

# Analysis of material and module parameters and correlation to degradation modes (ESR\_2)

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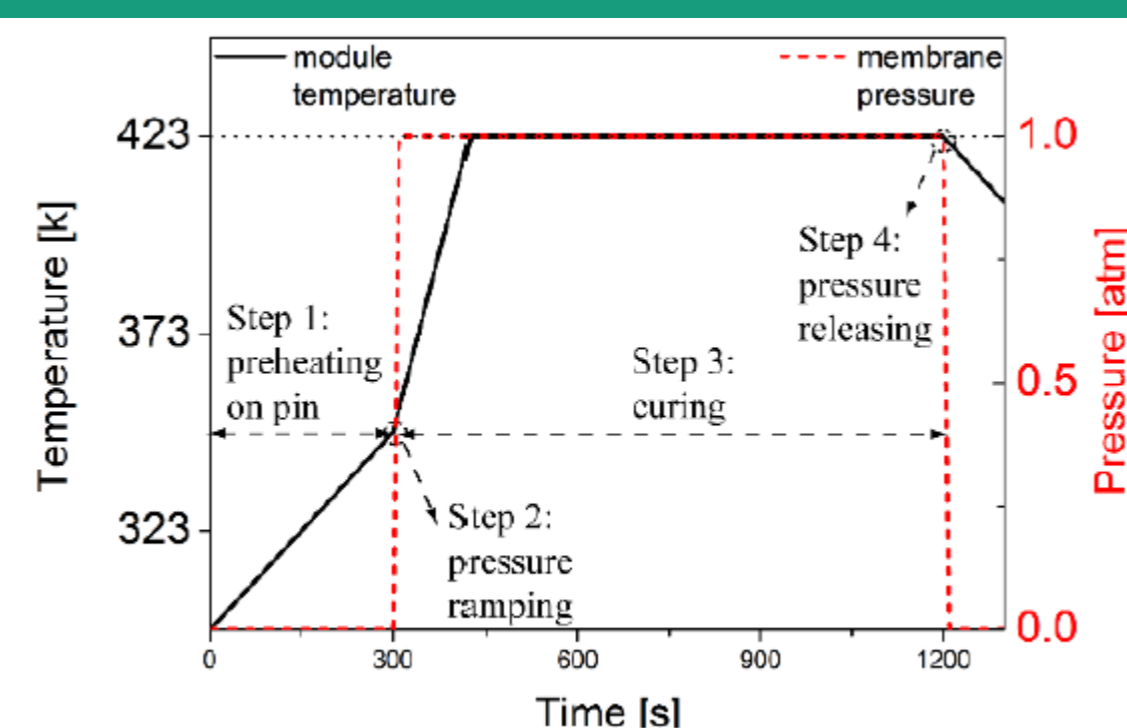
## FROM PV MATERIALS TO PV MODULES PARAMETERS

- Surface interactions of different material combinations
- Effect of additives (crosslinking promoter, UV stabilizer, antioxidant, coupling agent)
- Material properties:
  - Adhesion bonding
  - Transparency of the encapsulant
  - Viscoelasticity of polymeric materials
  - Permeability of water vapor and oxygen

## MANUFACTURING PROCESS

### Lamination parameters

- Duration
- Curing temperature
- Pressure
- Cooling press



Temperature and pressure profiles of a standard EVA encapsulation process (Li, H.-Y., et al. 2014)

## ACCELERATED AGING PROCEDURES

- Single stresses
- Thermal cycling
  - Mechanical loading
  - UV radiation
  - Electrical insulation
  - Potential Induced Degradation PID



Mechanical load test of PV module

- Combined stresses
- Light and temperature
  - UV radiation and damp-heat
  - Mechanical load at low temperature



Climate chamber with combined light / temperature stress

To identify degradation mechanisms, the analytical methods will be used before and after accelerated aging

