Optical Detection of EVA Gel Content in PV Modules

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Introduction
Reliability of the PV modules is the key to the future of PV technology in which the encapsulant material plays a major role. Currently, ethylene vinyl acetate (EVA) is the most common material in the market and the gel content of EVA is influencing the adhesion, optical and mechanical performances of the PV modules. In order to fulfill these requirements, the minimum gel content of EVA is reported to be 80%. Currently destructive methods for the determination of the EVA gel content exist in the market, which are Soxhlet Extraction, Differential Scanning Calorimetry (DSC) and Dynamic Mechanical Analysis (DMA). Related to this, a fast and non-destructive method is required to enable in-line analysis of EVA gel content. Regarding that, optical detection of the EVA gel content is a promising method.

Destructive Methods

Soxhlet Extraction
Extraction of the organic compounds within the sample. Ratio of the final mass to the initial mass provide the gel content:

- Reliable method
- Destructive method, time consuming (24 h)

DSC
DSC monitors the exothermic thermal decomposition of the remaining peroxide content in the EVA to determine the gel content:

- Fast and reliable method
- Destructive method

DMA
Cross-linking would change the dynamic modulus of the material. DMA detects the increase in the network density that imply the gel content:

- Fast and reliable method
- Destructive method

Non-Destructive Method For Transparent Modules

- Crystalline and amorphous phases of EVA possess different refractive indexes.
- Crystalline parts scatter light diffusely at certain wavelengths.
- As the EVA gel content increases, crystalline parts are contracting that implies a decrease in the haze of the material.

This method monitors the haze factor of EVA in transmission mode in order to determine its gel content:

- Fast and non-destructive
- Valid only for transparent modules

Homogeneity of Heating Plate

- 20 points were investigated along the heating plate by PT100 sensor at 140°C (Figure Left).
- Uniform temperature profile along the heating plate with only a deviation of ±1°C obtained (Figure Right).
- Partial conclusion: The heating plate is homogeneous.

Homogeneity of EVA Gel Content

- Optical measurements could be conducted independently of the location on the sample, which is crucial for the reproducibility of the measurements.
- 5 samples were investigated: Fresh (directly cut from the roll), 0s (only preheating), 300s, 600s and 900s cured EVA.
- 16 points have been selected along each film and they were analyzed by DSC between the temperature interval of 110-195°C.

- Inhomogeneity of the Fresh EVA would have caused the rest of the measurements to be pointless: Inhomogeneous peroxide distribution.
- Small variations: Average enthalpy value of 15.93 J/g with a deviation of only ±0.39 imply homogeneity of the Fresh EVA sample (Figure Up).
- Average Enthalpy [J/g] (Deviation) respectively for 0s, 300s, 600s and 900s cured samples: 17.1 (±0.51), 13.26 (±0.68), 7.58 (±0.42), 5.45 (±0.49) (Figure Up).

- Each sample set possesses homogeneity in the distribution of EVA gel content with only small deviations (Figure Up).
- Partial conclusion: Optical measurements at different locations on a sample would give similar results.

Conclusion

- Optical detection of EVA gel content can lead up an in-line analysis of the modules in a fast and non-destructive way.
- Homogeneity of EVA gel content along a sample ensures that optical detection can provide reliable results.
- Optical methods should cover both transparent and non-transparent PV modules.