Solar Cell I-V Test System – Automated

User Manual

Manual version 1.0.A

Product code: T2003

Product Version 2.0

Software version: 1.0

Contents

1. Overview

The Ossila Solar Cell I-V Test System is a low-cost solution for reliable current-voltage characterisation of solar cells. The system is controlled by specially-designed software which can perform multiple I-V measurements, determine key metrics of solar cells, and measure these properties over long periods of time. The automated version of the system enables automatic switching between pixels, making measurements faster and easier.

2. EC Declaration of Conformity

We

Company Name: Ossila Limited

Postal Address: Solpro Business Park, Windsor street.

Postcode: S4 7WB

City: Sheffield

Telephone number: +44 (0)114 2999 180

Email Address: info@ossila.com

declare that the DoC is issued under our sole responsibility and belongs to the following product:

Product: Solar Cell I-V Test System – Automated **(T2003A2/T2003B2/T2003C2)**

Serial number: T2003A2-2000-2000-1000-xxxx, T2003B2-2000-2000-1100-xxxx, T2003C2-2000-2000-1000-xxxx

Object of declaration:

Solar Cell I-V Test System – Automated **(T2003A2/T2003B2/T2003C2)**

The object of declaration described above is in conformity with the relevant Union harmonisation legislation:

EMC Directive 2014/30/EU

RoHS Directive 2011/65/EU

Signed:

Name: Dr James Kingsley
Place: Sheffield
Date: **15/01/2019**

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Производител: Ossila Ltd., Solpro Business Park, Windsor Street, S4 7WD, Великобритания
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3. Safety

3.1 Warning

Warning

- **Do NOT connect external voltage sources to either SMU channel.**
- **The absolute maximum input voltage for the Vsense channels is ±12 V. DO NOT apply input while not powered.**

3.2 Use of Equipment

The Ossila Source Measure Unit is designed to be used as instructed. It is intended for use under the following conditions:

- Indoors in a laboratory environment (Pollution Degree 2)
- Altitudes up to 2000m
- Temperatures of 5°C to 40°C; maximum relative humidity of 80% up to 31°C.

The unit is supplied with an 18 V/1.67 A power adapter with a power cord for the country of purchase, in accordance with European Commission regulations and British Standards. Use of any other electrical power cables, adaptors, or transformers is not recommended

3.3 Hazard Icons

The following symbols can be found at points throughout the rest of the manual. Note and read each warning before attempting any associated operations associated with it:

Table 3.1. Hazard warning labels used in this manual.

Symbol	Associated Hazard
	Electrical shock

3.4 General Hazards

Before installing or operating the Ossila Source Measure Unit, there are several health and safety precautions which must be followed and executed to ensure safe installation and operation.

3.5 Power Cord Safety

Emergency power disconnect options: use the power cord as a disconnecting method and remove from wall. To facilitate disconnect, make sure the power outlet for this cord is readily accessible to the operator.

3.6 Servicing

If servicing is required, please return the unit to Ossila Ltd. The warranty will be invalidated if:

- Modification or service has taken place by anyone other than an Ossila engineer.
- The Unit has been subjected to chemical damage through improper use.
- The Unit has been operated outside the usage parameters stated in the user documentation associated with the Unit.
- The Unit has been rendered inoperable through accident, misuse, contamination, improper maintenance, modification or other external causes.

3.7 Health and Safety – Servicing

Servicing should only be performed by an Ossila engineer. Any modification or alteration may damage the equipment, cause injury, or death. It will also void your equipment's warranty.

4. Requirements

The system requires a computer running Windows (Vista or newer) with an available USB (recommended) or network port. Further details are given in **Table 4.1**.

Table 4.1. Solar Cell I-V Test System requirements.

Monitor Resolution	• The software requires a monitor resolution of at least 1680 x 1050. I. The optimum resolution is 1920 x 1080.
Power	• The system requires an 18 V DC power supply. I. A power supply fitting this description is provided with the system.
USB	• To use the USB, your controlling device should support USB communication. I. A USB-B cable is supplied with system. II. *NOTE: The USB connection does not supply power to the system.*
Network	• The system should be connected to a network supporting 10/100Mbps transmission. • DHCP must also be running on the network, and available to the system for the device to operate properly. I. To check if DHCP is running on your network you should attempt to connect another device to the network (as you would connect to the system). II. If the device automatically obtains an IP address, then DHCP is working correctly.

5. Unpacking

5.1 Packing List

The standard items included with the Ossila Solar Cell I-V Test System – Automated are:

- The Ossila Solar Cell I-V Test System – Automated.
- 18 V / 1.67 A power adapter with a cord set specifically for the country of operation (UK, USA, EU, or AU).
- USB-B cable.
- USB memory stick pre-loaded with the user manual, USB drivers, quality control data, and software installer.

