Raman Spectroscopy Application to Characterize EVA after UV Exposure

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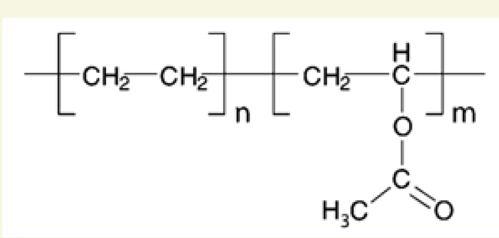
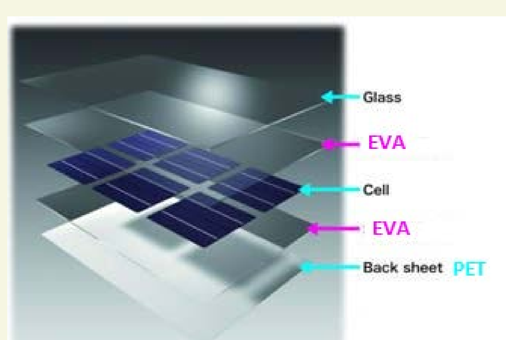
INTRODUCTION

The most commonly used photovoltaic (PV) encapsulant material is ethylene-vinyl acetate (EVA) co-polymer.
The encapsulant role is to provide protection to the brittle solar cell from different external stresses.
It binds the backsheet, usually based on polyethylene terephthalate (PET), which serves as a mechanical support to the solar cell, through the solar cell and eventually to the front glass.
The encapsulant properties requirements include: resistance to water/humidity absorption, good adhesion, optical transparence, electrical insulator, and to withstand UV.
The EVA that is generally used in PV has around 26%-34% vinyl acetate (VA).





TYPICAL EVA RAMAN BAND SHIFTS DESCRIPTION

Wavenumber (cm^{-1})	Chemical Bond	Description
629	O-C=O	VA CO stretching
869	O-O	peroxide
1020	C-C	Stretching due to vinyl
1060	C-C	Ethylene asymmetric stretching
1080	C-C	Ethylene asymmetric stretching-Amorphous
1127	C-C	Ethylene symmetric stretching
1170	C-H	CH_2 rocking-Crystallinity
1298	C-O-C and C-C	Acetate asymmetric stretching and polyethylene skeletal vibration
1340	C-H	CH_2 wagging
1370	C-H	CH_2 wagging
1416	C-H	PE CH_2 wagging crystalline band
1440	C-H	CH_2 bending crystalline band
1740	C=O	VA stretching
2854	C-H	Aliphatic CH stretching
2863	C-H	Ethylene asymmetric stretching
2885	C-H	symmetric stretching
2913	C-H	Ethylene symmetric stretching

References

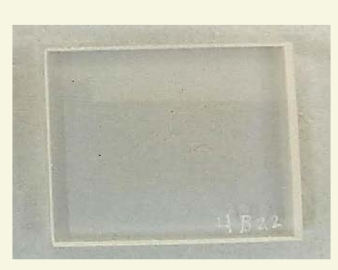
1. Chernev B. S. et al., (2013).
2. Peike C. et al., (2014).
3. Ren Y. et al., (1999).
4. Shimoyama M. et al., (1997).

UV EXPOSURE

Materials configuration:

Dog-Bone EVA:

Laminated EVA:



UV EXPOSURE:

NIST SPHERE - Simulated photo-degradation via high energy radiant exposure

Controlled Parameters include:

