RADIATION INDUCED DEGRADATION OF WPC IN THE FIELD AND IN LABORATORY CONDITIONS

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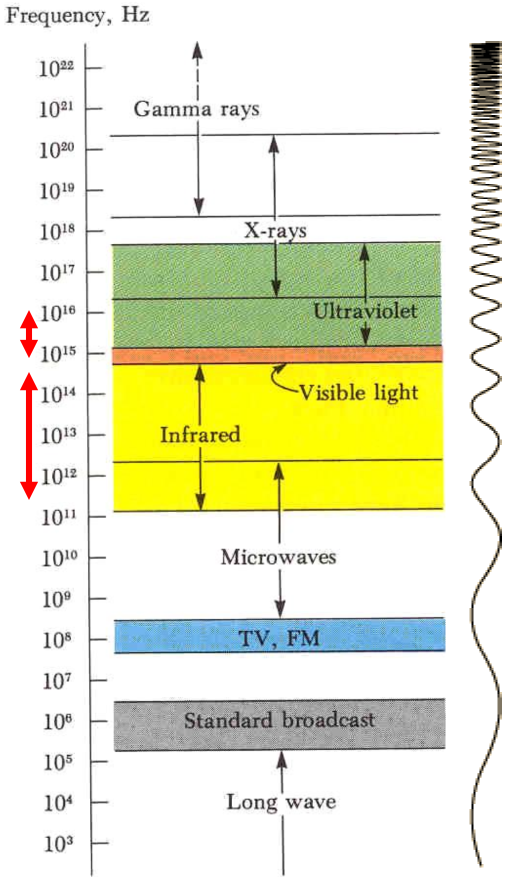
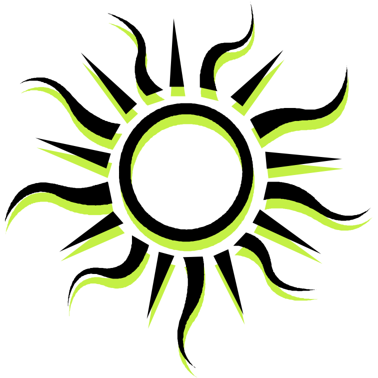
Natural Exposure of Materials to Irradiation

- UV radiation induced degradation
- Heat induced degradation



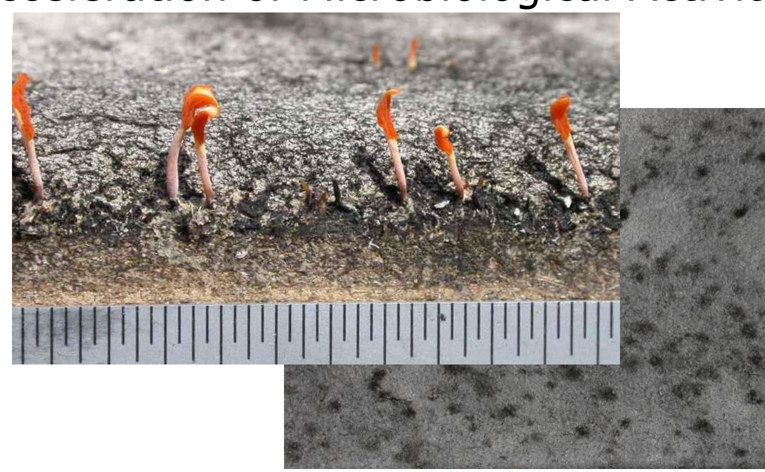


Effects of Ultraviolet Radiation

Colour Fading

Surface Cracking

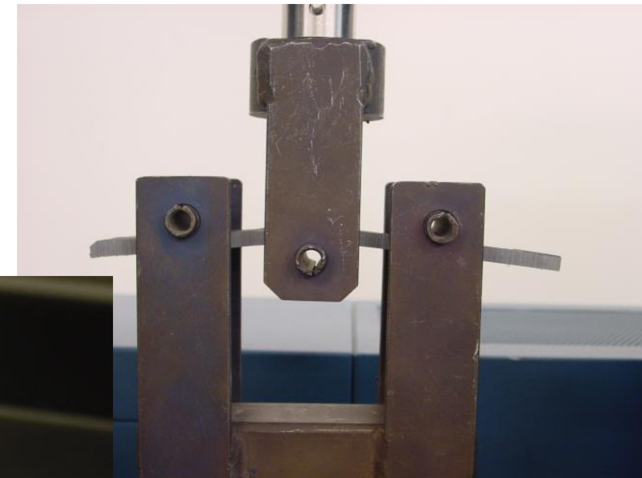
Acceleration of Microbiological Activity