## CHARACTERISATION OF MATERIALS IN PV-MODULES

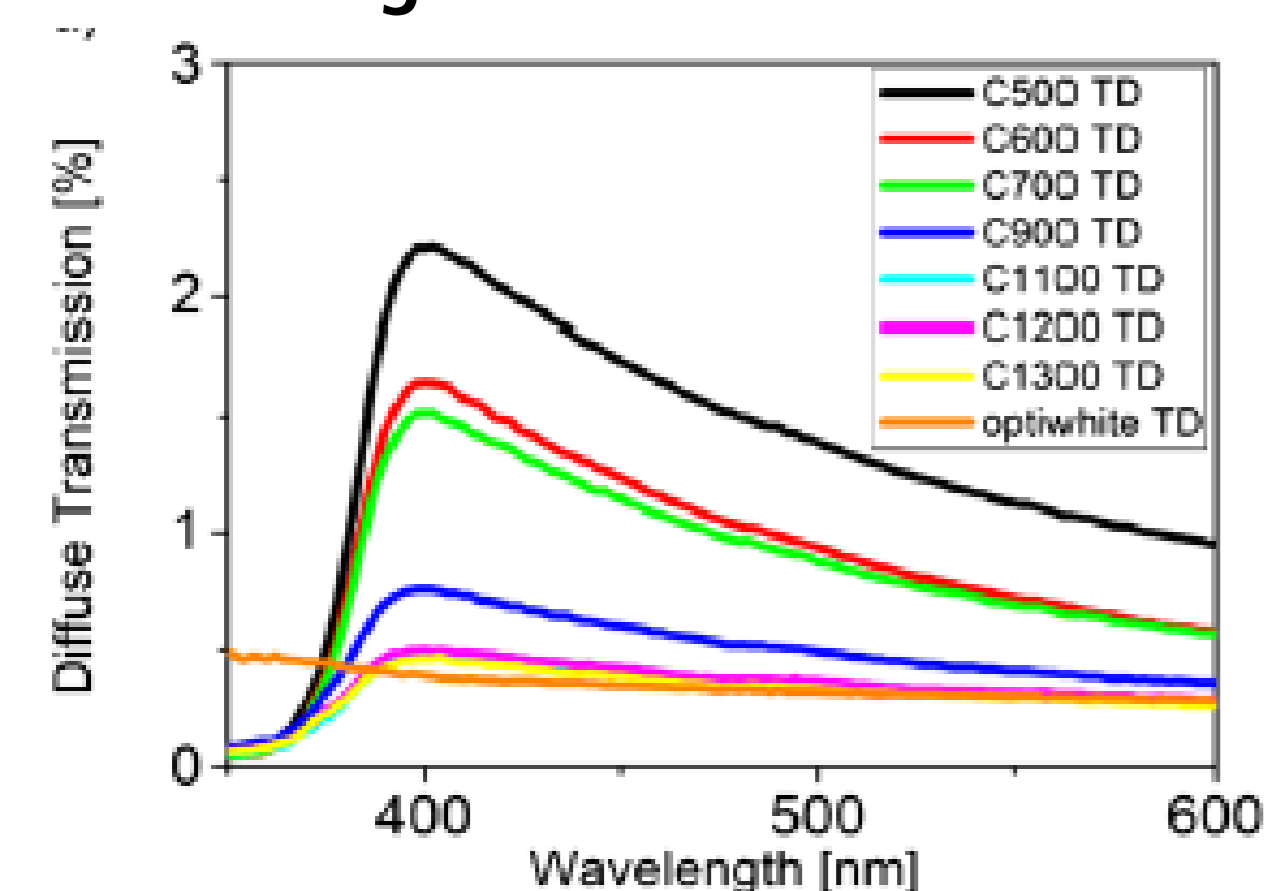
### Non-destructive analytics

- Raman spectroscopy
- FTIR/UV/vis spectroscopy
- Color measurement
- Scanning acoustic microscopy
- Lock-in thermography
- Electroluminescence imaging

