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Blunt, Liam and Elrawemi, Mohamed

Functional Modelling of Water Vapour Transmission through Surface Defects Using Surface Segmentation Analysis

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Flexible Photovoltaic (PV) modules are manufactured using roll to roll (R2R) technology. These modules require a flexible barrier material to prevent water vapour ingress into the core material.

Thin-Film Flexible PV Modules

Flexible solar modules comprise four functional layer groupings. The main focus of the investigation in this work is the barrier layer, which is incorporated in the encapsulation layers. This layer is typically formed from a planarised Polyethylene Naphthalate (PEN) sheet with an amorphous Al2O3 barrier coating (≤40 nm thick).

R2R Al2O3 ALD Barrier Film

Thin layers of aluminum-oxide, of the order of a few tens of nanometers deposited via R2R atomic layer deposition (ALD) method, have been introduced to allow PV modules transparency and flexibility and to provide an effective barrier layer.

Mathematical Model

The basic assumption of the model is that, the combined film of thickness L has a transparent flexible barrier coating of (Al2O3) with a single circular hole (defect), and that it is exposed to permeant water vapour from the lower side. This orientation is consistent with that used in a MOCON® test.

Permeability coefficient = \( \frac{(\text{quantity of permeant}) \times (\text{film thickness})}{(\text{area}) \times (\text{time}) \times (\text{pressure drop across the film})} \) (1)

\( P_L = \frac{D \times S}{T} = \frac{\frac{\pi D^2}{4}}{L} \times \frac{D}{L} \times P_d \) (2)

\( Q = \frac{g}{A} = \frac{\pi D^2}{L} \frac{D}{L} \) (3)

\( \text{WVTR} = \frac{Q}{A} \) (4)

Results

The results seem to show that for the barrier coating a small number of large defects dominates the WVTR, and thus these defects should be the focus of any detection system.

Conclusion

The segmentation analysis method and the theoretical model results, both indicate that the major contributing factor for determining the WVTR is the total number of larger defects, where the sample with higher density of defects > 3 μm (lateral diameter) exhibit inferior barrier properties. Therefore, the critical spatial resolution required for defect detection need not be less than 3 μm, as any defect that has less than this lateral size seems to have a much lower effect on the barrier properties.

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References

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