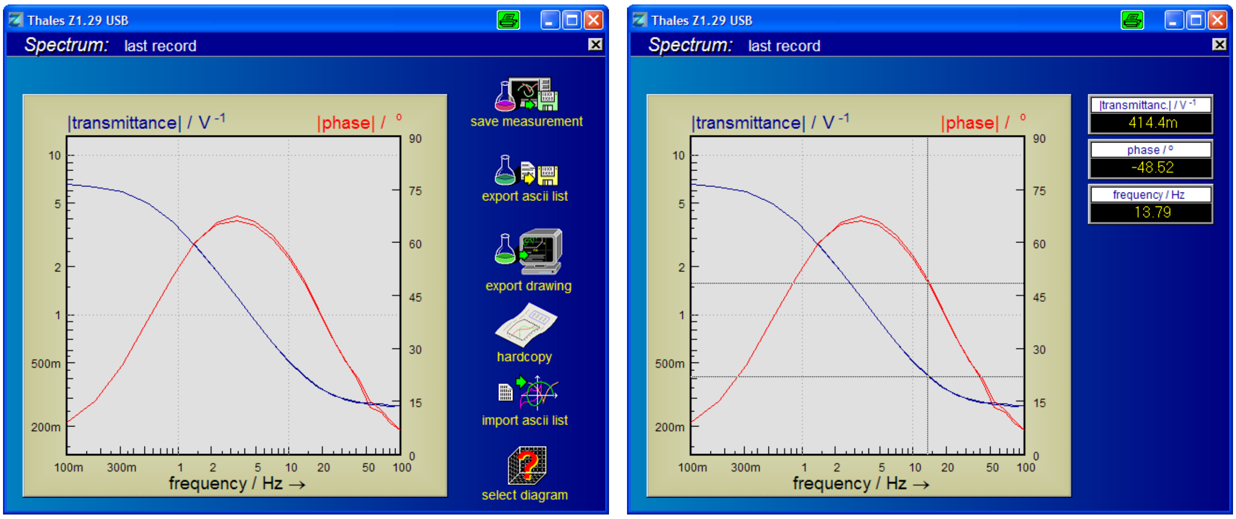


Fig. 21 Display of spectrum after measurement and crosshair mode

You can return to this screen from the CIMPS-dtr main screen using the “Last dynamic TF” button until a new measurement is started.

3.5.5. Saving Dynamic Transmittance Spectra

In the display spectrum screen (Fig. 21 see left hand side) click “save measurement” in order to save the spectrum. Now two options are available (Fig. 22 right hand side). “Save measurement & settings” returns to the display spectrum screen (see Fig. 21) after the file is saved. “Save & pass to analysis program” saves the file to disk and automatically opens it in SIM, the simulation and fitting program of Thales.

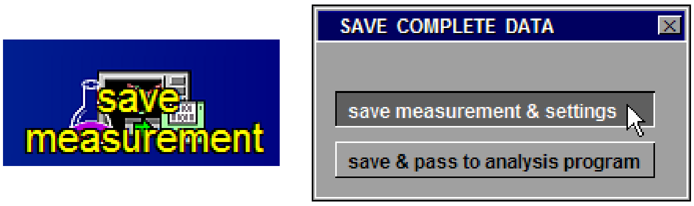


Fig. 22 Saving transmittance spectra

In both cases a dialog for entering additional information about the experiment is opened (Fig. 23 left hand side). The data entered here will be saved in the header of the file and can be retrieved when opening or exporting the spectrum later. When finished click the green button on the upper right corner. In the file dialog (Fig. 23 right hand side) select a path and filename for saving the spectrum.