5.2 Damage Inspection

Examine the components for evidence of shipping damage. If damage has occurred, please contact Ossila directly for further action. The shipping packaging will come with a shock indicator to show if there has been any mishandling of the package during transportation.

6. Specifications

The Solar Cell I-V Test System – Manual specifications are shown in **Table 6.1**.

Table 6.1. Ossila Solar Cell I-V Test System – Automated specifications.

Voltage range	±333 µV to 10 V
Current range	±10 nA to 150 mA
Substrate Size	20 mm x 15 mm
Substrate Compatibility (T2003A)	S101 (OLED substrates)
Substrate Compatibility (T2003B)	S211 (PV substrates)
Substrate Compatibility (T2003C)	S171 (Pixelated cathode substrates)
Overall Dimensions	Width: 155 mm Height: 73 mm Depth: 316 mm

7. System Components

The Solar Cell I-V Test System – Automated is comprised of 3 items: the Solar Cell I-V Test System (**Figure 7.1**), power adaptor (**Figure 7.2**), and the Ossila I-V Curve software (**Figure 7.3**).

Figure 7.1. Solar Cell I-V Test System.

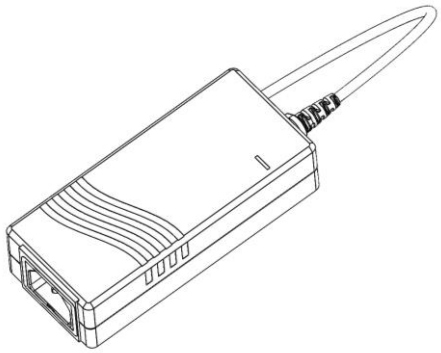

Figure 7.2. 18 VDC power adaptor.

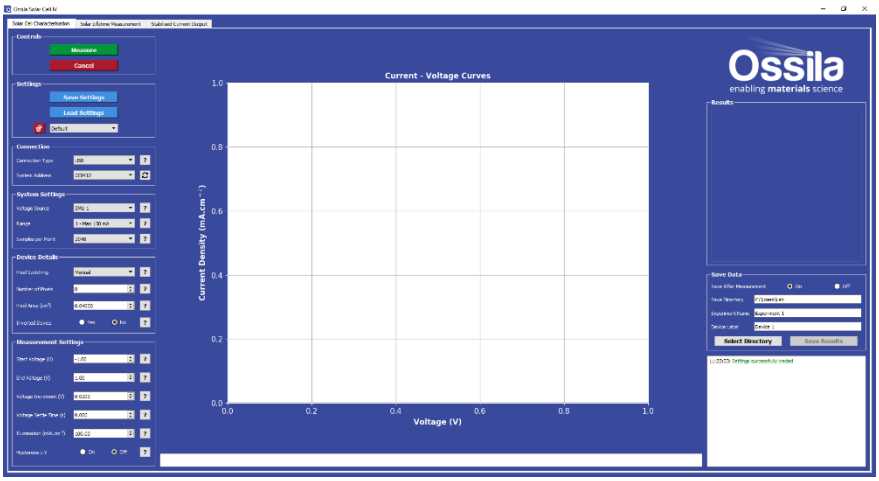

Figure 7.3. Ossila Solar Cell I-V software.

8. Installation

1. Install the Ossila Solar Cell I-V software on your PC.
    I. Run the file 'Ossila-Solar-Cell-IV-Installer-vX-X-X-X.exe' on the USB memory stick provided.
    II. Follow the on-screen instructions to install the software.
2. Install the Source Measure Unit USB drivers on your PC.
    I. On the USB memory stick provided, open the 'SMU-Driver' folder and run either 'Windows 32-bit SMU Driver' for 32-bit operating systems, or 'Windows 64-bit SMU Driver' for 64-bit operating systems.
    II. Note that, on Windows 10, the drivers will install automatically when the unit is connected.
    III. If the drivers fail to install, please refer to the SMU USB Driver Installation Guide found on the USB memory stick.
3. Connect the 18 VDC power adaptor to the power socket on the rear of the unit.
4. Connect the unit to your PC using the provided USB-B cable, or an Ethernet cable if preferred.
    I. If you are using a USB connection and the unit is not detected, please refer to the SMU USB Driver Installation Guide found on the USB memory stick.

Note: *The Ossila Solar Cell I-V software and Source Measure Unit USB drivers can also be downloaded from [https://www.ossila.com/pages/downloads.](https://www.ossila.com/pages/downloads)*

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9. Operation

9.1 Measurement Types

The Solar Cell I-V software can perform 3 different types of measurements. Each measurement type can be selected using the tabs at the top of the window. The available measurements are:

1. Solar Cell Characterisation (**Section 9.1.1**).
2. Solar Lifetime Measurement (**Section 9.1.2**).
3. Stabilised Current Output (**Section 9.1.3**).

