Solution Series 13

Exercise 1: Module technology

a) What are the advantages and the drawbacks of a glass-glass laminate compared to a glass-backsheet laminate?

Solution:

The glass-glass laminate wins in terms of mechanical solidity. However, the glass-backsheet laminate shows a better protection against water ingress and corrosion, as it enables the modules to breathe and eliminate a part of the adsorbed water vapor. In contrast to glass-backsheet, water can enter a glass-glass laminated module by the side and diffuse even further, unable to escape. As it propagates to the center it will strongly influence the device performance.

b) Is it ideal to have a perfectly airtight laminate (for instance glass-glass laminate and waterproof seals on the sides)?

Solution:

In theory it should be better to have a perfectly airtight laminate as no water vapor could enter the module. However, in practice it is very difficult to have a perfectly airtight laminate. The risk is that, if the seal breaks in a small localized region, the water vapor could enter through this leak and would be very difficult to eliminate from the module, thus creating corrosion or delamination.

c) What could we change or improve to speed up PV encapsulation processes?

Solution:

The time consuming process step is the curing of the polymer under high temperature. If there was a possibility to polymerize under ambient temperature, for instance by exposition to UV, it would increase the throughput of the whole process.

d) What would be the properties of the "ideal" encapsulant?

Solution:

First, it should be transparent, light, and age without degradation. Secondly, the adherence to the glass and TCO should be good. Last, the encapsulation process should work at ambient temperatures, for manufacture throughput.

e) What is the role of the frame in a module?

Solution:

It provides mechanical rigidity, watertightness, and airtightness.

f) Modules found on the market for building integration are often criticized for being anaesthetic, what would you change to improve it?

Solution:

The color aspect could be changed, for example, by using a different anti-reflection layer. If the reflection is diffuse, then it is more pleasant for the eyes, and therefore texturing of wafers is important for aesthetics. Furthermore, if a roof is entirely covered by solar modules it looks nicer than a partially covered roof.

g) Presently, modules have 20 years of warranty; if we want to push it over 30 years the modules reliability, on what aspects will need further developments?

Solution:

The main problem that remains is the water ingress in the modules. The encapsulation should therefore focus on better ways to manage this problem. Another solution could be to have TCO's which are less sensitive to water exposure.

Exercise 2: Polymer and water vapour

The diffusion of water vapour inside a polymer follow Fick's law for a semi infinite medium with an inexhaustible source of diffusive particles. Therefore the concentration of water vapour inside the polymer can be expressed as follow:

$$c(x,t) - c_i = (c_s - c_i)(1 - erf(\frac{x}{2\sqrt{Dt}}))$$

where x is the distance from the open edge, t is the time of vapour exposure, $c_{s(i)}$ is the saturation (initial) concentration.
If we take the following example: 85 °C, with a high relative humidity of 85 % the diffusion constant is around $D = 6.3 \times 10^{-6}\,\mathrm{cm^2\,s^{-1}}$, $c_s = 0.0055\,\mathrm{g\,cm^{-3}}$, $c_i = 0.0004\,\mathrm{g\,cm^{-3}}$ calculate the typical concentration at 1 cm from the front edge after 6 weeks (typical test for an encapsulant). How close is the module to reaching its saturation concentration?

Solution:

Solution: $0.0049\,\mathrm{g\,cm^{-3}}$
The module is 89% saturated (1cm from the edge) after just 6 weeks!