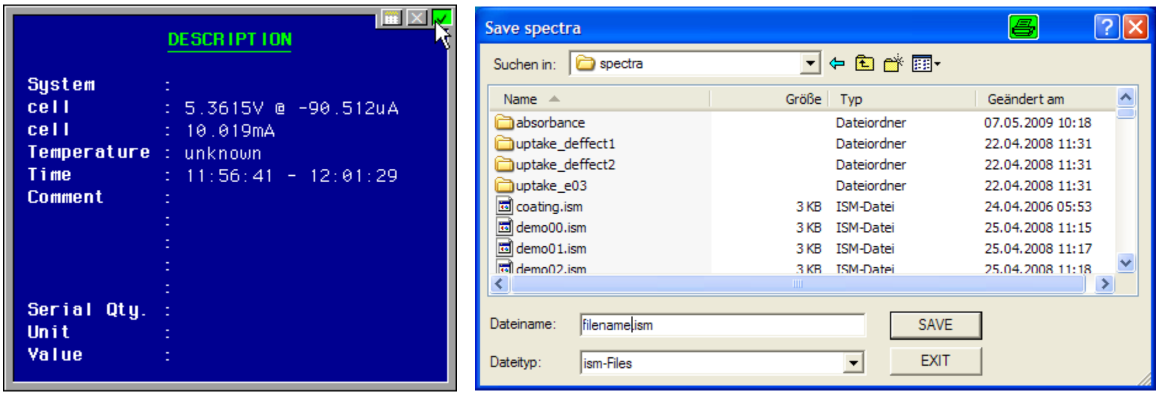


Fig. 23 Entering comments and choosing location and name while saving spectra

3.5.6. Text Export of Dynamic Transmittance Spectra

In order to export the measured data for use in third party software select “export ASCII list” in the display spectrum screen (Fig. 21 left hand side). Three options are available for ASCII text export (Fig. 24 left hand side). “Copy list to clipboard” passes the data to the Windows® clipboard from where it can be pasted to various Windows® applications. “Save list as textfile” opens a file dialog in order to save the ASCII list to disk.

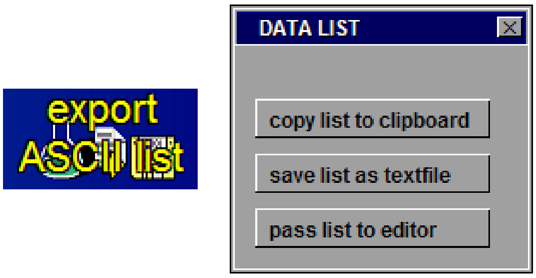


Fig. 24 Export of spectra as ASCII list

“Pass list to editor” transfers the ASCII data to the Thales editor where it can be further processed (Fig. 25).

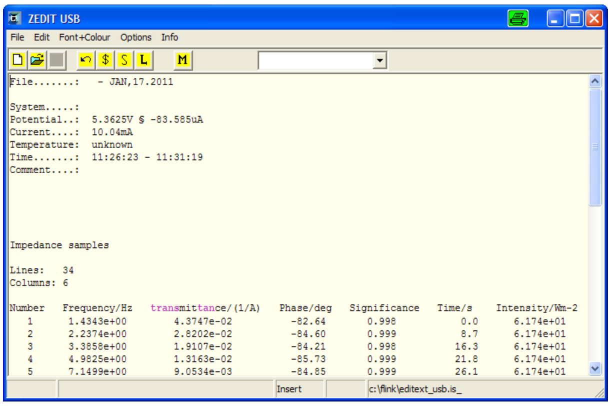


Fig. 25 Thales editor with exported ASCII data

3.5.7. Graphic Export of Dynamic Transmittance Spectra

The displayed spectrum (Fig. 21) can be exported as graphics. “Pass to clipboard” passes the graph to the Windows® clipboard from where it can be pasted to various Windows® applications. “Paste to CAD” transfers the graph to the Thales CAD application. For details concerning CAD refer to the CAD manual. “Save as EMF file” opens a file dialog in order to save a Windows® Enhanced Metafile. EMF is a vector graphics format which can be imported in various Windows® applications.

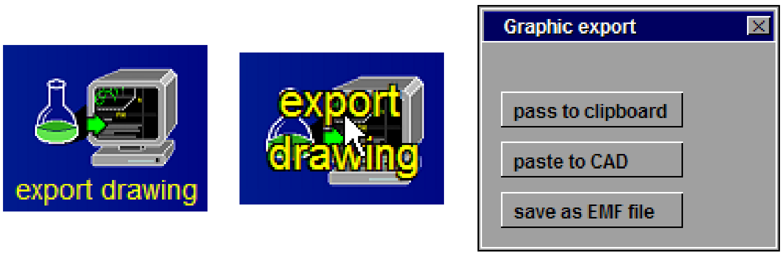


Fig. 26 Export of spectra as graphics

3.6. Static and Square Wave Transfer Functions

In addition to the frequency dependent transmittance/reflectance also measurements with changing DC bias can be recorded. Either control voltage sweeps or charge sweeps under current control can be selected.
Before recording static transfer functions the light source has to be activated, the desired channel of the MSS selected (refer to chapter 3.3) and a transmittance full scale calibration has to be performed (refer to chapter 3.2.4). In case several channels are selected, the first one in the order VIS1 (green), UV (violet), IR (brown), VIS2 (red), is used for the immediate display on the Thales screen.

3.6.1. Recording Voltage Scans

In order to record a voltage scan cell control has to be switched to potentiostatic mode. Therefore click the sample control icon (Fig. 27 left hand side and middle) to enter testsampling and potentiostat control (Fig. 27 right hand side). Here choose potentiostat and return to the CIMPS-mdtr main screen by pressing the middle mouse button or by clicking the x button at the top right.