Each measurement type requires several settings to be selected before it can be performed. Settings that are shared between all measurements are detailed in **Section 9.2**. Measurement-specific settings are detailed in **Sections 9.4**, **9.5**, and **9.6**.

9.1.1 Solar Cell Characterisation

The Solar Cell Characterisation tab performs current-voltage (I-V) measurement and analysis of solar cells. The analysis calculates the following properties:

- Power conversion efficiency (PCE)
- Fill factor (FF)
- Short-circuit current density (J_{sc})
- Open-circuit voltage (V_{oc})
- Shunt resistance (R_{sh})
- Series resistance (R_s)

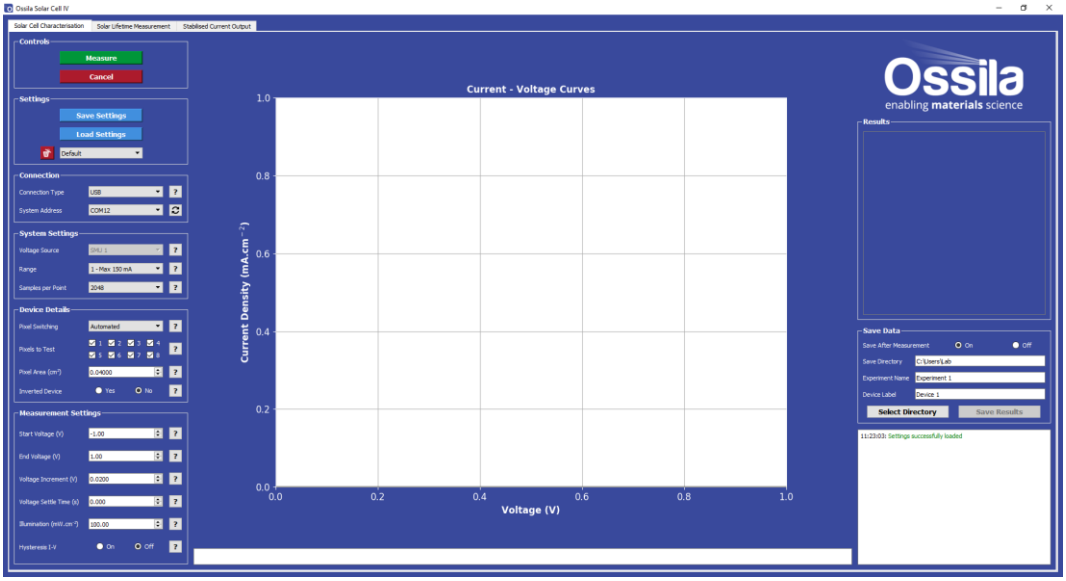


Figure 9.1. Ossila Solar Cell I-V software: The Solar Cell Characterisation tab.

9.1.2 Solar Lifetime Measurement

The Solar Lifetime Measurement tab tracks PCE, FF, J_{sc}, and V_{oc} over time by performing periodic I-V measurements and analysis. Between I-V measurements, the solar cell can be held at short-circuit, open-circuit, or maximum power.

Figure 9.2. Ossila Solar Cell I-V software: The Solar Lifetime Measurement tab.

9.1.3 Stabilised Current Output

The Stabilised Current Output tab lets you measure the evolution of the photogenerated current at specific voltages.