- Temperature
- Relative Humidity (RH)
- UV intensity

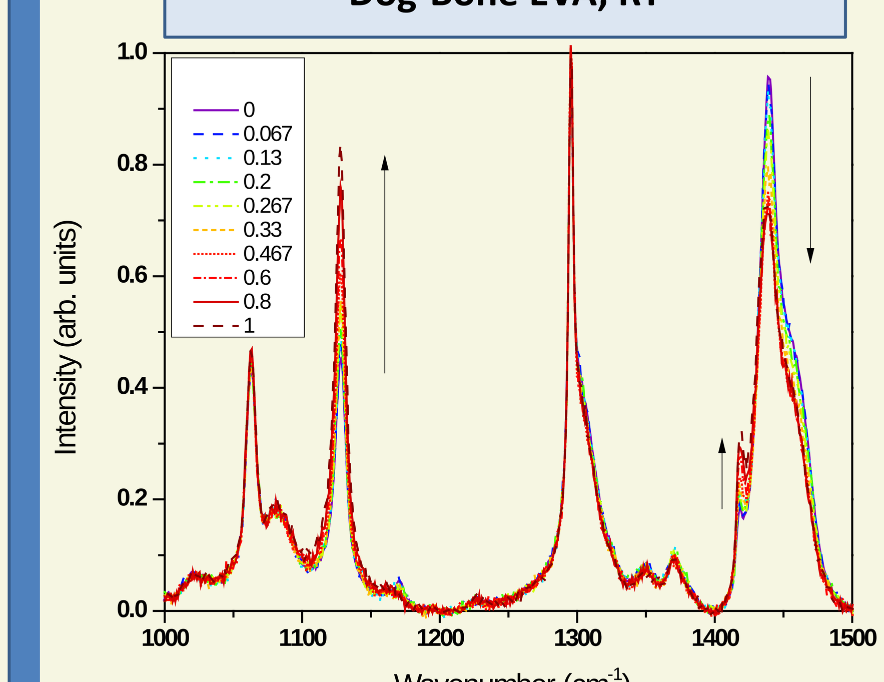
The exposure conditions:

55° C, 80% RH (WET)
55° C, 0% RH (DRY)

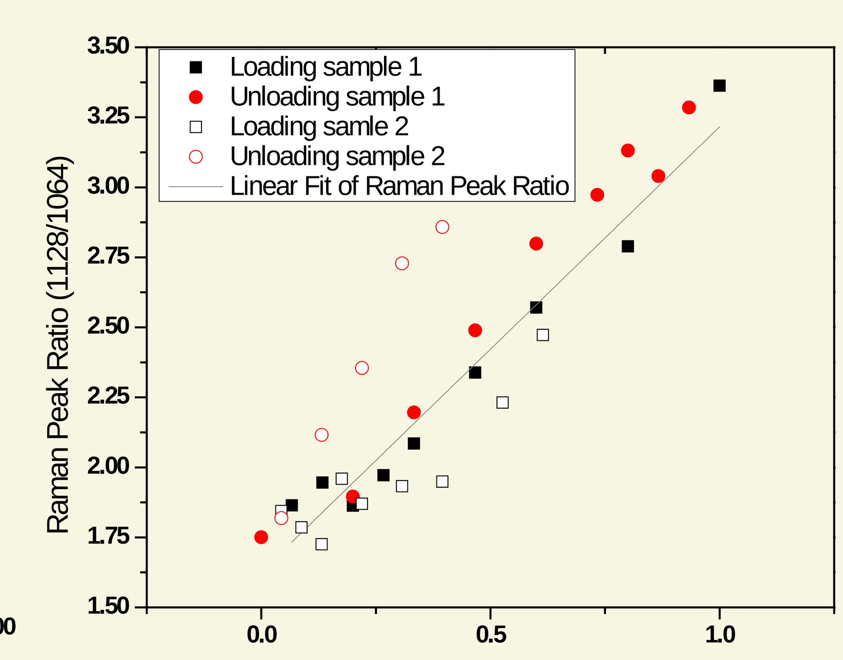
Chin et al, *Review of Scientific* Instruments (2004), 75, 4951; Martin and Chin, U.S. Patent 6626053