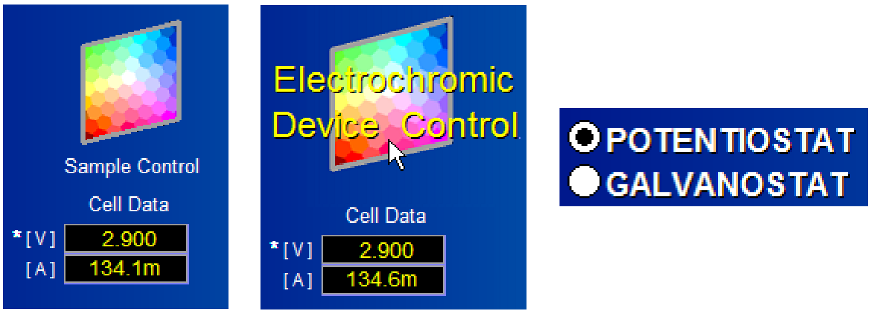


Fig. 27 Switching sample control to potentiostatic mode for voltage scans

Now the scan parameters are automatically switched to voltage scan (Fig. 28, left hand side). In order to set up the experiment click the parameters (Fig. 28, left hand side) to enter the parameter window (Fig. 28, right hand side).

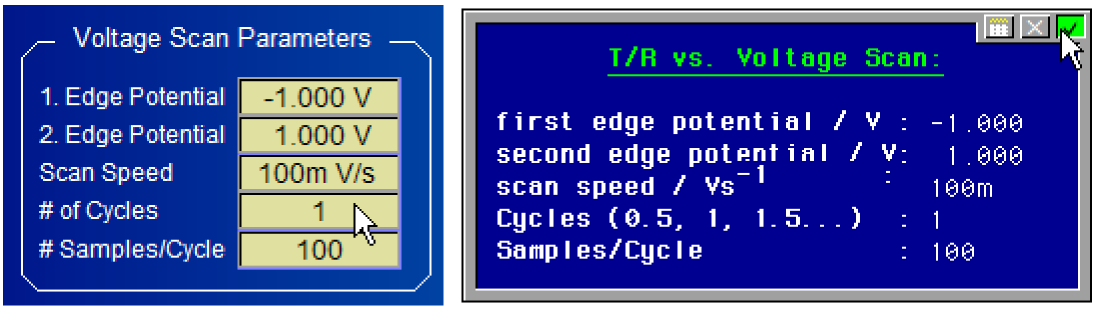


Fig. 28 Setting parameters of voltage scans

The limits of the parameters are:

- edge potentials: within the potential limits of the used main workstation potentiostat
- scan speed: 0.1 mV/s to 0.1 V/s
- cycles: 0.5 to 1000
- samples/cycle: 10 to 1000
- samples/s: max. 10. Samples are put in as samples/cycle. If the combination of the parameters violates the max. sample/s, this input will be rejected and corrected automatically.

One cycle is understood as sweep from the first edge potential to the second edge potential and back to the first edge potential. In order to stop the measurement at the second edge potential add a half cycle. After the parameters are set, start the measurement by clicking “Start voltage scan” as shown in Fig. 29 left hand side.

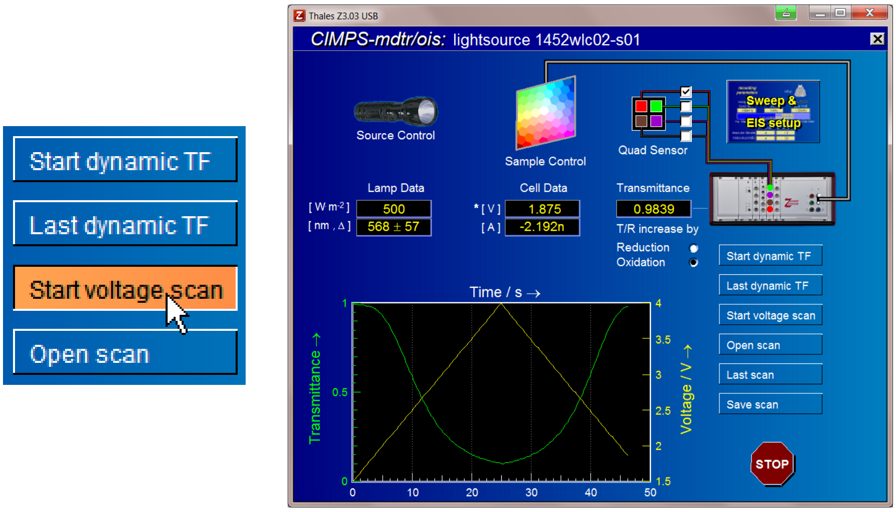


Fig. 29 Voltage scans: start button and online display

During the measurement recorded data are displayed online as shown in Fig. 29 right hand side, where a scan of 1 cycle is nearly finished.