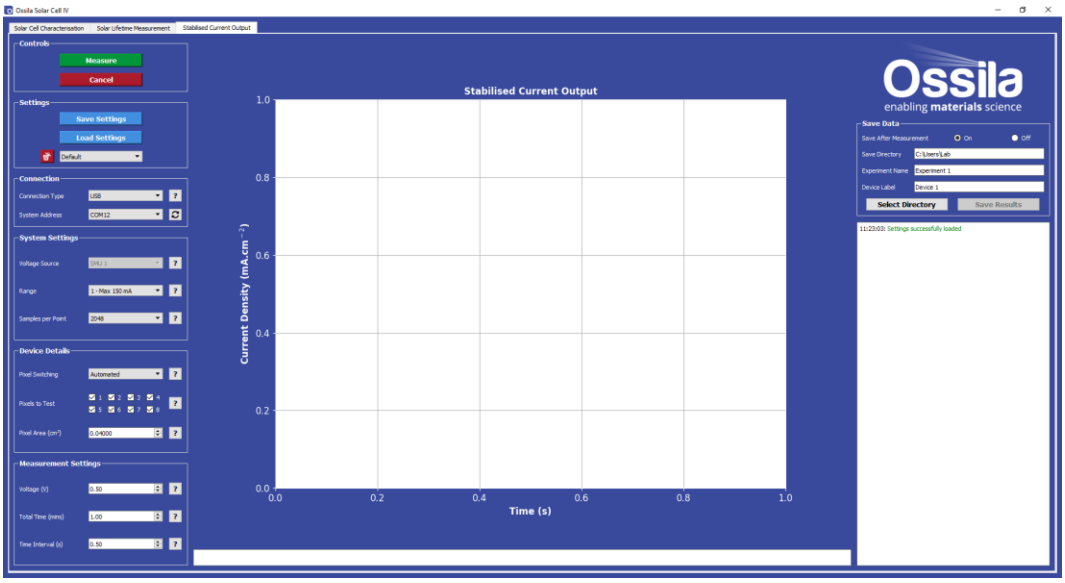


Figure 9.3. Ossila Solar Cell I-V software: The Stabilised Current Output tab.

9.2 Quick Start Guide

1. Start the Ossila Solar Cell I-V software. The window shown in **Figure 9.1** will open.
2. Choose a measurement type as described in **Section 9.1**.
3. Place your sample in the test board.
4. Place the test board beneath your solar simulator.
5. Set the appropriate settings in the software (explained in more detail in **Sections 9.4 - 9.8**).
    I. Set 'Pixel Switching' to 'Automated'.
6. Open the shutter of your solar simulator.
7. Click the 'Measure' button.
    I. For each pixel, measurements are performed using the chosen measurement settings.
    II. After the measurement has completed, the results are displayed in the central plot.
    III. This process is repeated until all pixels have been measured.
8. If automatic saving is turned on, the measurement data and settings will then be saved.

9.3 Shared Software Settings

The settings in these sections are shared between all measurement types.

9.3.1 Connection

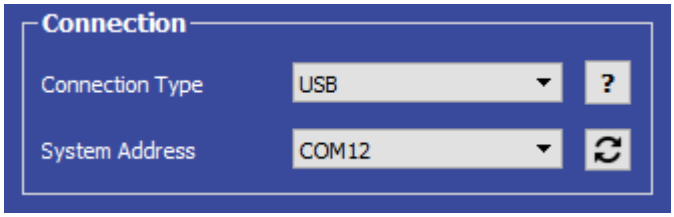


Figure 9.4. Connection settings.

(I) Connection Type

- Select the type of connection you are using (either USB or Ethernet).
    I. Any connected units will be automatically detected when a selection is made and the 'System Address' box will be populated.
- The software will search for units connected via USB on start-up.
    I. To rescan for connected units (in case the connection is changed), click the refresh icon next to the 'System Address' box.

(II) System Address

- Select the COM port or IP address of the connected unit you intend to use (USB and Ethernet connection respectively).
    I. This box will be populated automatically with the addresses of any units connected to the computer via the method selected in the 'Connection Type' box.

9.3.2 System Settings

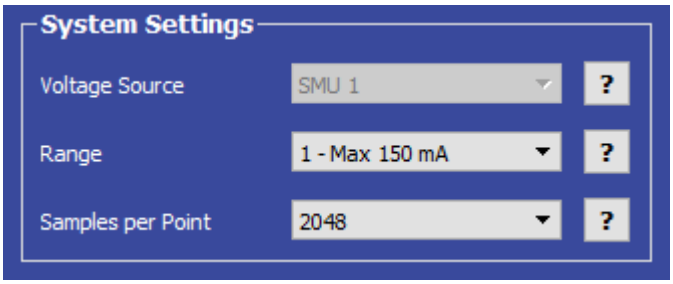


Figure 9.5. System settings.

(I) Voltage Source

- 'SMU 1' will be automatically selected when pixel switching is set to 'Automated'.

(II) Range

- Select the range of currents to be used for the measurement.
    I. This defines the upper limit and accuracy of current measurements that can be performed by the unit. The values for each range are given in **Table 9.1**.
    II. The maximum current values for each range are also shown in the range selection box.

Table 9.1. Maximum current and accuracy for the different range settings for the Ossila Solar Cell I-V Test System.

Range	Maximum Current	Accuracy
1	±150 mA	±200 µA
2	±20 mA	±10 µA
3	±2000 µA	±1 µA
4	±200 µA	±100 nA
5	±20 µA	±10 nA

(III) Samples per Point

- Select the number of samples to be taken for each measurement.
    I. A higher number of samples per point will improve the accuracy and precision of the measurement. However, this will increase the time taken for the measurement to be performed.

