Characterization and Aging Study of Encapsulant (EVA) and Backsheet for PV Modules

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Abstract

- Given the warrantee and customer expectation for a 25 to 30 year product, all components used with PV module must exhibit very high durability in a multitude of climates. This study focuses specifically on EVA encapsulant and polymer backsheet that are relatively standard components for crystalline silicon PV modules.
- Durability is considered from the standpoint of stress aging via UV exposure, damp heat and thermal exposure.
- Durability characterization utilized FTIR, TGA and spectrophotometer measurement.
- Relative performance of EVA and backsheet from different commercial vendors are presented.
- Based on failures observed, recommendations are given to further improve the quality of these two key components for the industry.
  - EVA - improve for the UV stability;
  - Backsheet – improve UV stability, hydrolysis resistance and interlayer adhesion strength.

Characterization Techniques for EVA and Backsheet

- FTIR (Fourier Transform Infrared)
  - Chemical Compositions
  - Easy Technique for IQA;
- DSC (Differential Scanning Calorimetry)
  - Melting Points, Degree of Curing and Crystallization Behavior
  - Quick and Easy Technique for Production Control
- TGA (Thermo gravimetric Analysis)
  - Thermal stability
- Spectrophotometry
  - Transmission, Reflection, Haze, Yellow Index

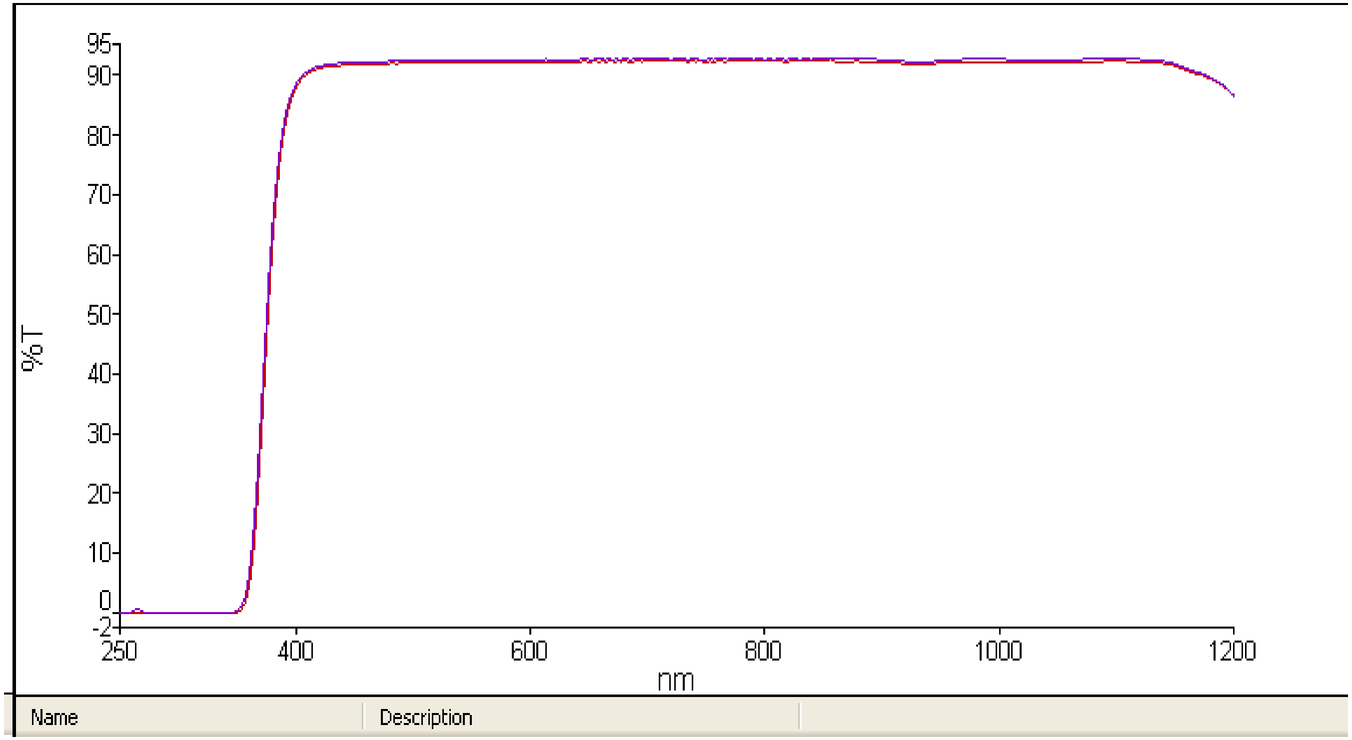
Aging Study of EVA/Backsheet

- UV Dosage: 0.72 $W/m^2/nm$ at 340nm (37W/m^2) for 1030hrs at 60°C
- Damp Heat: (85%RH/85°C, 1030hrs)
- Thermal oven aging: 105°C 1176hrs/49days)
- Thermal stability by TGA (ramp rate: 10C/min)