### Destructive analytics

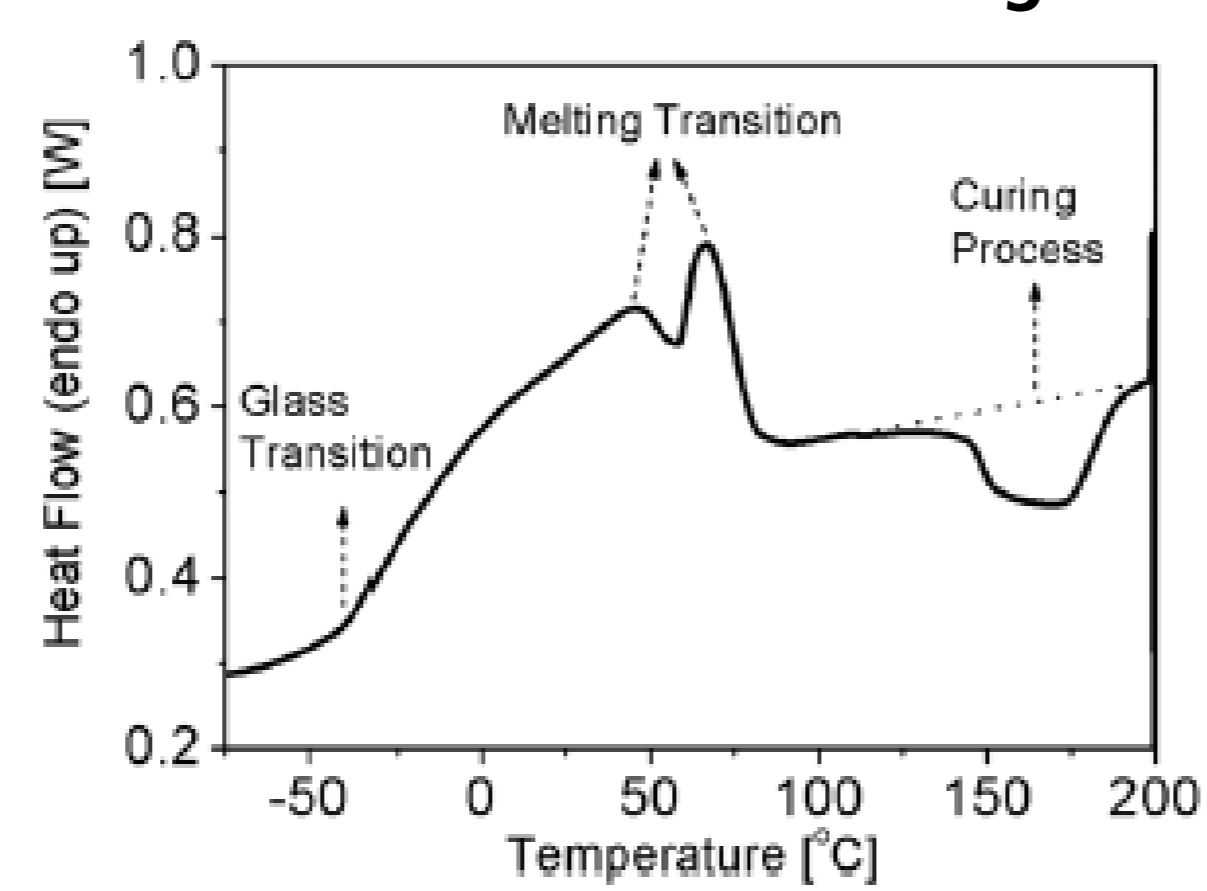
- Peel test
- Tensile testing
- Nanoindentation
- Dynamic mechanical analysis
- Differential scanning calorimetry
- Energy dispersive x-ray spectroscopy