9.3.3 Device Details

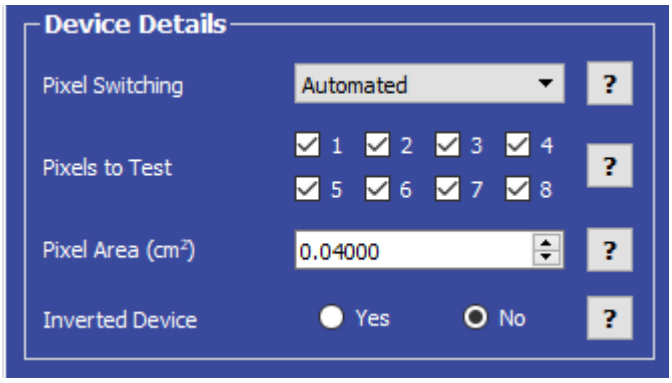


Figure 9.6. Device Details settings.

(I) Pixel Switching

- Select 'Automated' in the pixel switching setting.

(II) Pixels to Test

- Select which pixels to measure.
    I. The pixel numbers are labelled on the test board.

(III) Pixel Area

- Set the are in cm^2 of each pixel in the device.

(IV) Inverted Device

- Set whether the device to be measured is inverted.
    I. This option should be on if the anode of your device connects to the 'cathode' pins in the device holder.

9.4 Solar Cell Characterisation Settings

9.4.1 Measurement Settings

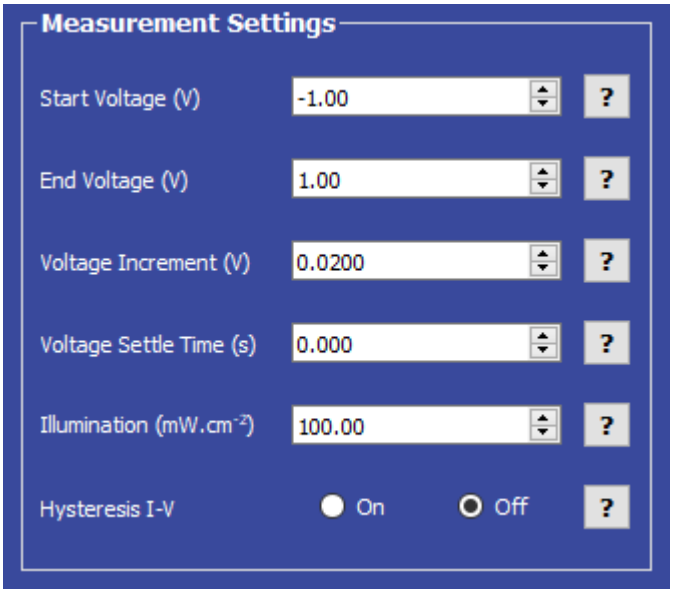


Figure 9.7. Measurement Settings for the solar characterisation and lifetime measurements.

(I) Start Voltage

- Set the voltage in volts at which to start the current-voltage measurement.
    I. This can be set between -10 V and +10 V.

(II) End Voltage

- Set the voltage in volts at which to end the current-voltage measurement.
    I. This can be set between -10 V and +10 V.

(III) Voltage Increment

- Set the step size in volts for changing the voltage during current-voltage measurement.

(IV) Voltage Settle Time

- Set the time in seconds between applying a voltage and measuring the current.
    I. This has a maximum of 10 seconds.

(V) Illumination

- Set the illumination intensity (in $mA.cm^{-2}$) being used during the measurement.

(VI) Hysteresis I-V

- This option performs a reverse current-voltage measurement after the forward current-voltage measurement has completed.
    I. This reverses the set start and end voltages and uses the same voltage increment and settle time as the forward measurement.

9.5 Solar Lifetime Measurement Settings

9.5.1 Measurement Settings

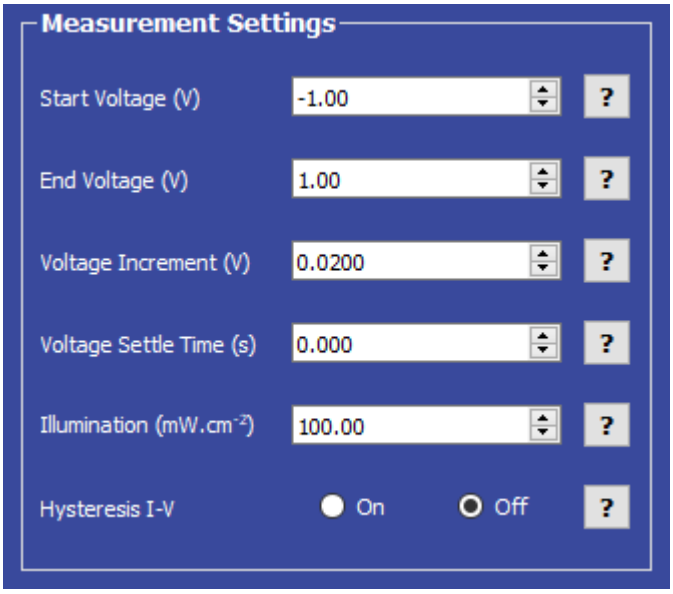


Figure 9.8. Measurement Settings for the solar characterisation and lifetime measurements.