EVA Durability/Aging Summary

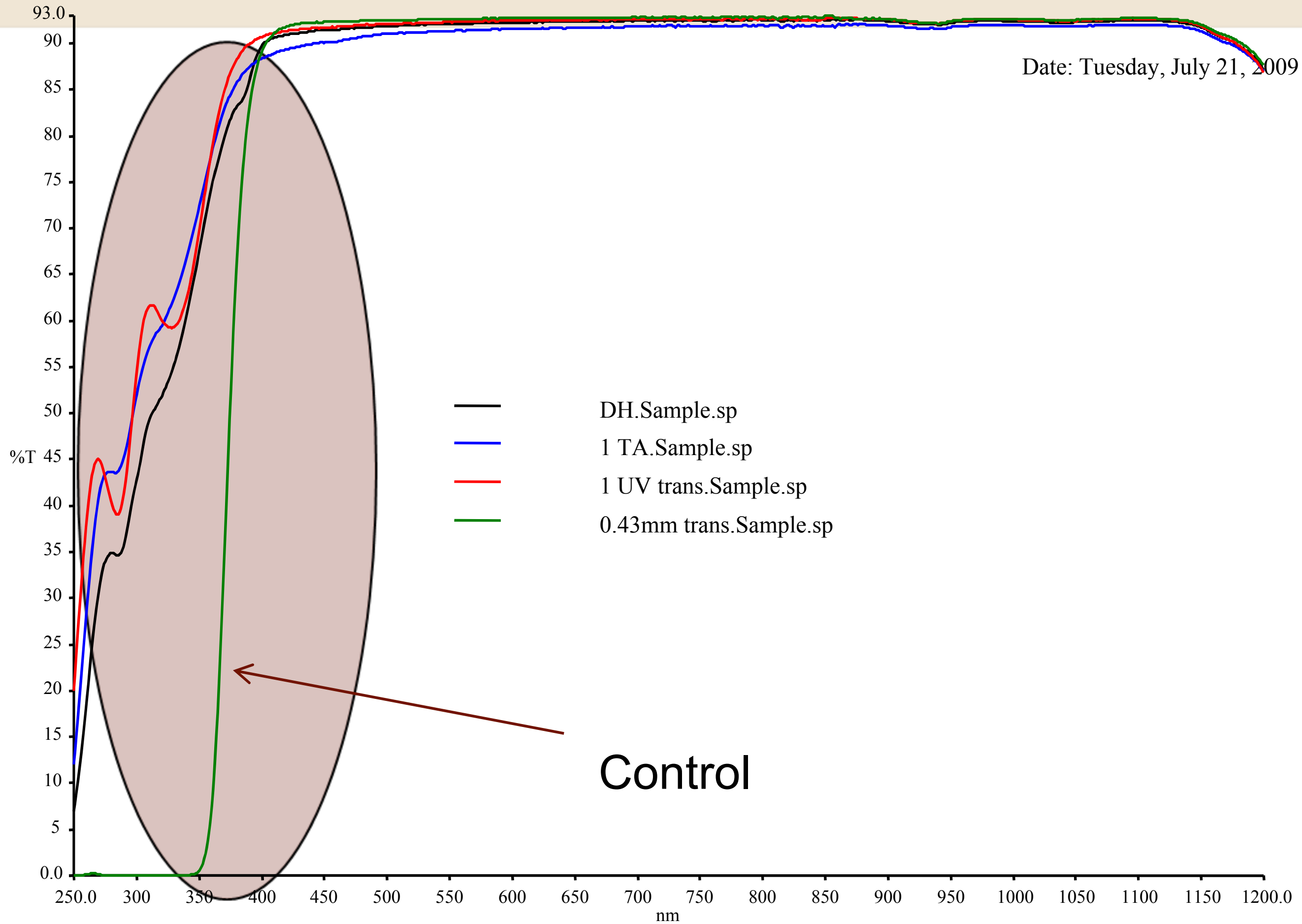
- Transmission/FTIR/Yellowness Index/Refractive index were characterized
- **Significant Changes**
  - **Transmission-wise, very obvious difference between vendors upon aging, especially in UV range**
  - **The degradation of EVA is detectable in FTIR and different vendor shows different level of degradation for the different aging**
- Minor Changes
  - YI (Yellowness Index) showed minimal change, indicating color change is small
  - Refractive index change is also minimal, guarantees good optical coupling without risk of increasing of reflection loss to PV cells