### A fast tool for determination of EVA curing state in PV modules



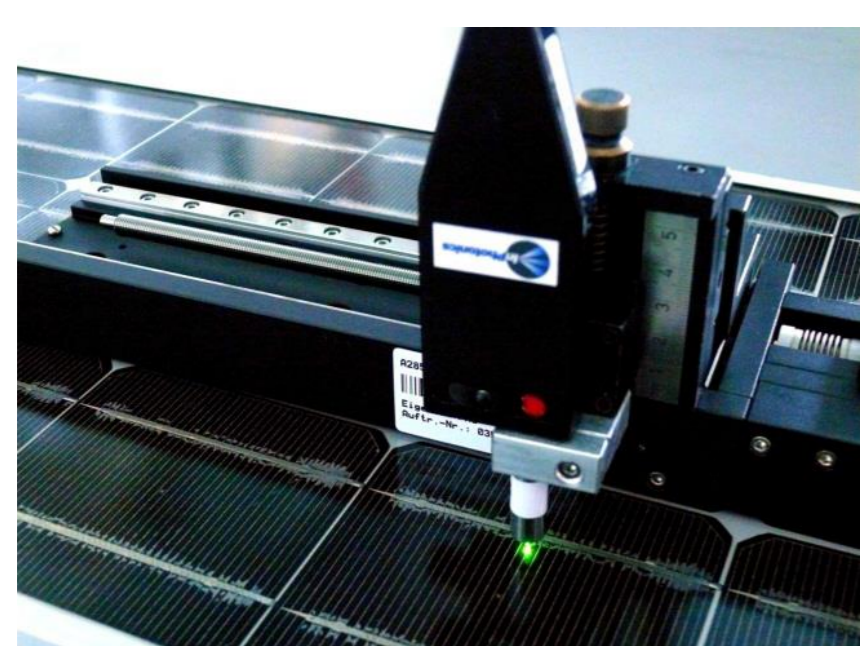
Diffuse transmission through the laminates with different curing times (Li, H.-Y., et al. 2012)

### Temperature-dependence measurement for determination EVA curing state



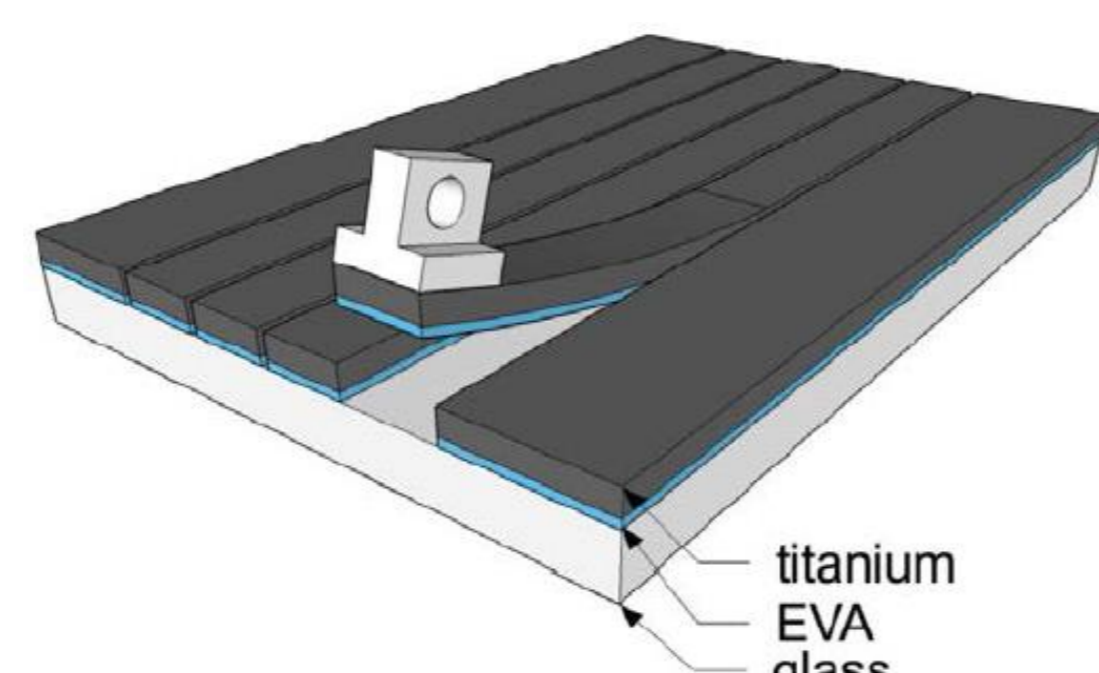
Typical differential scanning calorimetry thermogram of ethylene-co-vinyl acetate (EVA) (Li, H.-Y., et al. 2012)