(I) Start Voltage

- Set the voltage in volts at which to start the current-voltage measurement.
    I. This can be set between -10 V and +10 V.

(II) End Voltage

- Set the voltage in volts at which to end the current-voltage measurement.
    I. This can be set between -10 V and +10 V.

(III) Voltage Increment

- Set the step size in volts for changing the voltage during current-voltage measurement.

(IV) Voltage Settle Time

- Set the time in seconds between applying a voltage and measuring the current.

I. This has a maximum of 10 seconds.

(V) Illumination

- Set the illumination intensity (in $mA.cm^{-2}$) being used during the measurement.

(VI) Hysteresis I-V

- Set whether to perform a reverse current-voltage measurement after the forward current-voltage measurement has completed.
    I. This reverses the set 'start' and 'end' voltages and uses the same voltage increment and settle time as the forward measurement.

9.5.2 Lifetime Parameters

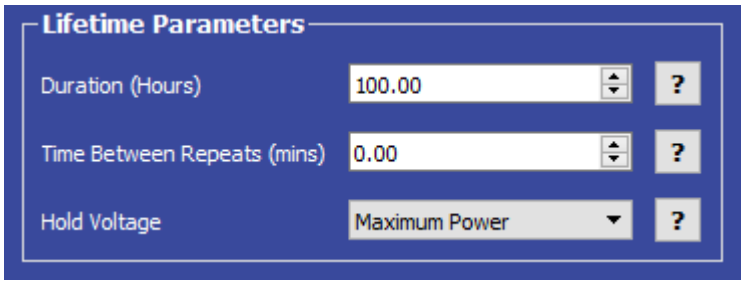


Figure 9.9. Lifetime Parameters settings.

(I) Duration

- Set the total duration in hours of the lifetime measurement.

(II) Time Between Repeats

- Set the time interval in minutes between performing repeat current-voltage measurements of the device.

(III) Hold Voltage

- Set the voltage that all pixels will be held at between measurements.
- This can be set as:
    I. Short-Circuit – hold at 0 V.
    II. Maximum Power – hold at the average maximum power point determined from most recent current-voltage curve.
    III. Open-Circuit – hold at the average open-circuit voltage determined from the most recent current-voltage curve.

Note: *As the voltage source is only a single channel, the hold voltage will be the same for all pixels being tested.*

9.6 Stabilised Current Output Settings

9.6.1 Measurement Settings

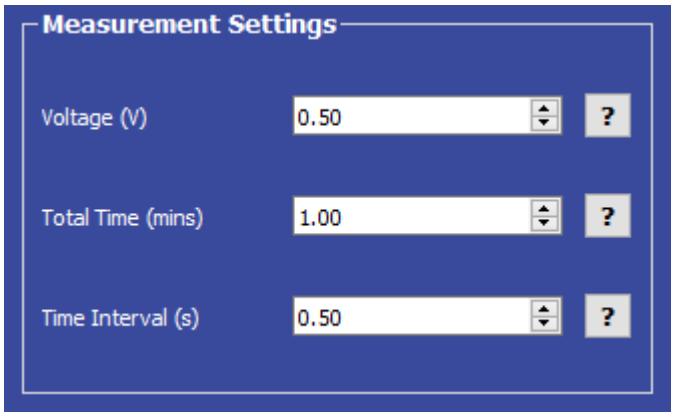


Figure 9.10. Experimental Parameters settings for the Stabilised Current Output.

(I) Voltage

- Set the voltage to apply to the sample for the measurement.
    I. This can be set between -10 V and +10 V.

(II) Total Time

- Set the total length of the measurement in minutes.

(III) Time Interval

- Set the time between each current measurement in seconds.
    I. This has a minimum of 0.1 seconds.

9.7 Saving and Loading Settings

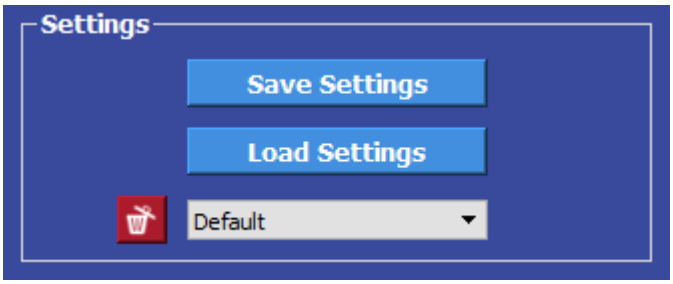


Figure 9.11. Controls for saving and loading settings profiles.