3.6.2. Recording Charge Scans

Charge scans are recorded in galvanostatic mode at fixed current which is automatically integrated by Thales to yield the charge. In the first half of a cycle the sample is charged with the preset current (starting sign of current), in the second half of the cycle it is discharged again (inverse sign of current). In order to record a charge scan cell control has to be switched to galvanostatic mode. Therefore click the sample control icon (Fig. 30 left hand side and middle) to enter testsampling and potentiostat control (Fig. 30 right hand side). Here choose galvanostat and return to the CIMPS-mdtr main screen by pressing the middle mouse button or by clicking the x button at the top right.

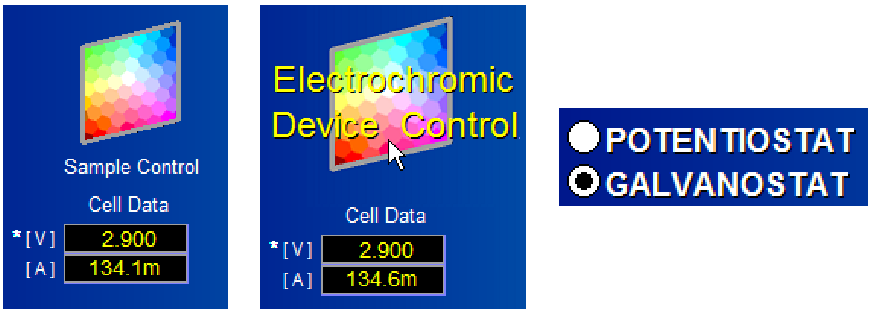


Fig. 30 Switching sample control to galvanostatic mode for charge scans

Now the scan parameters are automatically switched to charge scan (Fig. 31, left hand side). In order to set up the experiment click the parameters (Fig. 31, left hand side) to enter the parameter window (Fig. 31, right hand side).

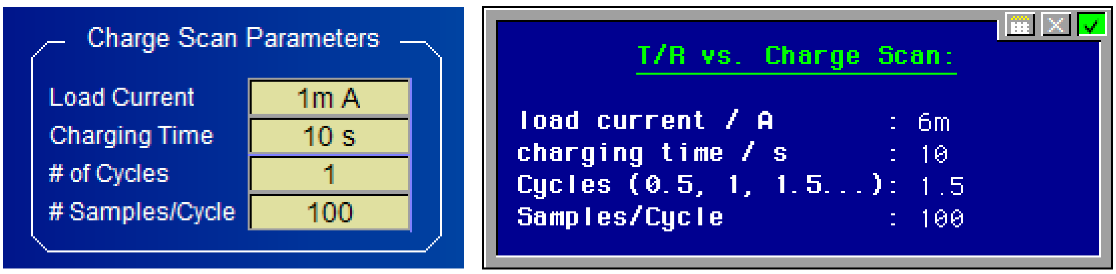


Fig. 31 Setting parameters of charge scans

The limits of the parameters are:

- load current: within the limits of the used potentiostat
- charging time: 1 to 3600 s
- cycles: 0.5 to 1000
- samples/cycle: 10 to 1000
- samples/s: max. 10. Samples are put in as samples/cycle. If the combination of the parameters violates the max. sample/s, this input will be rejected and corrected automatically.

One cycle is understood as a charging phase in the first half of the cycle and a discharging phase in the second half of the cycle. In order to stop the measurement after a charging phase add a half cycle. After the parameters are set, start the measurement by clicking “Start charge scan” as shown in Fig. 32 left hand side.