### Chemical analytic allows spatially resolved measurements of PV modules



Raman probe microscope which is attached to a linear motor (Peike et al. 2014)

### A simple metrology to measure interfacial adhesion between EVA and glass



Schematic of traditional SCB implementation for encapsulation coupon specimens. (Bosco et al. 2015)

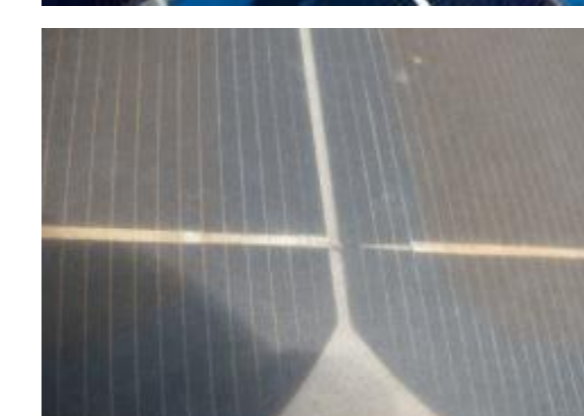
## RESEARCH QUESTIONS

- Quality vs module reliability? Critical material parameters vs failure modes?

## FAILURE MODES



- The delamination generates mechanical stability loss, optical loss, water accumulation...

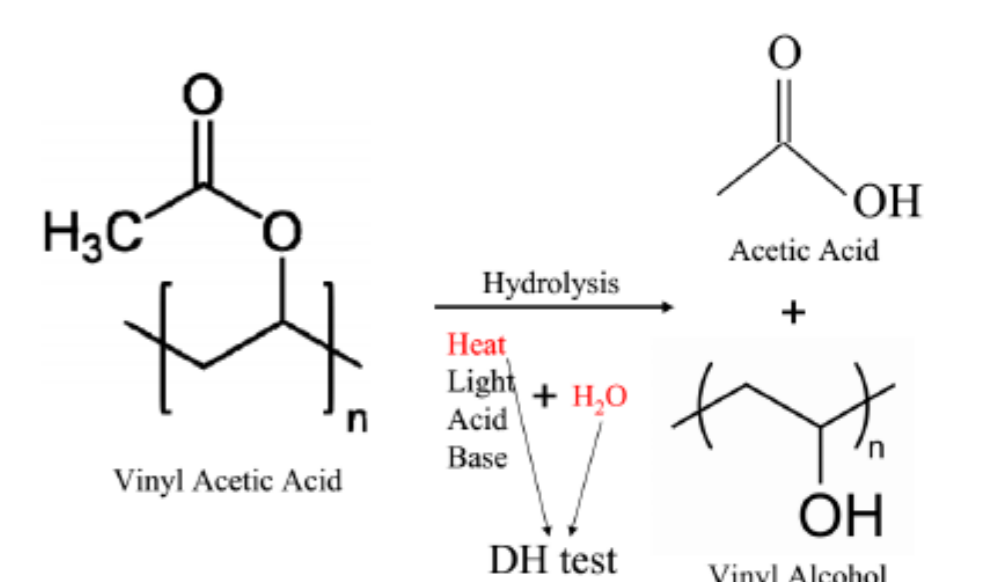


- The Browning of the encapsulant causes a large T% loss and so power loss...



- The corrosion could accelerate the encapsulant discoloration, electrical conductivity loss...

- The photo-degradation of the encapsulant EVA (degradation under the combination of DH and UV radiation)



## CORRELATION OF PV MODULES PARAMETERS TO FAILURE

- Evaluation of degradation mechanisms in polymers due to effects of environmental loads
- The influence of encapsulation method and processing conditions on the lamination quality and reliability of PV modules
- Optimisation of PV modules parameters by using design of experiments DOE

