

Application News

No. A483

Spectrophotometric Analysis

Band Gap Measurement of Polycrystalline Silicon Wafer

In the research and development of semiconductors, one of the fundamental physical quantities that are typically measured is band gap, as it is used to help determine electrical conductivity. The band gap of silicon wafer is located in the approximate wavelength range of 1000 – 1200 nm. When measurements are conducted using a typical ultraviolet-visible-near-infrared (UV-VIS-NIR) spectrophotometer, noise is easily generated due to the reduced sensitivity of the detector in this region. To satisfy the demand for a detector with greater sensitivity in this wavelength region, we developed the MPC-603 large sample compartment with built-in integrating sphere containing three detectors, thereby achieving high-sensitivity measurement over the entire region from the ultraviolet to the near-infrared wavelengths. Here, using the band gap calculation Excel spreadsheet macro (option), we introduce an example of band gap determination in a polycrystalline silicon wafer commonly used in solar cells, etc.

■ Measurement and Results

The MPC-603 large sample compartment is equipped with an integrating sphere with three built-in detectors, including a photomultiplier tube, InGaAs and PbS detectors. Conventional instruments conduct measurements over all regions by relying on two detectors; a photomultiplier tube with sensitivity in the ultraviolet and visible regions and a PbS detector for sensitivity in the near-infrared region. The problem with this configuration, however, has been the drop in sensitivity at the wavelength switching region of the two detectors. Here, with the newly added InGaAs detector with sensitivity in that particular wavelength region, high-sensitivity detection becomes possible across the entire measurement regions.

A UV-3600 Plus UV-VIS-NIR spectrophotometer and MPC-603 large sample compartment were used to conduct total transmittance measurements of a polycrystalline silicon wafer. The system comprising the UV-3600 Plus with the attached MPC-603 large sample compartment is shown in the photograph of Fig. 1. For comparison, measurement was also conducted in the same manner using the conventional configuration with two detectors. Fig. 2 shows the overlaid spectra measured using both systems, and Fig. 3 shows a magnified view of a selected region of those spectra. Also, Table 1 shows the analytical conditions. In the wavelength region of 800 nm – 1000 nm, it is clear that very little noise is generated with the MPC-603 as compared with the conventional system.



Fig. 1 UV-3600 Plus with Mounted MPC-603

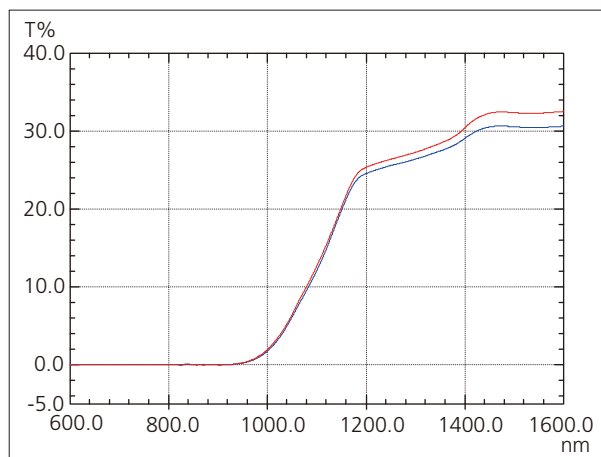


Fig. 2 Transmittance Spectra of Sample Measured with MPC-603 and Conventional System with Two Detectors (Blue: MPC-603, Red: Conventional System)

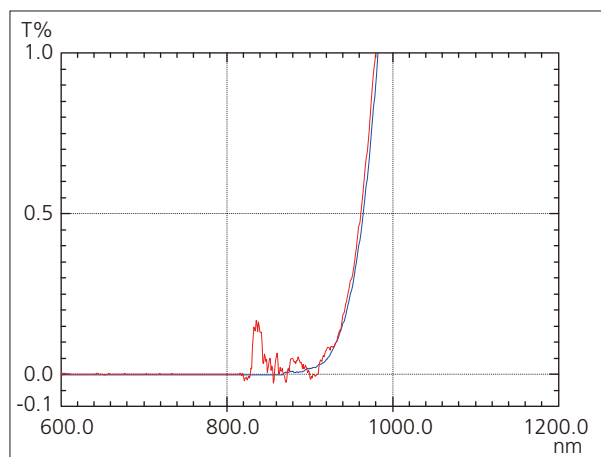


Fig. 3 Enlarged Spectra of Fig. 1 (Blue: MPC-603, Red: Conventional System)

