Measuring the optical properties of photovoltaic cells using the Agilent Cary 5000 UV-Vis-NIR spectrophotometer and the External DRA-2500

Application Note

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Introduction

The term 'photovoltaic' stems from the Greek word for light (photo) and the physicist Volta# (the inventor of the electric battery). It is applied to the direct conversion of sunlight into energy by means of solar cells. The conversion process is based on the photoelectric effect (discovered by Bequerel* in 1839), which involves the release of positive and negative charge carriers in a solid when light strikes its surface.

Solar cells are composed of various semi-conducting materials, with the majority (>95%) of solar cells manufactured made primarily of silicon. To produce a solar cell, the semiconductor is 'doped'. Doping involves the intentional introduction of other elements, with the aim of obtaining a surplus of either positive (p) or negative (n) charge carriers within the semiconductor material. When two differently contaminated semiconductor layers are combined, a so-called 'p-n' junction results at the boundary of the layers. This junction results in an electric field which leads to the separation of the charge carriers that are released by light. By using metal contacts, an electric charge can be drawn and, if the outer circuit is closed, direct current flows. Silicon solar cells are generally 10 × 10 cm in size, with a transparent anti-reflection (AR) coating used to protect the cell and decrease reflective losses on the cell surface. Figure 1 shows a schematic diagram of a typical photovoltaic cell.

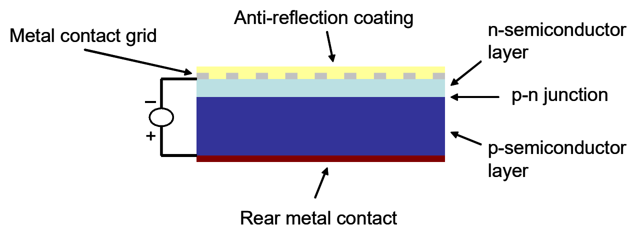

Figure 1. Schematic diagram of a typical solar cell

In any photovoltaic cell, the current intensity obtained increases with higher light flux. And, whilst many factors can affect the efficiency of a particular cell, reflectance of light at the surface of the cell is a parameter of obvious importance. To perform these types of reflectance measurements a high-performance UV-Vis-NIR spectrophotometer equipped with integrating sphere is required. An integrating sphere is designed to collect reflected radiation (diffuse or total) from a solid surface (such as a photovoltaic cell). Using the appropriate sampling geometry, integrating spheres can also be used for the measurement of the diffuse transmission properties of solar cells.

This paper will demonstrate how the reflectance properties of a solar cell and its precursors can be measured at various stages of the manufacturing process using a Cary 5000 UV-Vis-NIR spectrophotometer equipped with an External Diffuse Reflectance Accessory 2500 and Small Spot Kit attachment.

Instrumentation[1]

- Agilent Cary 5000 UV-Vis-NIR spectrophotometer
- Agilent External DRA-2500
- Small Spot Kit attachment

Conditions

The External DRA-2500 was installed into the spectrophotometer and aligned[2]. UV-Vis-NIR spectra were, in general, acquired in the region 250-2500 nm using appropriate baseline correction (Zero/baseline correction). Indicative instrumental parameters were as follows: 2 nm SBW, 0.1 s SAT, 1 nm data interval (UV-Vis) and Energy 3, 0.2 s SAT, 3 nm data interval (NIR); 'double-beam' mode using full slit height. The reflectance spectra were collected using a Cary 5000 UV-Vis-NIR spectrophotometer equipped with an External DRA-2500 and a Small Spot Kit when small beam images were required.

Discussion

Figure 2 shows diffuse reflectance spectra of the finished solar cell and its precursors. Obvious spectral differences are evident between the uncoated, textured wafer (TS3), the AR coated wafer (TS2), and the 'finished' wafer (TS4) with metal contact grid (see Figure 3). The spectra were acquired at two different locations on each sample to test for surface homogeneity.

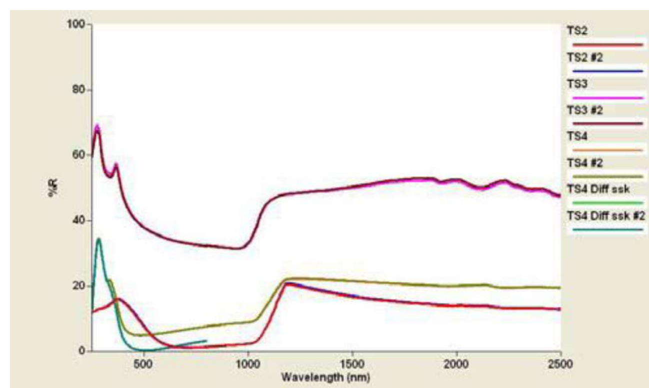

Figure 2. UV-Vis-NIR diffuse reflectance spectra of solar cells

Figure 3. A finished solar cell with metal contact grid and anti-reflection coating

Furthermore, additional differences are evident between the 'average' reflectance spectrum of the finished cell (TS4; where the area sampled includes both cell surface and metal contact grid), and the spectrum of the cell surface only (TS4 Diff ssk; without reflectance contribution from the reflective metal contacts). This highlights the advantage of being able to reduce beam size to the point where it is small enough (~1 mm diameter) to allow the collection of spectra from an area between the metal contacts of the grid itself. Not surprisingly, the results confirmed the relatively high reflectivity of the metal grid compared to the 'active' surface of the cell itself.

Conclusion

Both the reflectance and transmission properties of solar cells are readily measured using UV-Vis-NIR spectrophotometry. Using a high-performance spectrophotometer (such as the Cary 5000) equipped with integrating sphere permits the fast acquisition of high quality spectra (high resolution, low noise).

For the measurement of small areas of solar cells, some type of focusing optics are required to reduce the size of the beam image focused on the sample surface. The External DRA-2500 with Small Spot Kit attachment available from Agilent allows such measurements to be made.

References

1. Part numbers :

Product	Part Number
Agilent Cary 5000 UV-Vis-NIR spectrophotometer	0010079300
External DRA-2500	0010082000
Small Spot Kit	7910047200

2. Cary WinUV Software, online help, Version 3.0.

Allssandro Volta (1745–1827)

* Alexandre-Edmond Bequerel (1820–1891)

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