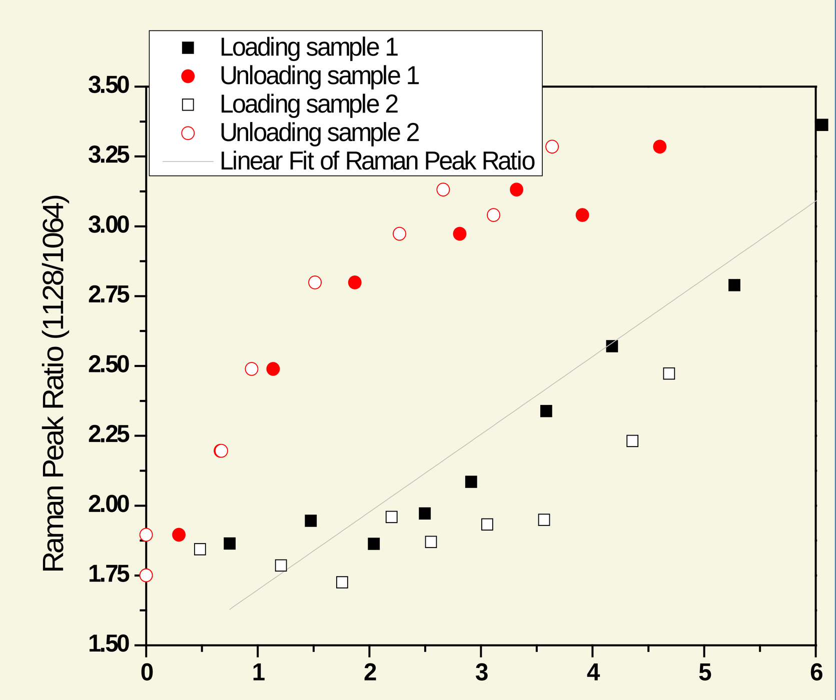
EVA CHEMICAL DEGRADATION BY RAMAN SPECTROSCOPY

Dog-Bone EVA, RT



1. Internal stresses analysis:

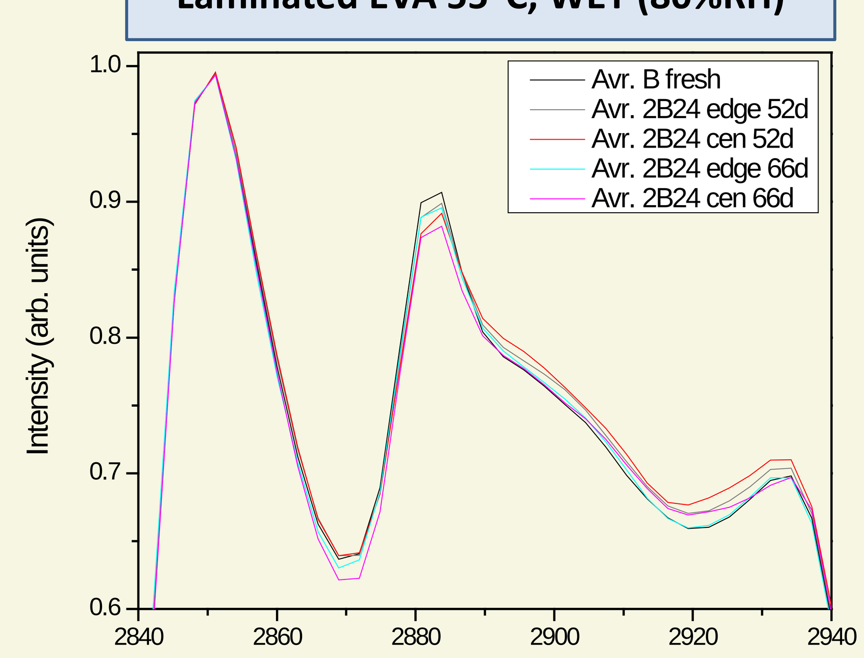




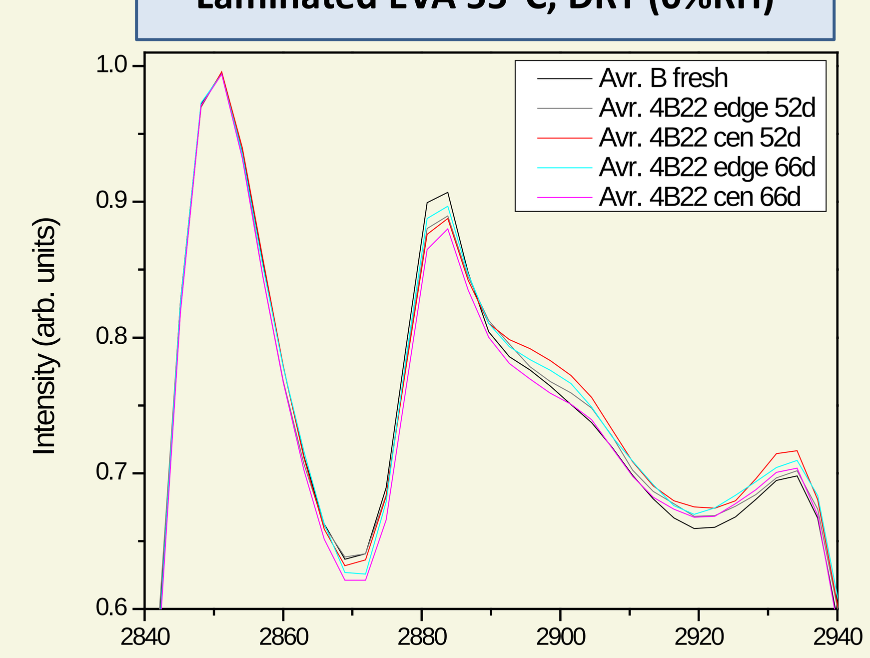
EVA DB samples were strained in steps while continuously monitoring both the load response and the intensity of Raman shift, and a correlation was made. It was shown that the EVA stress and strain can be measured in a non-destructive manner using Raman spectroscopy and it is directly related to the $C\text{-}C_{sym.}/C\text{-}C_{asym.}$ stretching.