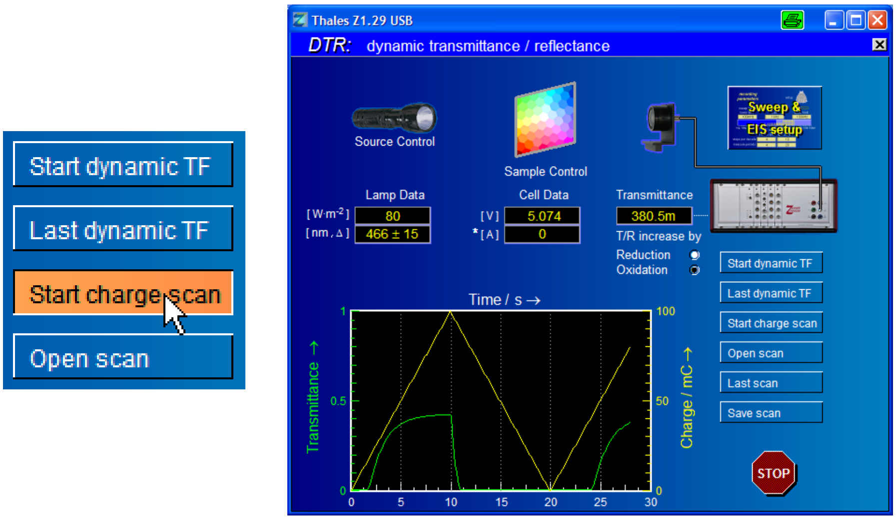


Fig. 32 Charge scans: start button and display during a scan.

During the measurement recorded data are displayed online as shown in Fig. 32 right hand side, where a scan of 1.5 cycles is nearly finished.

3.6.3. Main Screen Display of Static Transfer Functions

After a voltage or charge scan has finished it is displayed for review (Fig. 33). By clicking “Select Graphic” different options for plotting the data are available (Fig. 34).

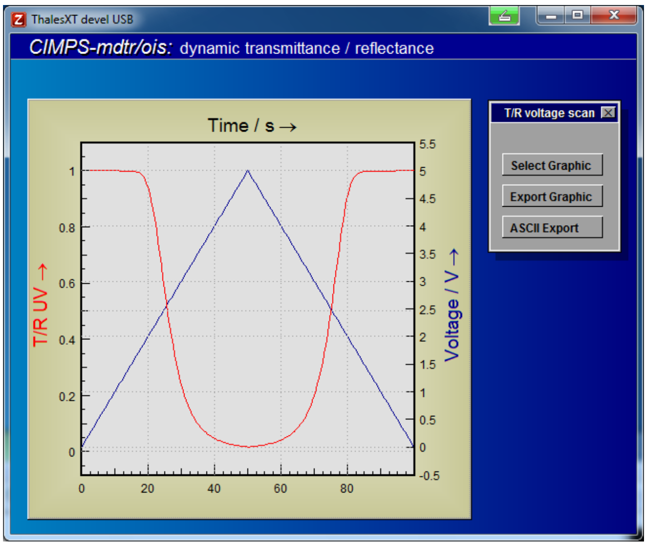


Fig. 33 Display of a voltage scan (3D TV glass)

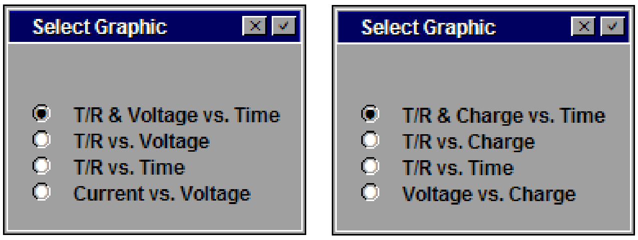


Fig. 34 Display options of voltage scans (left hand side) and charge scans (right hand side)

3.6.4. Graphic Export of Static Transfer Functions

The displayed scan can be exported as graphics (Fig. 35) using the “Export Graphic” button. “Pass to clipboard” passes the graph to the Windows® clipboard from where it can be pasted to various Windows® applications. “Paste to CAD” transfers the graph to the Thales CAD application. For details concerning CAD refer to the CAD manual. “Save as EMF file” opens a file dialog in order to save a Windows® Enhanced Metafile. EMF is a vector graphics format which can be imported in various Windows® applications.

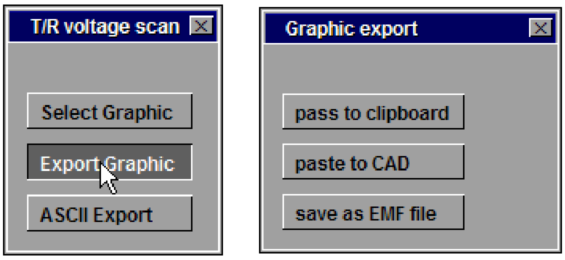


Fig. 35 Export of voltage scans as graphics

3.6.5. ASCII Export of Static Transfer Functions

Both voltage or charge scans can be exported as ASCII files. While the scan is displayed (Fig. 33) select ASCII Export (Fig. 36) in order to save an ASCII file to disk.

