Illuminated JV – Setup and Measurement

In the first video about the illuminated JV characterisation method we have discussed the purpose of the measurement, the most commonly adopted conditions for terrestrial applications, and the requirements and classification system for solar simulators. In this video we will show a typical illuminated JV testing setup, and we will discuss the various components in detail. Secondly we will demonstrate the measurement procedure on a lab-scale solar simulator setup.

This diagram shows an overview of a typical illuminated JV curve measurement system. First of all it requires a single light source or combination of multiple light sources, to simulate the spectral intensity of the sunlight accurately. Typically the light source is a xenon arc lamp. By modifying the xenon lamp using certain filters to remove the high intensity emission lines in the infrared region, it simulates the solar spectrum more accurately. With halogen lamps it is also possible to match the solar spectrum, mostly combined with a xenon lamp. Halogen lamps are an improved type of incandescent bulb and produce a black body radiation spectrum with a filament temperature of about 2800 kelvin. Halogen lamps are more stable than xenon arc lamps. However, the temperature of the tungsten filament is much lower than the surface temperature of 5800 kelvin of the sun. Therefore it lacks intensity in the UV region and must be filtered in the infrared. More frequently also different colours of high power L_E_Ds are used to build class triple A solar simulators. This spectrum shown here is a combination of 19 different LED types placed in an array.

Please note that any deviation from the AM1.5 spectrum will influence the charge-carrier generation profile in the solar cell under test, since this generation profilel is directly influenced by the wavelength dependent photon flux and not so much by the total incident light intensity. Therefore the obtained JV curve should be corrected with for instance an external quantum efficiency measurement, as we will explain in another video.

The light of the solar simulator can be blocked by a shutter to stop the lamps from heating the solar cell prior to taking the measurement. The solar cell is placed on a stage attached to a liquid cooling system that keeps the stage at 25 degrees celsius. The temperature of the stage is monitored by a temperature probe. The highest accuracy JV curve is obtained by a 4 point probe measurement, meaning that separate sets of probing wires are used for supplying the voltage and collecting the current. In a simple 2-probe measurement, the voltage and current will be sensed through the same wires at the same time. This implies that the inevitable contact resistance and voltage drop across the wires is not accounted for and the measurement will be inaccurate. A quick calculation shows what current flows we can expect from a single 6 inch crystalline silicon wafer based solar cell under 1 sun illumination. The short-circuit current density of a good performing cell can be up to 40 milliamps per square centimeter. With an area of about 225 square centimeters, this gives a total of 9.6 amps of current! When this current runs through the wires that are used to accurately apply a given voltage, the actual voltage across the solar cell will not be accurate.

With a 4 point probe measurement, the voltage supply and sourcemeter are attached to the solar cell with separate pairs of wires. This makes it possible to apply the voltage very accurately, since there will not be any current flowing through these wires. All the current will flow through the sourcemeter, since this device has a very low internal resistance compared to the DC voltage supply.

We have now discussed the most important elements of an illuminated JV testing setup. But before we can take the actual measurement, we need to calibrate the light source to ensure the measurement will be taken under AM 1.5 illumination at one thousand watts per square meter.

In order for a light source to operate at a stable light intensity, it needs to work at a constant temperature and power. Therefore the light sources need to warm up before a measurement can be taken. When the lamps are operating at stable conditions, their intensity needs to be checked since the light intensity of a lamp will typically degrade over time. This requires the use of reference cells that have a known and well calibrated spectral response. Based on the output current and voltage of these reference cells, the power supplied to the light sources can be adjusted.

We will now demonstrate how a typical illuminated JV measurement is performed on a lab-scale solar simulator system.

Here we see a lab-scale dual-beam solar simulator with a xenon and halogen lamp for measuring accurate illuminated JV curves using the 4-point probe method. The system can measure two different solar cells at the same time.

This is the system rack which holds the power electronics and measuring devices. The lamps are powered by separate power supplies, which keep track of the lamp lifetime. The power fed to the lamps can be adjusted individually. The voltage is supplied by a fast scanning measuring device, while the current data is taken by an accurate sourcemeter.

The water cooling system keeps the temperature of the stage at 25 degrees celsius.

First the spectral intensity of the lamps will be checked with two reference cells. Their calibrated spectral response gives little room for error, since the open circuit voltage and short circuit current are allowed to have only a small deviation. When the stage is at the right temperature, these values should be met, or changes to the lamp power should be made.

After placing the solar cell under test, the front contact probes for voltage and current are placed on the busbars of the cells.

The gold plated surface of the stage serves as current collector, while the voltage probes contact the cells separately and are isolated.

Upon taking the measurement, the shutter is shortly opened to limit heating of the cells. Now the voltage will be sweeped and current measurements are taken at each step. This goes rather quick.

The resulting illuminated JV curve will appear on the computer screen, accompanied by all the parameters that can be derived from the graph.

To summarise this video, we have discussed that an accurate AM 1.5 spectrum can be obtained by combining different light sources, applying filters and even by using various colours of high power L_E_Ds. The current that is produced by a single wafer can be significant, which is why the 4-point probe method should be adopted to overcome measurement inaccuracy. Finally we have discussed that the spectral intensity of the solar simulator should be checked with calibration cells before taking a measurement, since the output power and spectrum of the lamps will degrade over time.