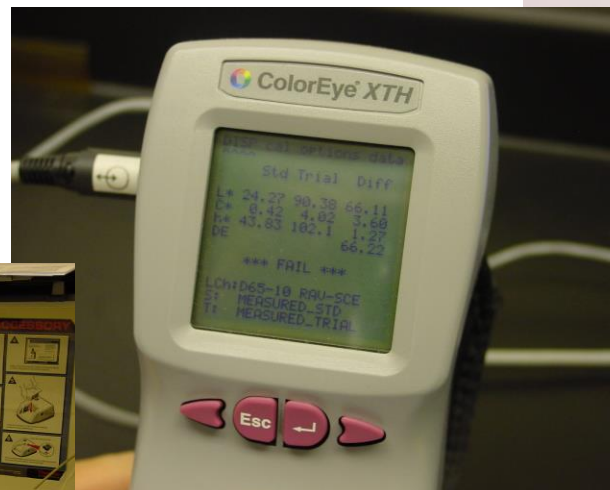
Wear Acceleration

Measurement of Ultraviolet Induced Degradation

- Change in mechanical properties[1]



- Colour change (fading)[2]

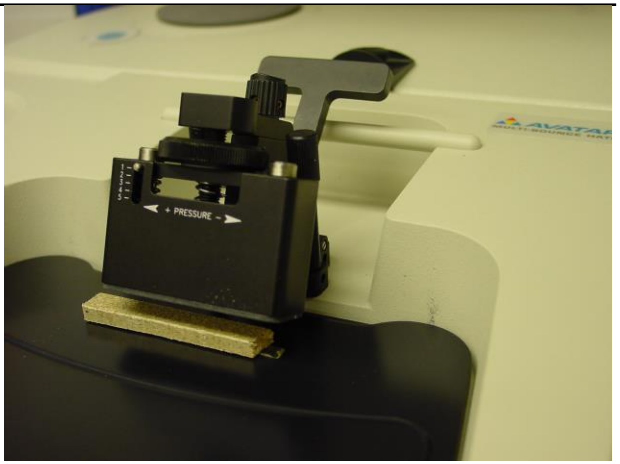


- Changes in materials chemistry (detectable by infrared spectroscopy)[3]

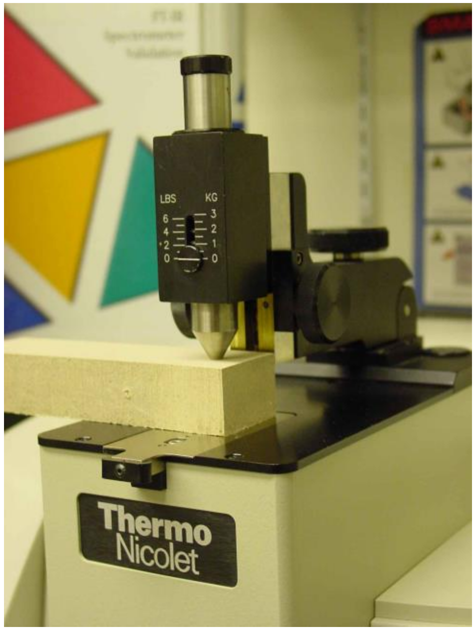
1. Stark, N.M. and L.M. Matuana, *J App Poly Sci,* 2004. *94*: p. 2263-2273.
2. Stark, N.M. and L.M. Matuana, *J App Poly Sci,* 2003. *90*: p. 2609-2617.
3. Stark, N.M. and L.M. Matuana, *Polym Degrad Stab,* 2004. *86*: p. 1-9.