Table 1 Analytical Conditions

Instrument	: Shimadzu UV-3600 Plus UV-VIS-NIR spectrophotometer MPC-603 large sample compartment
Measurement Wavelength Range	: 600 nm – 1600 nm
Scan Speed	: Medium
Sampling Pitch	: 1.0 nm
Photometric Value	: Transmittance
Slit Width	: (20) nm
Detector Switching Wavelength	: 870 nm, 1650 nm

■ Calculation of Band Gap

Using the Excel band gap calculation macro, we calculated the band gap by the Tauc plot method.

The measured spectrum is converted to a Tauc plot curve, and a tangent line is drawn at the inflection point. The intersection point (eV value) of the tangent line and the horizontal axis represents the band gap value. Fig. 4 shows the tangent line that was drawn using the conventional system, and Fig. 5 shows the tangent line drawn when measurement was conducted using the MPC-603. It is difficult to draw a tangent line in data obtained using the conventional system due to the excessive noise, but a smooth tangent line can be drawn on the data generated using the MPC-603 with its three detectors. The silicon wafer band gap value was calculated to be 1.15 eV using the Excel band gap calculation macro with the data obtained using the MPC-603.

For further details regarding the Tauc plot method, refer to Application News A428, "Measurements of Band Gap in Compound Semiconductors," and for further information regarding the Excel band gap calculation macro, refer to Application News A460, "Measurement of Band Gap for Titanium (IV) Oxide."

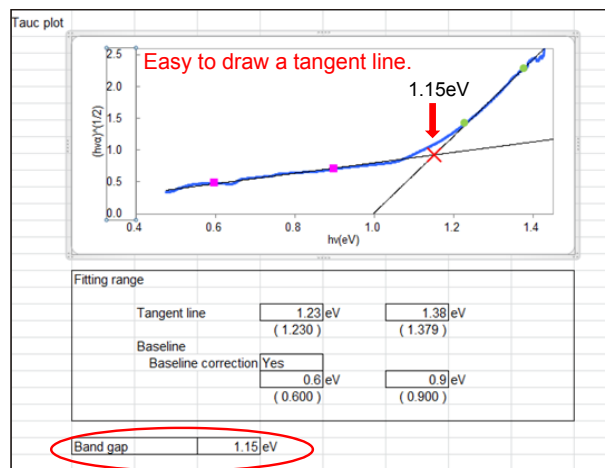


Fig. 5 Tangent Line Obtained Using a Spectrum Measured with MPC-603

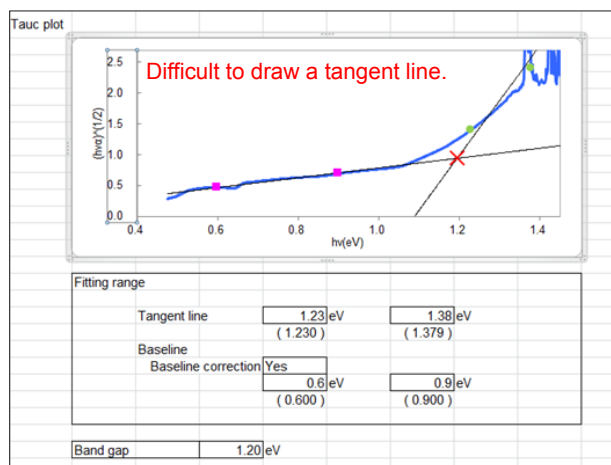


Fig. 4 Tangent Line Obtained Using a Spectrum Measured with a Conventional System

■ Conclusion

We determined the band gap for polycrystalline silicon wafer using the MPC-603 with its built-in integrating sphere containing three detectors. Compared to band-gap determination using the conventional two-detector system, determination using the MPC-603 was found to be more accurate. Further, the MPC-603 proved to be useful for high-sensitivity measurement in the near-infrared region.