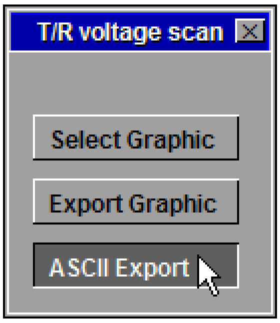


Fig. 36 ASCII Export of voltage and charge scans

3.6.6. File Operations for Static Transfer Functions

Voltage and charge scans can be loaded and saved using the buttons in the CIMPS-dtr main screen (Fig. 37). Please note the “Save scan” button is not displayed until measured data are available.

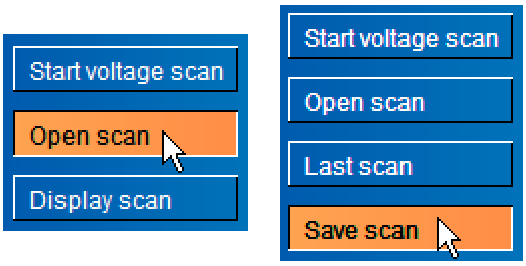


Fig. 37 Buttons for file operations of voltage and charge scans

After clicking the save button (Fig. 37 right hand side) a dialog for entering additional information about the experiment is opened (Fig. 38 left hand side). The data entered here will be saved in the header of the file and can be retrieved when opening or exporting the spectrum later. When finished, click the green button on the upper right corner. In the file dialog (Fig. 38 right hand side) select a path and filename for saving the spectrum.

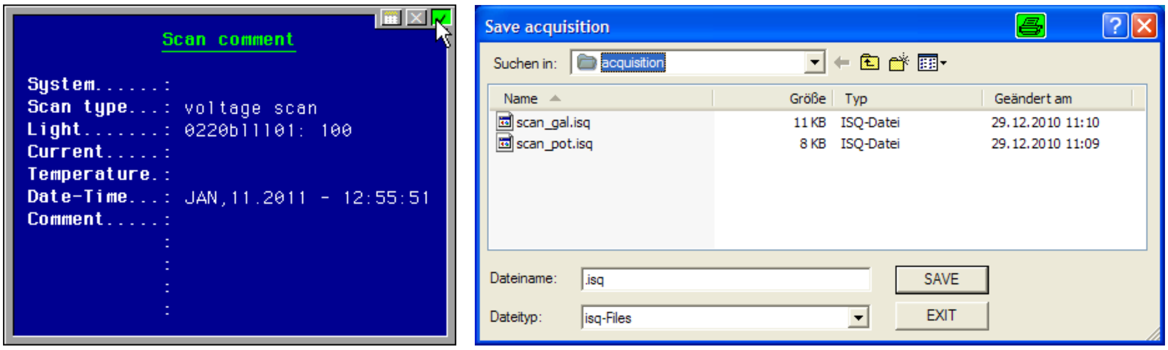


Fig. 38 Saving voltage and charge scans to disk

3.6.7. Recording Square Wave Scans

In order to record a square wave scan cell control has to be switched to potentiostatic mode. Therefore click the sample control icon (Fig. 39 left hand side and middle) to enter testsampling and potentiostat control (Fig. 39 right hand side). Here choose potentiostat and return to the CIMPS-mdtr main screen by pressing the middle mouse button or by clicking the x button at the top right.

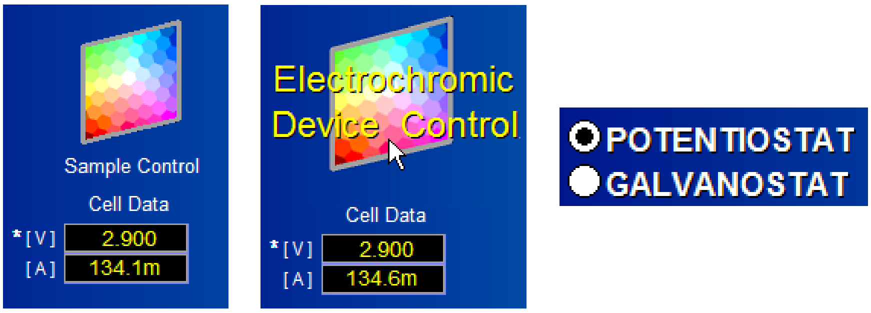


Fig. 39 Switching sample control to potentiostatic mode for square wave scans

Now the scan parameters are automatically switched to square wave scan (Fig. 40, left hand side). In order to set up the experiment click the parameters (Fig. 40, left hand side) to enter the parameter window (Fig. 40, right hand side).