(I) Save Settings

- Saves the current settings as a profile that can be loaded quickly for use at another time.
- When clicked, you will be prompted to name the settings profile.
    I. If the name is already in use, you will be asked if you wish to overwrite the previous profile.
    II. The name cannot contain the characters: \ / : * ? " < > |
    III. You can change the default settings by choosing the name 'Default'.
- The settings profile will be added to the drop-down box using the given name.

(II) Load Settings

- Opens a dialog box to navigate to a settings file that has been created as part of a previous measurement.
    I. The settings fields will be populated with the values in the settings file.

(III) Settings Profiles

- Select a saved settings profile from the drop-down box.
    I. The settings fields will be populated with the saved values.
- Settings profiles can be deleted by selecting the profile, and then clicking the red 'delete' icon next to the drop-down box.

9.8 Saving Results

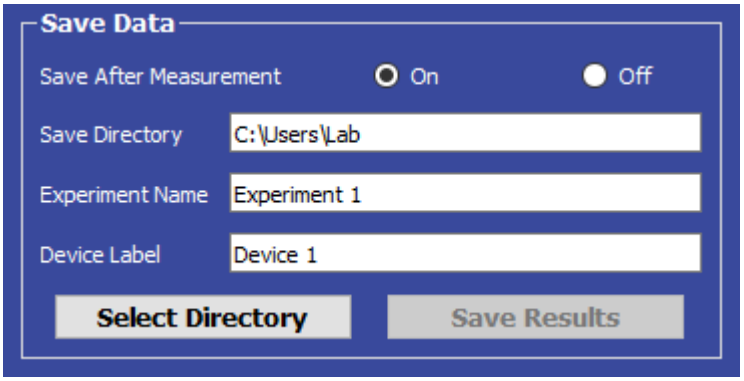


Figure 9.12. Saving measurement data settings.

(I) Save After Measurement

- Set whether the measurement data will be saved after the measurement has completed.

Warning: *Automatic saving can be turned off for lifetime measurements. However,* ***manual saving is unavailable for lifetime measurements****, so you will not be able to save your data if it is turned off.*

- The program allows for data to be saved automatically (and manually) once the measurement is complete.
    I. To enable or disable automatic saving, choose the appropriate option from the drop-down box.
    II. For automatic saving, the 'Saving' fields must be filled in before the measurement can start, these are detailed below.
    III. The 'Save Results' button is enabled once a measurement has been completed.
- For all measurements, a save directory must be specified. This can be done either by:
    I. Manually typing the directory into the 'Save Directory' field,
    II. Copy and pasting from your file explorer,
    III. Clicking the 'Select Directory' button, which will open a dialog box to allow the selection of a folder to save to.
- All output files are comma separated variable (.csv) files.

(II) Save Directory

- Set the directory in which to create the data files.
- This can be filled in by:
    I. Manually typing the directory into the 'Save Directory' field,
    II. Copy and pasting from your file explorer,
    III. Clicking the 'Select Directory' button, which will open a dialog box to allow the selection of a folder to save to.

(III) Experiment Name

- Set the name of the folder that the data will be saved into.
- For the solar cell characterisation measurements, this will also be used to name the file containing the device properties.
- This field cannot contain the following characters:
    I. \ / : * ? " < > |

(IV) Device Label

- Set the name of the device being tested.
- This is used to label the files for I-V data and measurement settings.
- This field cannot contain the following characters:
    I. \ / : * ? " < > |

(V) Save Data Format

- All data is saved as .csv (comma separated value) files.
- All data will be saved into a folder with the Experiment Name.
- The figures below show the files that are created when saving data for each of the measurements.

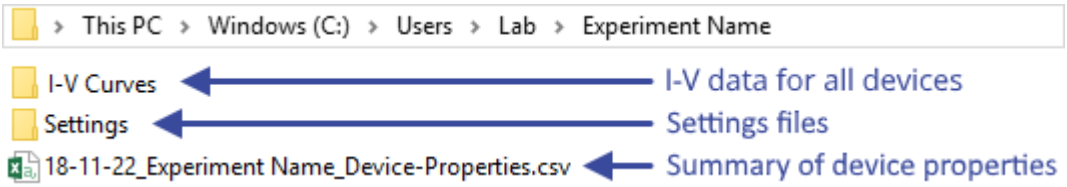


Figure 9.13. Solar Cell Characterisation save data format.

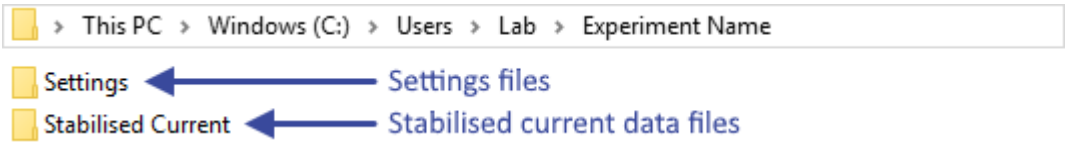


Figure 9.14. Stabilised Current Output save data format.