Raman response for laminated EVA samples showed that the ratio of $CC_{sym.}$ to $CC_{asym.}$ Stretching I_{1128}/I_{1064} had decreased with time at the center of the sample, which is an indication of compressional stresses inside the EVA of about 45% more than the fresh sample. At the edge of the sample these stresses are relaxed and the compression is only 8% after 66 days in comparison to the fresh sample.

2. Chain scission versus cross-linking analysis:

Laminated EVA 55°C, WET (80%RH)



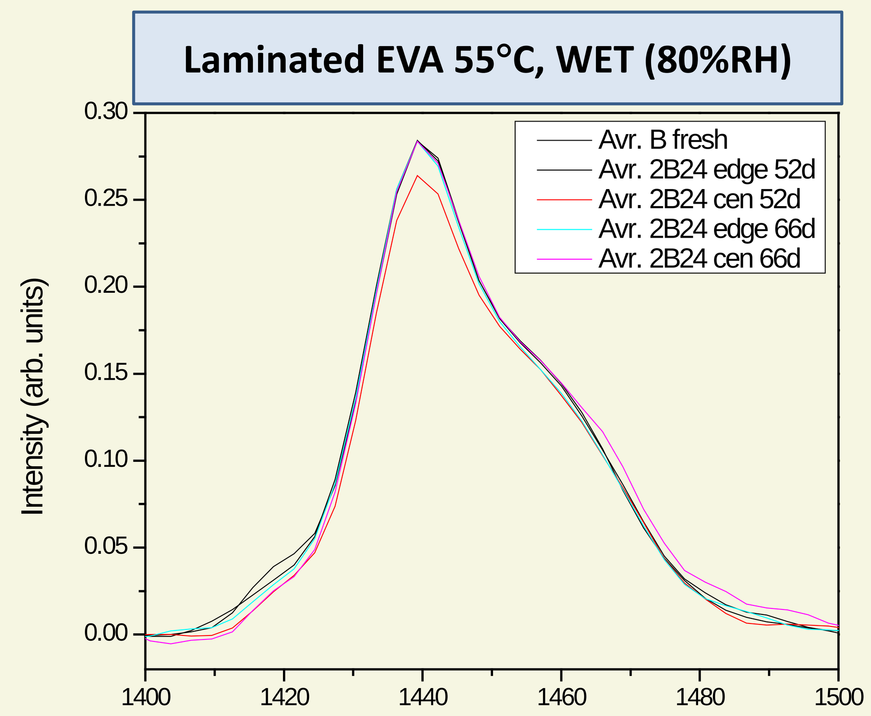
Laminated EVA 55°C, DRY (0%RH)