Transmission of as-built EVA



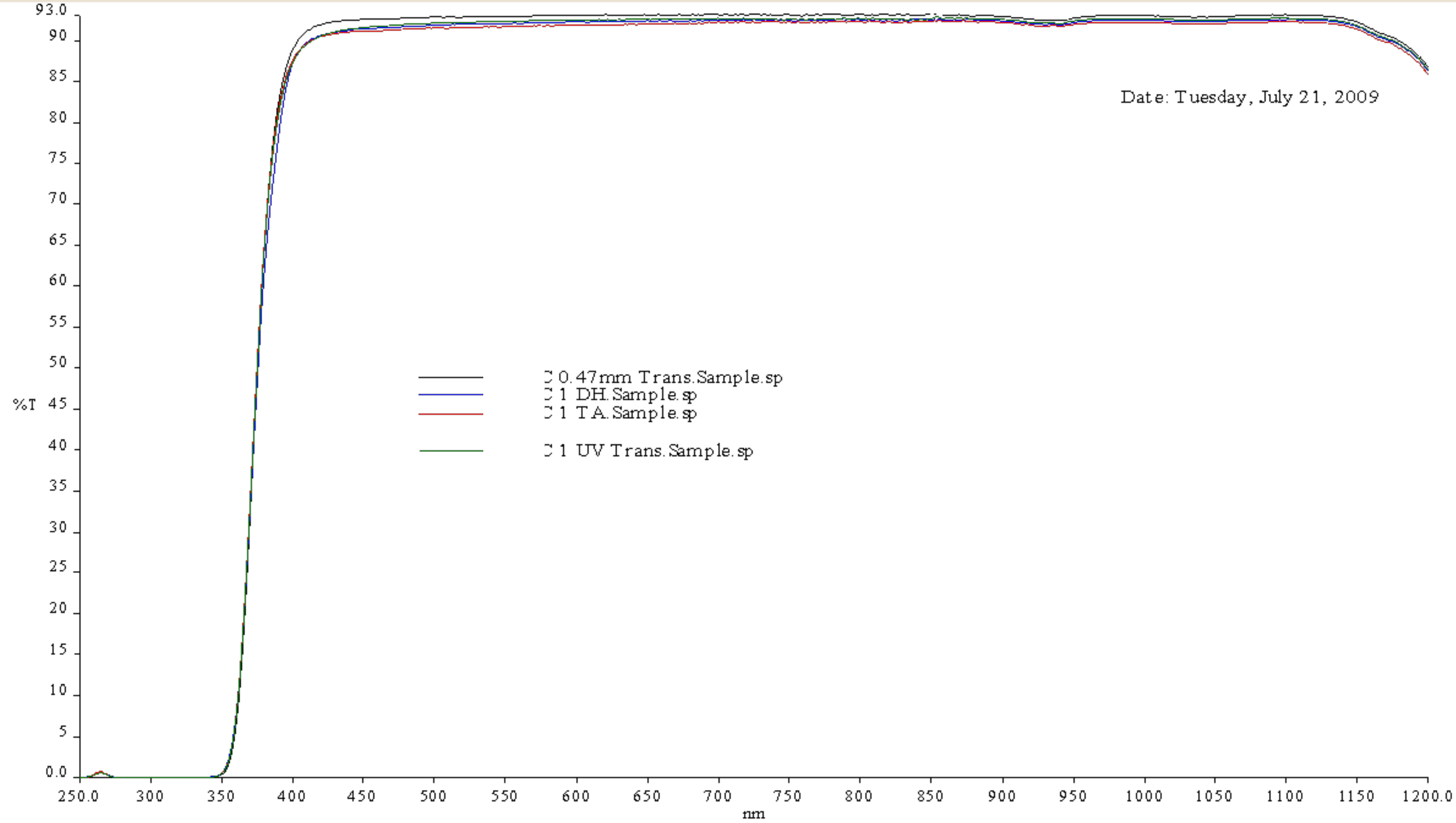
* Very similar transmission curve; 350nm UV cutoff