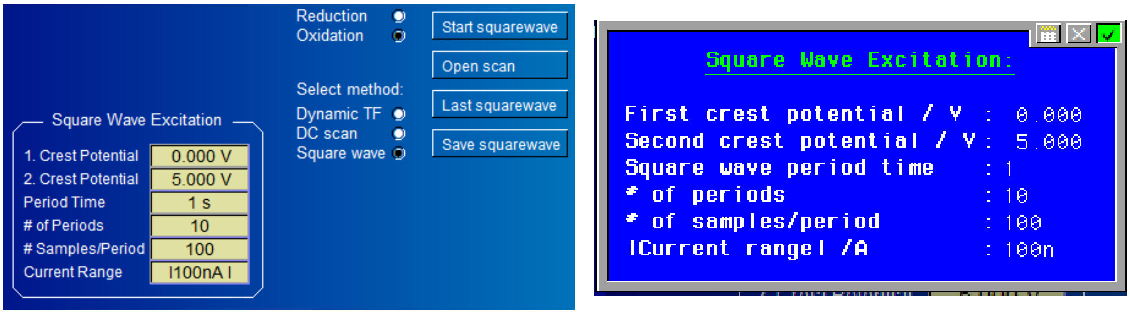


Fig. 40 Setting parameters of square wave scans

The limits of the parameters are:

- crest potentials: within the potential limits of the used main workstation potentiostat
- square wave period time: 0.01 to 3600 s
- # of periods: 1 to 1000
- # of samples/period: 10 to 1000
- │Current range│: While Dynamic and DC scan methods use auto ranging for the DC current measurement, square wave excitation must use a fixed current range due to the fast up- and down transition of a square wave. If one wants a highly accurate current record, an appropriate current range between 1nA and 1A, dependent on the properties of the sample must be chosen. Usually the current course vs. time is not so important, in this case use simply a sufficient high current range, for instance the default value of 100mA.

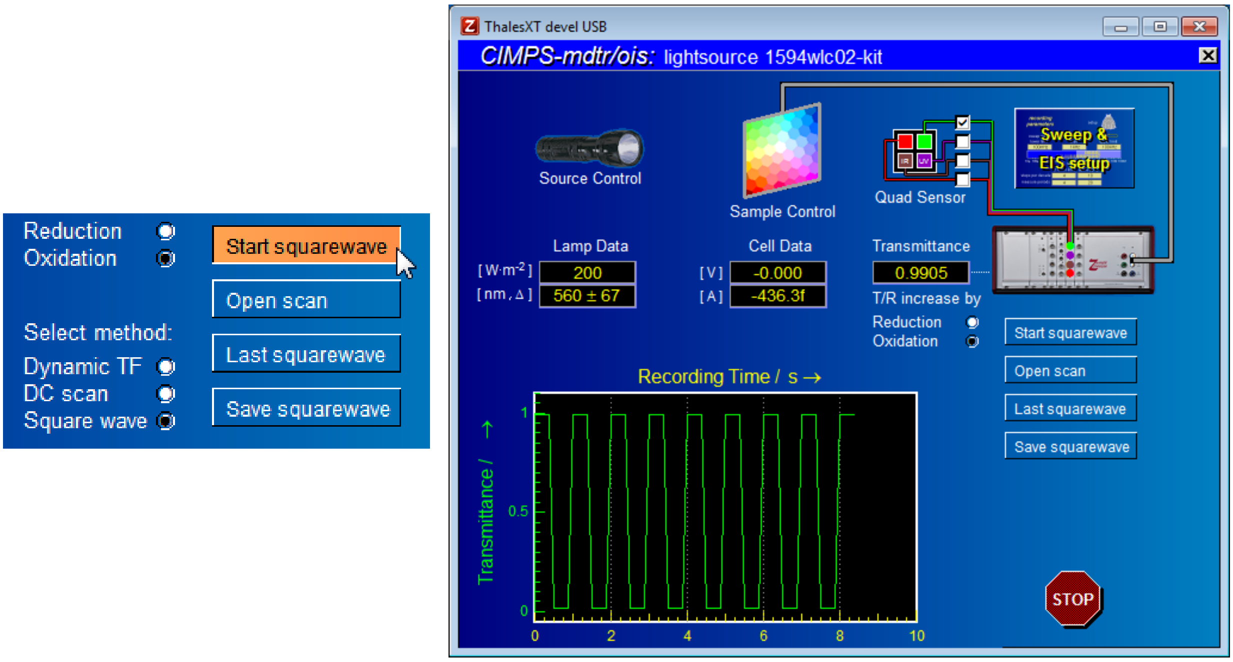


Fig. 41 Square wave during record on the Thales screen

During the measurement recorded data are displayed as shown in Fig. 41 right hand side, where a square wave scan of 10 periods is nearly finished.

3.6.8. Main Screen Display, Export and File Operations for Square Wave Scans

Display, Export and File Operations for Square Wave Scans are performed in a similar way orthogonal to corresponding functions for voltage and charge scans. Please refer to the previous section 3.6.3 to 3.6.6 for details.