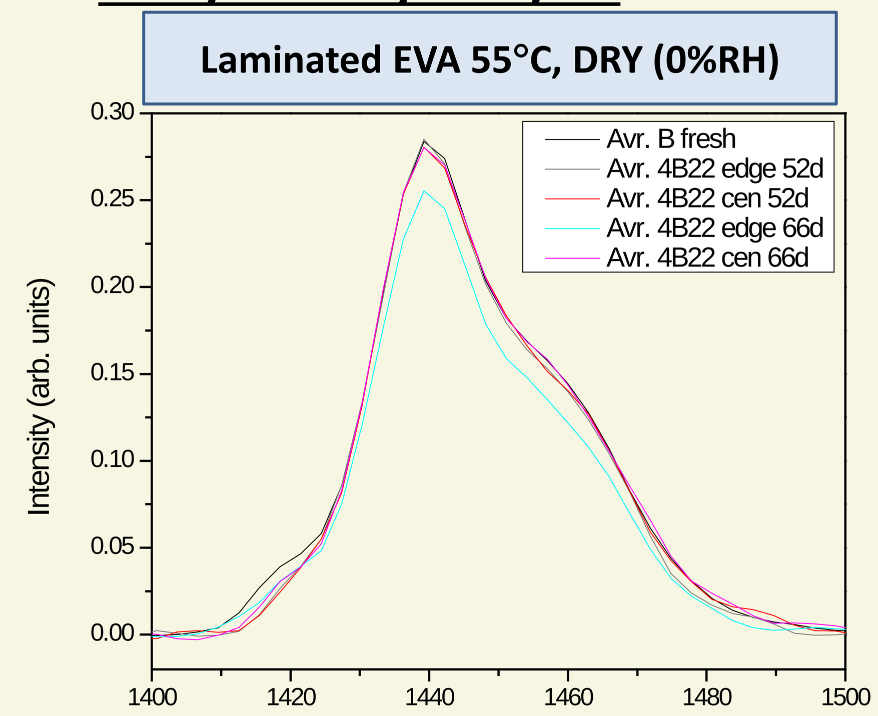
For laminated EVA samples, CH peak at 2882 cm^{-1} had decreased indicating an increase in cross linking with time.
The decrease was more pronounced in the center, where an anaerobic environment exists leading to cross linking reaction.
At the edge of the samples, under aerobic conditions (higher O_2 availability) there was less cross linking reaction.

3. Crystallinity analysis:

Laminated EVA 55°C, WET (80%RH)



Laminated EVA 55°C, DRY (0%RH)



Laminated EVA samples under both WET and DRY conditions indicated a reduction in the crystallinity.

CONCLUSION

Raman spectroscopy was found to be a powerful and a non destructive tool to investigate PV EVA encapsulant material degradation with UV exposure.
Three aspects of EVA modifications due to UV exposure were analyzed using the Raman:

1. Internal stresses analysis:

The ratio between the C-C symmetric stretching at 1128 cm^{-1} to the C-C asymmetric stretching at 1063 cm^{-1} was changing, due to strain induced alignment.
For laminated EVA I_{1128}/I_{1064} had decreased.

2. Chain scission versus cross-linking analysis:

CH peak ratio I_{2882}/I_{2854} had indicated that UV exposure of laminated EVA samples caused additional cross linking under anaerobic conditions and that under aerobic conditions there was also chain scission competitive reaction leading to a lower reduction of CH peak ratio (I_{2882}/I_{2854}).

3. Crystallinity analysis:

Raman band shift at 1416 cm^{-1} which is related to PE orthorhombic vibration mode, is a fingerprint for EVA crystallinity. For laminated EVA there is a reduction in the crystallinity.