Transmission of Sample 1 Aged



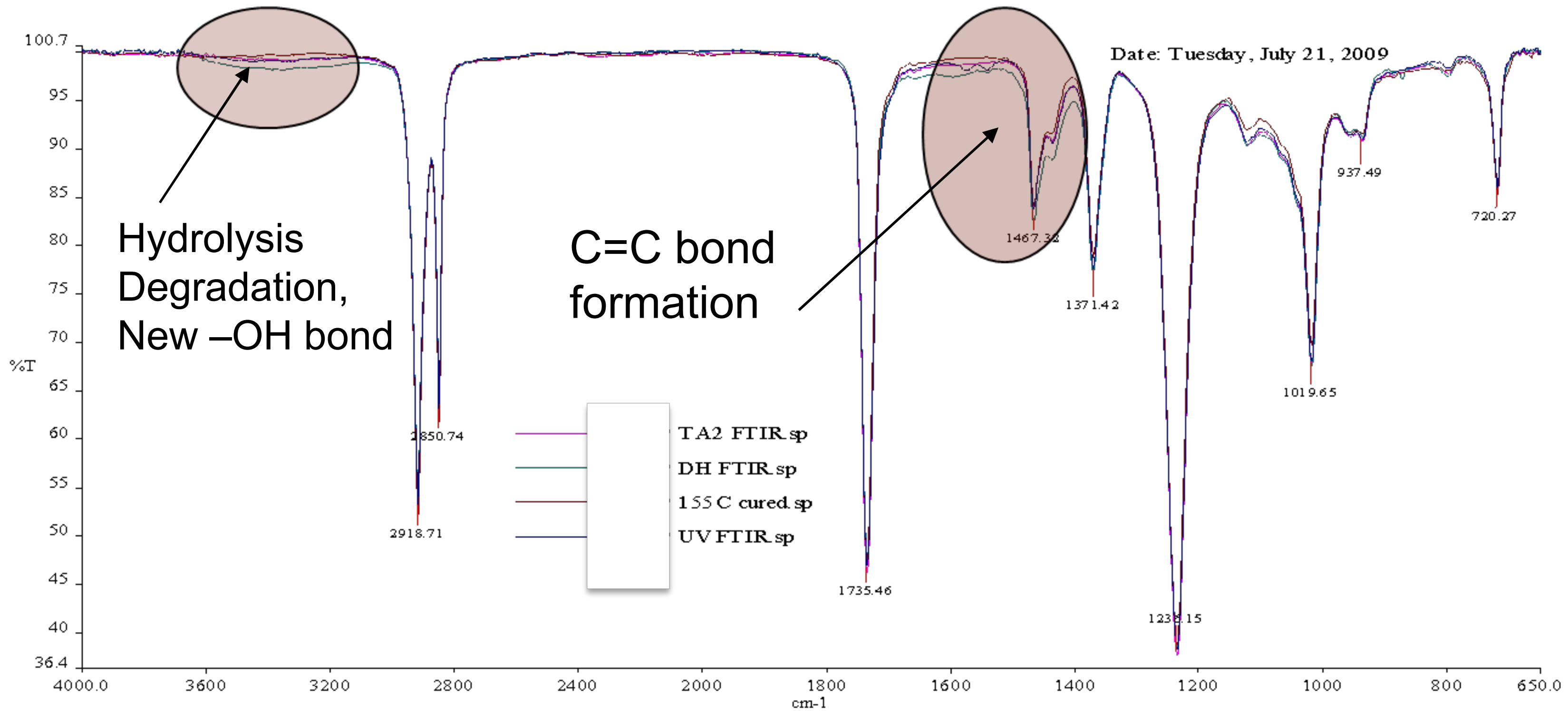
- Very obvious transmission behavior change, especially in UV range. UV package loss