3.7. MDTR/OIS Online Display

It is strongly recommended to switch on the Online Display support. When entering the MDTR/OIS software via the expert function of the Thales-XT panel, the online display is automatically activated. Different from that, the Online Display support must be switched on manually from the corresponding icon on the desktop, or by the Thales window pull down menu (Fig. 42). Here, click on the Z-symbol to open the pull down menu and then click "Online Display".

Fig. 42 Activating the online display support via the Thales pull down menu

The Online Display allows the display of all actual data during the measurement to be displayed in an arbitrarily manner. Appropriate default presets are automatically presented, when a measurement is started. Besides, Online Display writes a copy of the incoming data as an ASCII file to a default directory in order to present a text export and a security copy, even if the record was not completed or saved manually.
For details please refer to the Online Display manual.
Fig. 43 shows three typical examples for the graphical output of MDTR/OIS Online Display data.

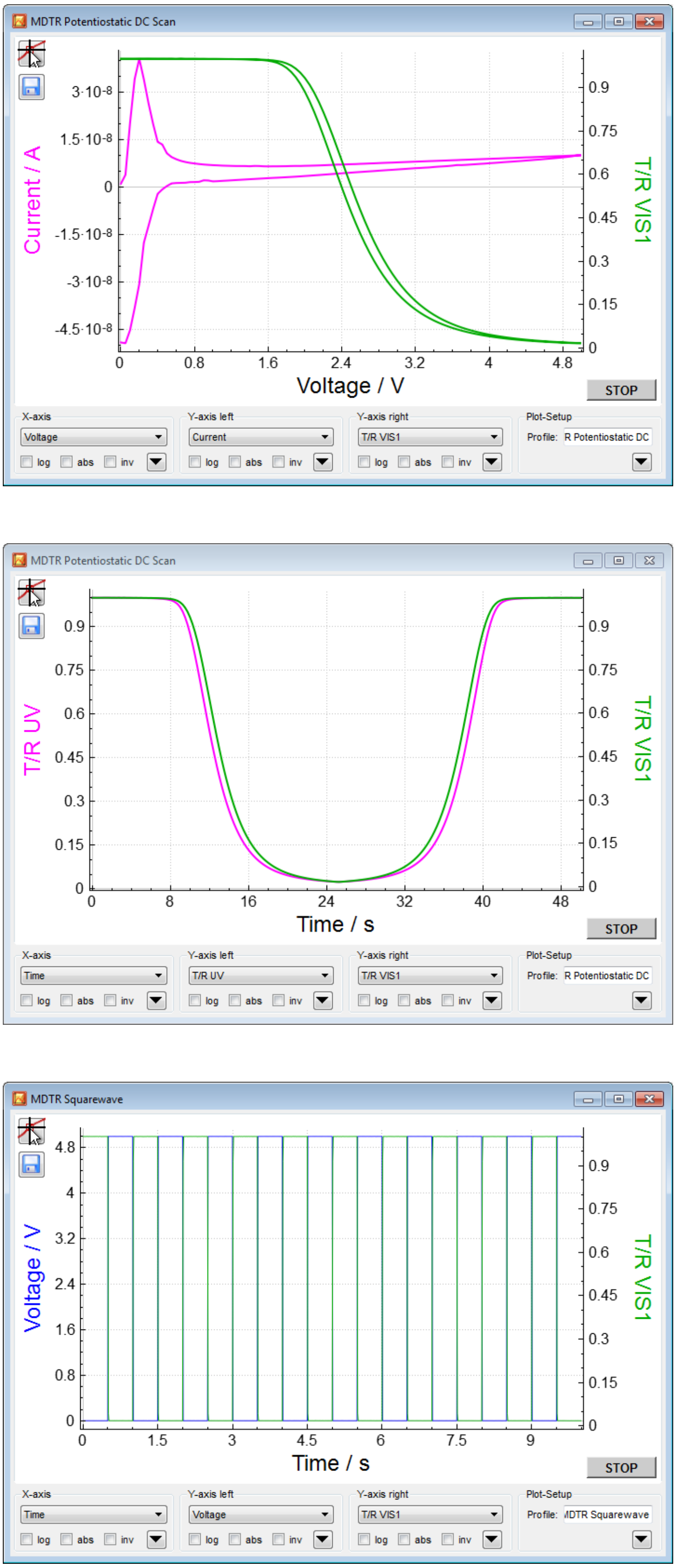


Fig. 43 Typical examples for the graphical output of MDTR/OIS Online Display during measurements on a 3D-TV glass