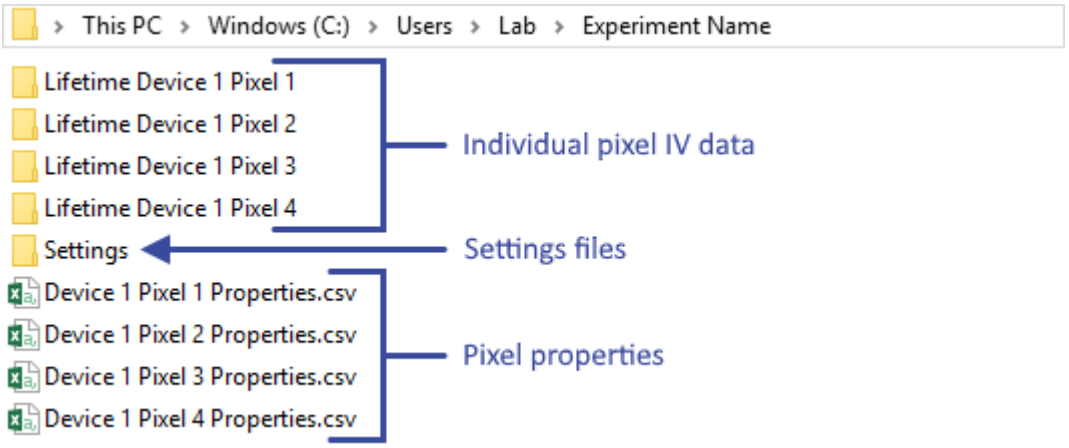


Figure 9.15. Solar Lifetime Measurement save data.

9.9 Controls

Figure 9.16. Controls for the measurements.

(I) Measure

- Clicking this button will start the measurement using the chosen settings.
- This button cannot be clicked if the software has not detected the test system.

(II) Cancel

- Stops a measurement that is currently in progress.
    I. Note that if the measurement is stopped before it completes, the user will be unable to save the experimental data.

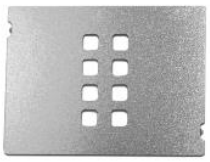
10. Troubleshooting

Most of the issues that may arise will be detailed here. However, if you encounter any issues that aren't in this list, please contact us by email at info@ossila.com, and we will respond as soon as possible.

Problem	Possible Cause	Action
No power	The power supply may not be connected properly.	Ensure the system is firmly plugged into the power supply, and that the plug is connected to both the adaptor and a working power socket.
	The power supply adaptor has a fault.	Contact Ossila for a replacement power supply adaptor.
Software does not start	The wrong version of Windows is installed on the computer.	Install the software on a computer with Windows Vista or newer.
	The software has not installed properly.	Try reinstalling the software.
Cannot connect to the system via USB	The USB cable may not be connected properly.	Ensure the USB cable is firmly plugged in at both ends.
	The USB cable may not be connected to a working USB port.	Try connecting the unit to a different USB port on the computer.
	The USB drivers may not be installed, or may not have installed properly.	Try installing or reinstalling the USB drivers. If the drivers on the USB provided are not working, try following the Windows 7 installation instructions found in the Installation Guide.
	The USB cable is defective.	Try using a different USB-B cable, and contact Ossila if necessary.
Cannot connect to the system via network	The MAC address of the unit is not registered with the internal network.	Register the system on the network using the MAC address obtained via a USB connection (see Source Measure Unit manual).
	The Ethernet cable may not be connected properly.	Ensure the Ethernet cable is firmly plugged in at both ends.
	The Ethernet cable is defective.	Try using a different Ethernet cable.

11. Related Products

ITO Glass - Photovoltaic Substrates (8 Pixel) – S211

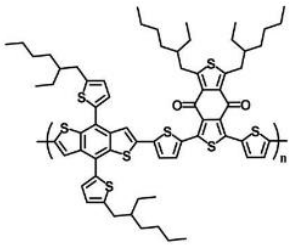


Measurement Aperture Mask for Photovoltaic Substrates (8 Pixel) – E521

ITO Substrates for OLEDs (Pixelated Anode) – S101

Spin Coater – E441

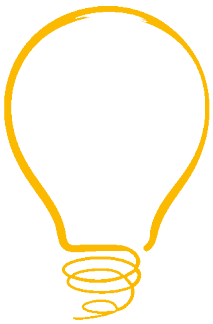
Perovskite Precursor Ink (for Air Processing) – I101



PCE12 (PBDB-T) – M1001

12. Revision History

Rev	Date	Description
A	Dec 2018	Initial version



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