Transmission of Sample 2 Aged



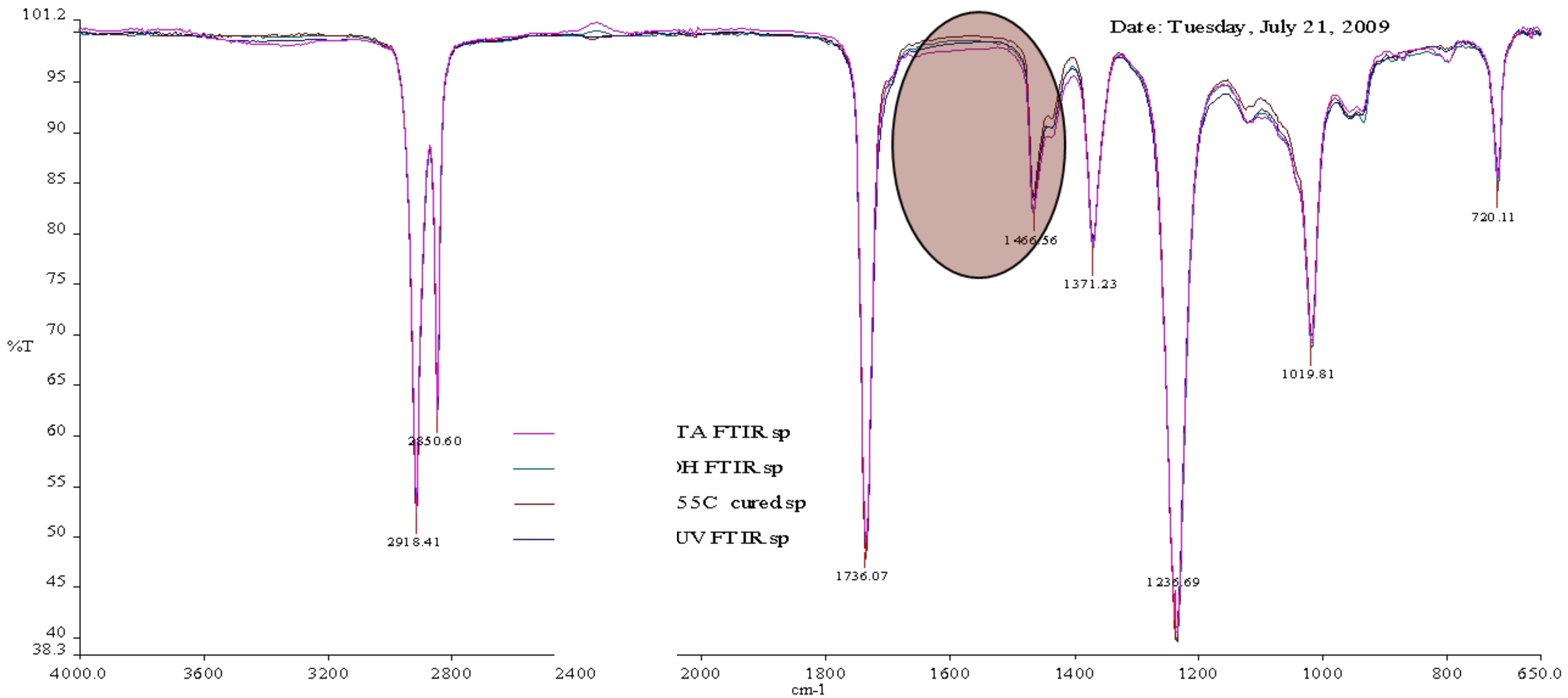
* Extremely stable compared to sample 1

FTIR of Sample 1 Aged



* Noticeable peak change observed due to aging: New –OH and C=C bond

FTIR of Sample 2 Aged



- Chemical composition change observed, but less compared to Sample 1, thus sample 2 is more stable than Sample 1

Yellowness Index of Aged Samples

- Yellowness index (YI): number calculated from spectrophotometric data that describes change in color of a sample from clear/white toward yellow
- The YI change of the aged samples are quite minimal, indicating the materials' resistance to color change is quite good.

	Fresh Cured	UV 1030hrs	DH 1030hrs	105C/1176hrs
Sample 2	0.88	1.29	1.46	1.01
Sample 1	0.81	1.14	1.21	1.41

Refractive Index (RI) of Aged Samples

- Negligible RI change
- This is important that the encapsulant EVA is in the optical path, minimal refractive index change is critical for power stability, especially with low concentration PV.

	Fresh Cured	UV 1030hrs	DH 1030hrs	105C/1176hrs
Sample 2	1.482	1.483	1.484	1.483
Sample 1	1.482	1.481	1.482	1.482

Key EVA Aging Summary

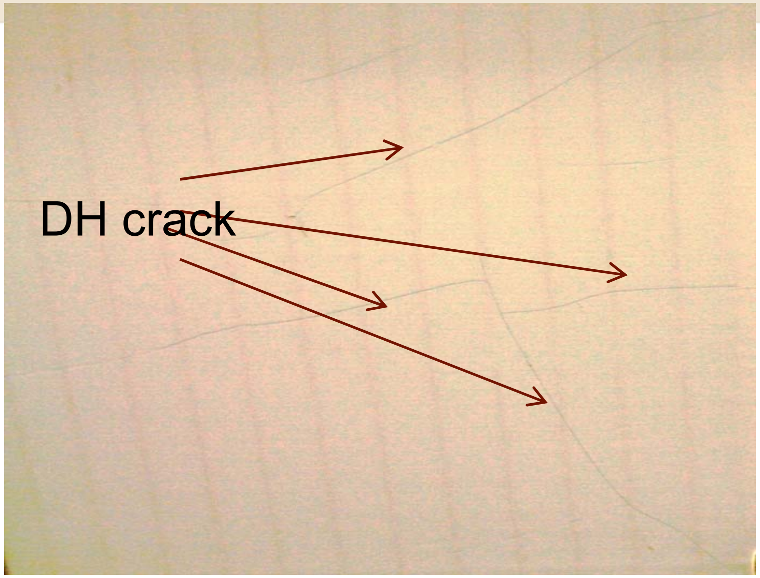
- Aging effect on transmission in visible range: thermal aging>DH>UV
- Resistance to aging: Sample 2 better than Sample 1
- Sample 1 needs to improve the UV stability package for the additives to last longer in the material

Backsheet Aging Summary

- Characterization
  - TGA
  - FTIR
  - Reflection

Common backsheet failure modes

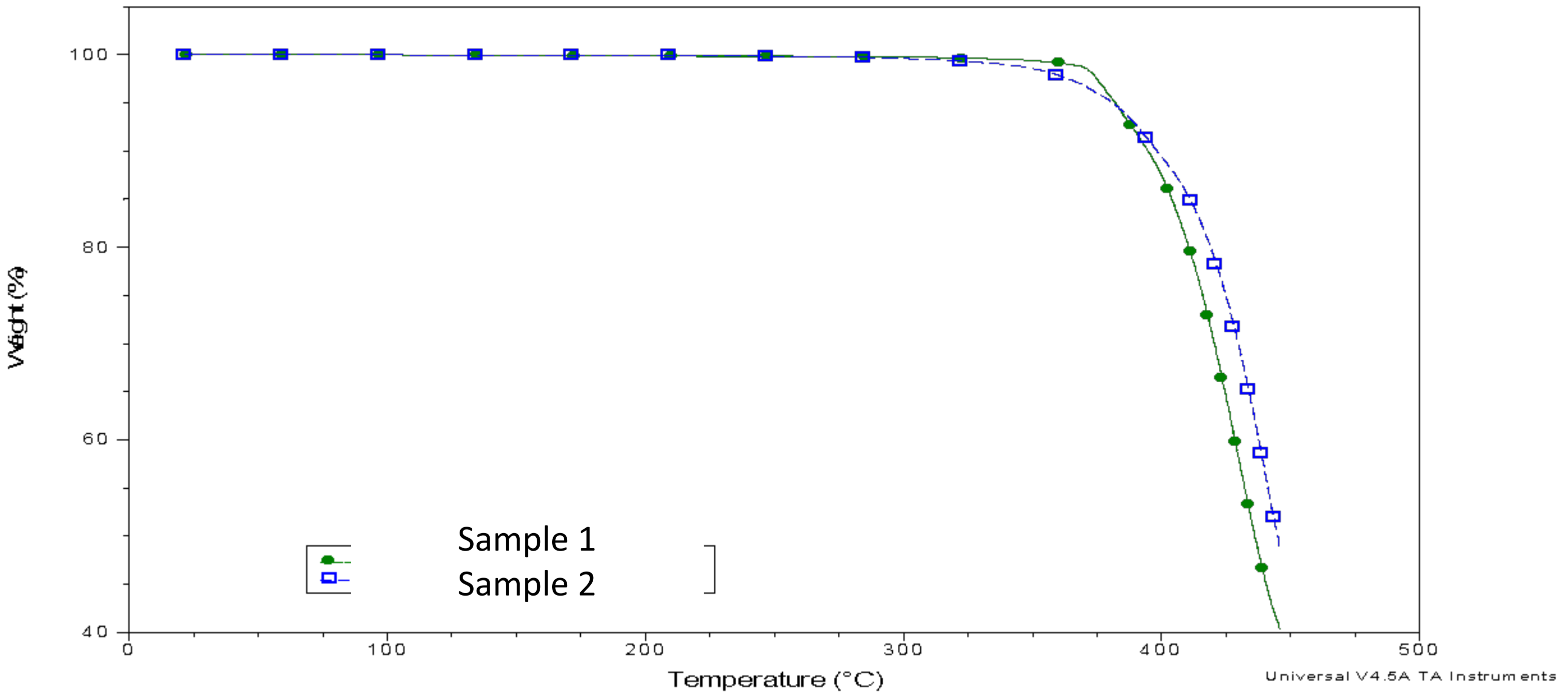
- **Backsheet crack** due to hydrolysis. The middle PET layer provides mechanical strength and electrical insulation. However, PET is very prone to hydrolysis.
- **Delamination** due to poor inter-layer adhesion quality
- **Yellowing/crack of inner EVA** layer due to the poor UV package for the material.



Thermal Stability

- Normal modules’ operating temperature is about 50°C. It is important for the backsheet to be thermally stable at or above this temperature for 25 year service life
- TGA is a simple way to characterize the thermal stability of the backsheet

TGA Sample Curves:

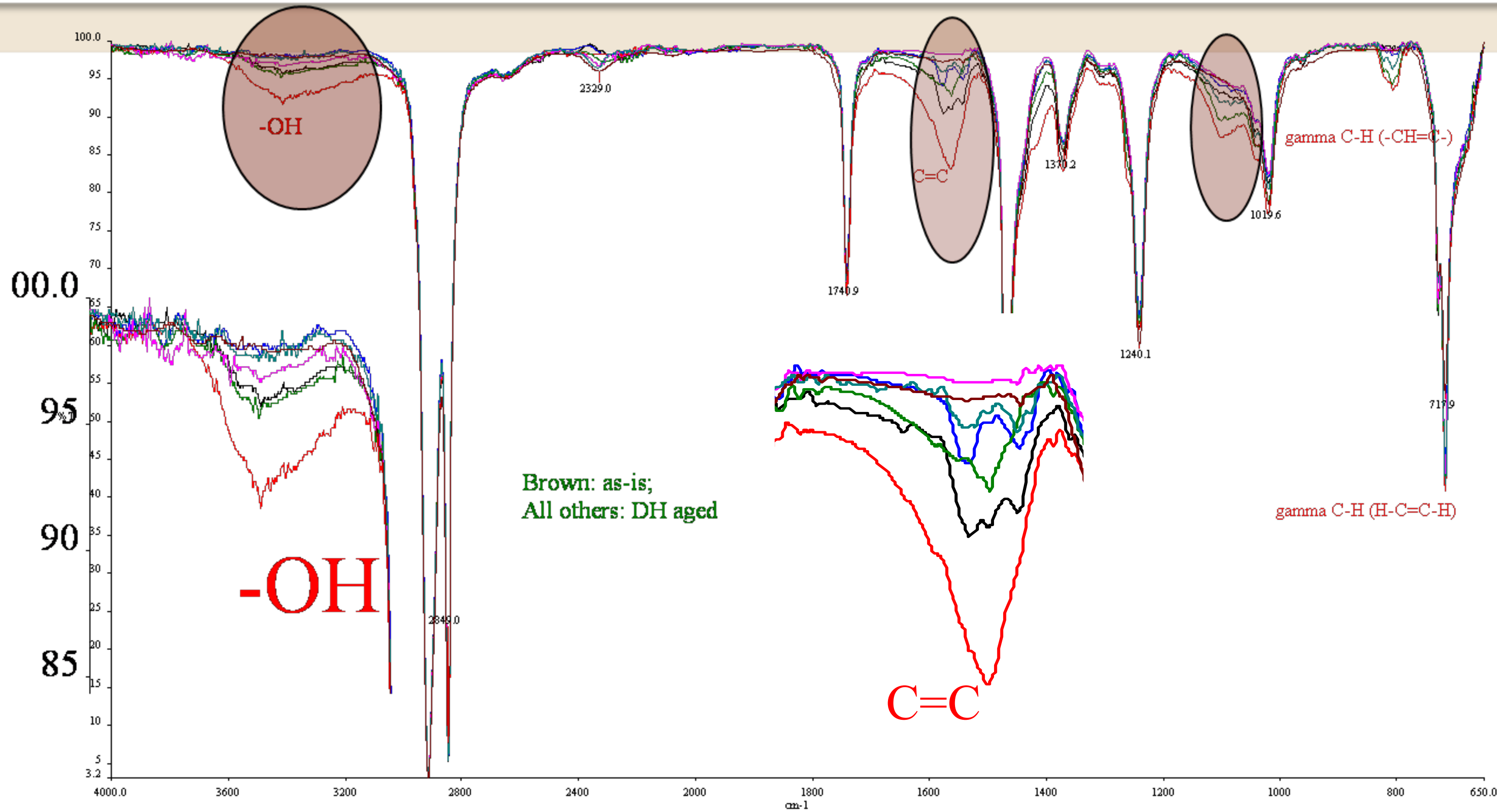


• Generally similar behavior, however, Sample 2 showed earlier degradation onset

Damp Heat aging

- A common polymeric backsheet structure is a 3-layer composite film: EVA(or alternative)/PET/Fluoro layer
- Fluoro layer's weatherability well characterized
- PET, however, can suffer **hydrolysis failure**

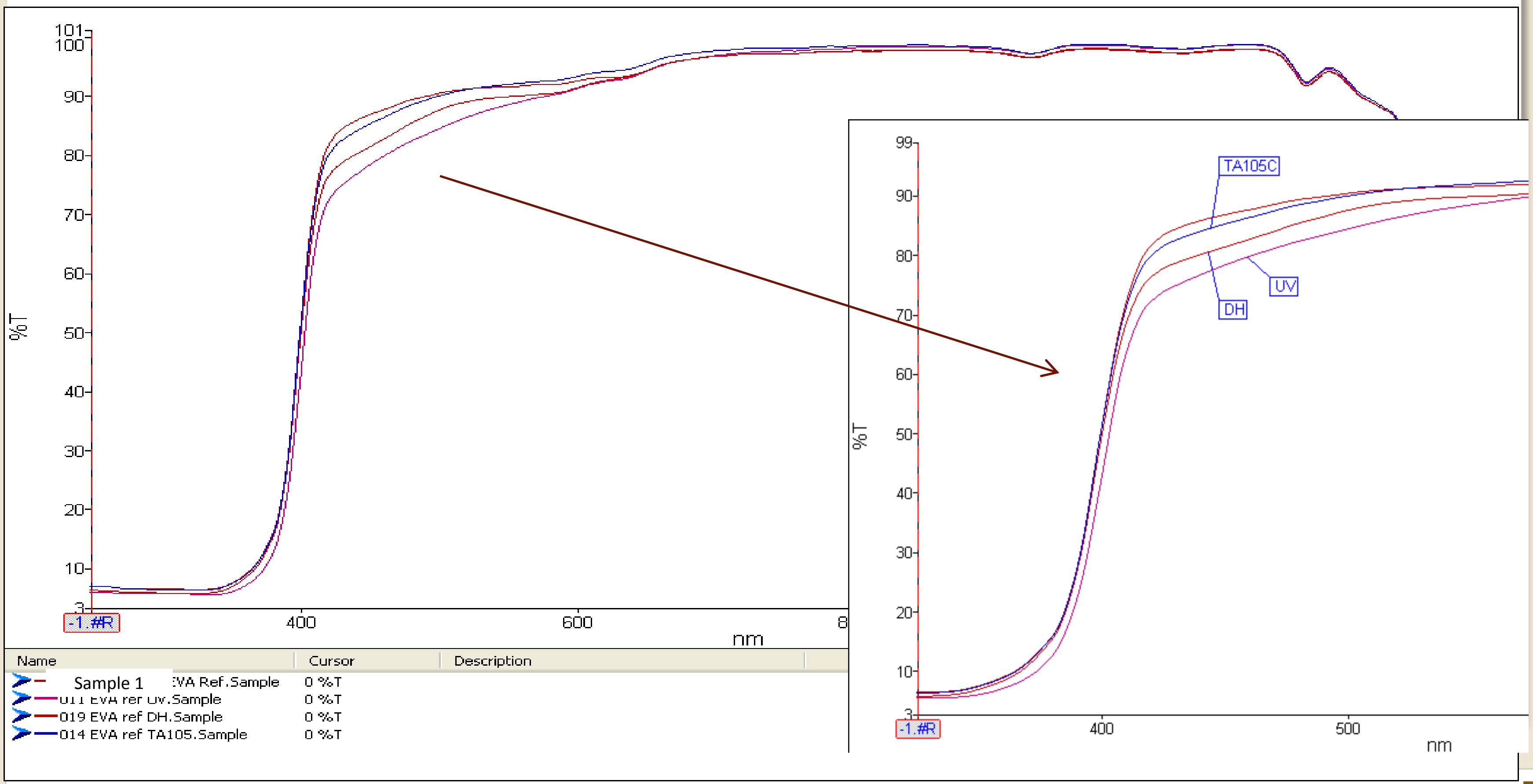
DH Aged Sample 1, EVA side



* Obvious hydrolysis: More –OH, C=C, C-H

Sample 1 Reflection: UV aging showed most loss

Higher reflection of inner side of backsheet helps to redirect more leaked Light back to PV cell service thus higher power gain



Backsheet Aging Summary

- Damp Heat Resistance (Hydrolysis Resistance of the PET layer) is a major failure to many backsheets, visual backsheet crack were observed in DH chamber testing. Also the failure is obvious in FTIR characterization.

- The UV resistance of inner layer is also important. 2X IEC61215 precondition UV aging showed yellowing/browning/cracking of EVA layer. Much more effort is needed for UV stability

Conclusion

- EVA
  - Though in the past 30 years, EVA formulation has improved a lot, especially for UV stability. Still there is room to improve to keep the EVA as transparent as possible for the service life. Some suppliers' materials tend to turn hazy after aging.
- Backsheet
  - Different supplier's material varies a lot in regard to UV resistance, hydrolysis resistance, inter-layer adhesion strength and reflectivity. No perfect material is available in the market. A lot more effort is needed to develop quality material to meet the demand of the world's growing solar market.