Infrared Spectroscopic Techniques

- Attenuated Total Reflectance ATR[1,2]



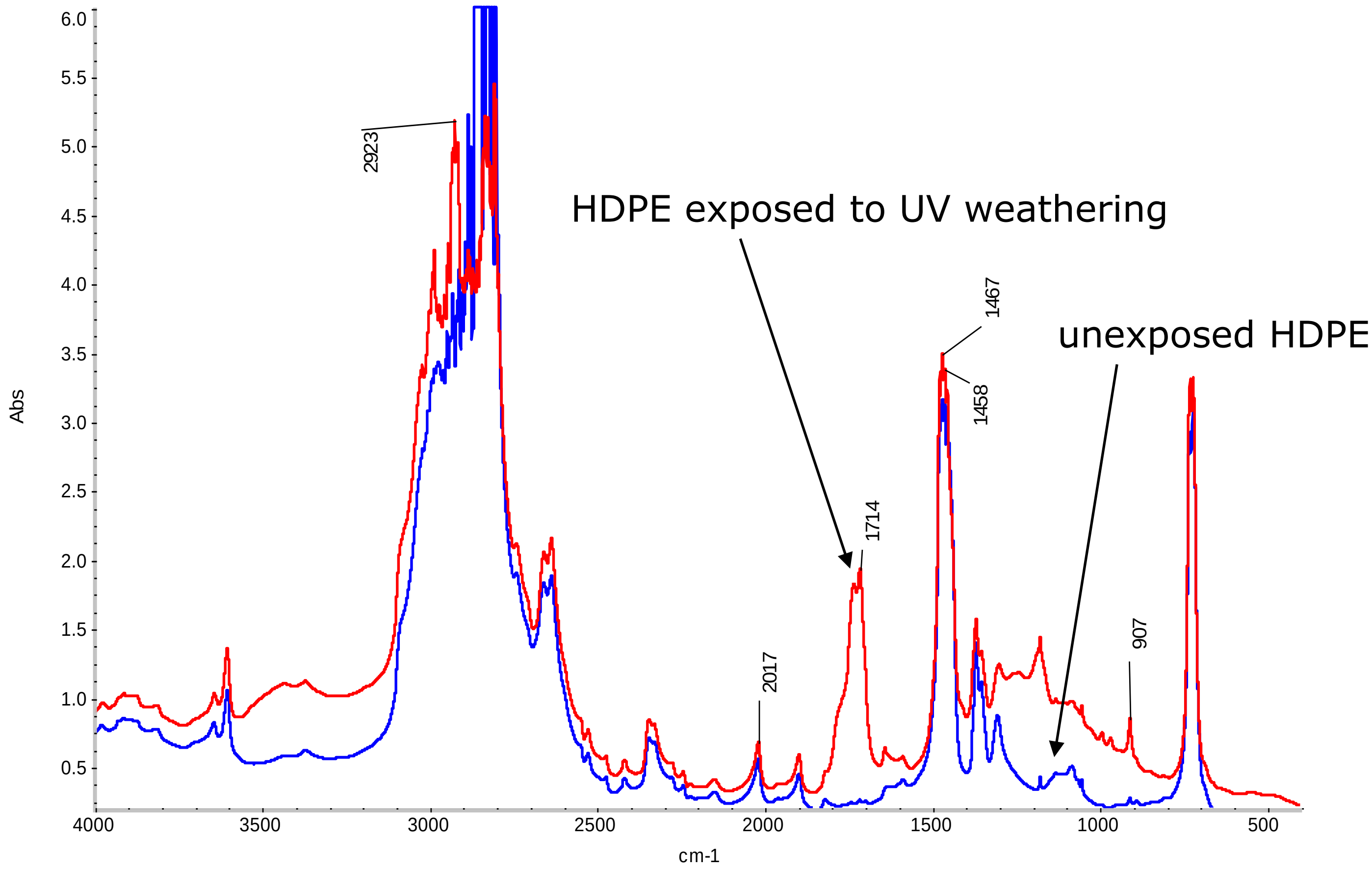
- Semimicro ATR



- Transmission

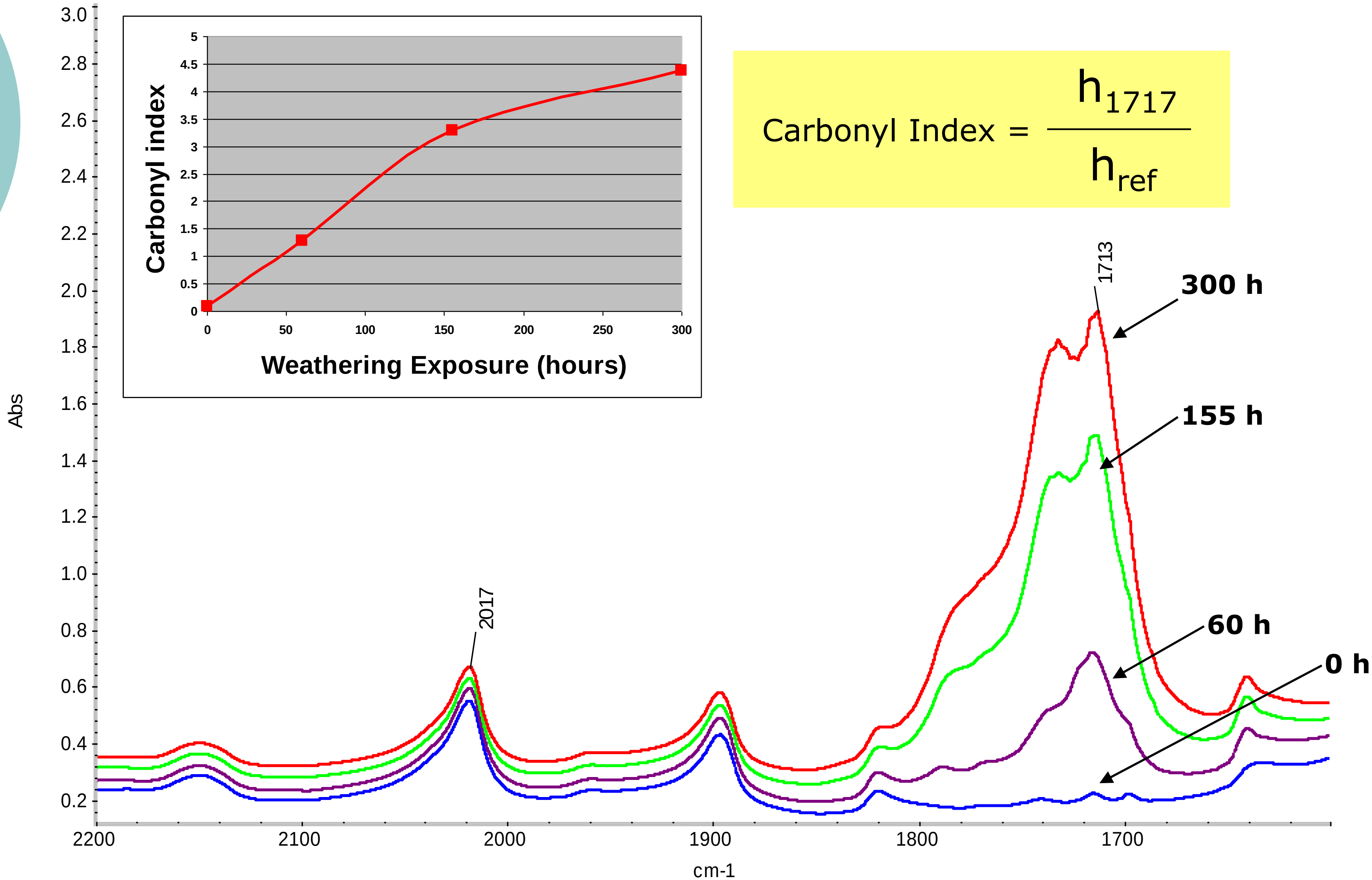
1. Stark, N.M. and L.M. Matuana, *Polym Degrad Stab,* 2004. *86*: p. 1-9.
2. Fabiyi, J.S., A.G. McDonald, M.P. Wolcott, and K. Englund. in *Progress in Woodfibre Plastic Composites International Conference*. 2006. Toronto, Canada.

Infrared Spectroscopy of HDPE



Infrared Spectroscopy of HDPE

$$\text{Carbonyl Index} = \frac{h_{1717}}{h_{ref}}$$



Infrared Spectroscopy of HDPE from WPC

Carbonyl Peak Structure[1]

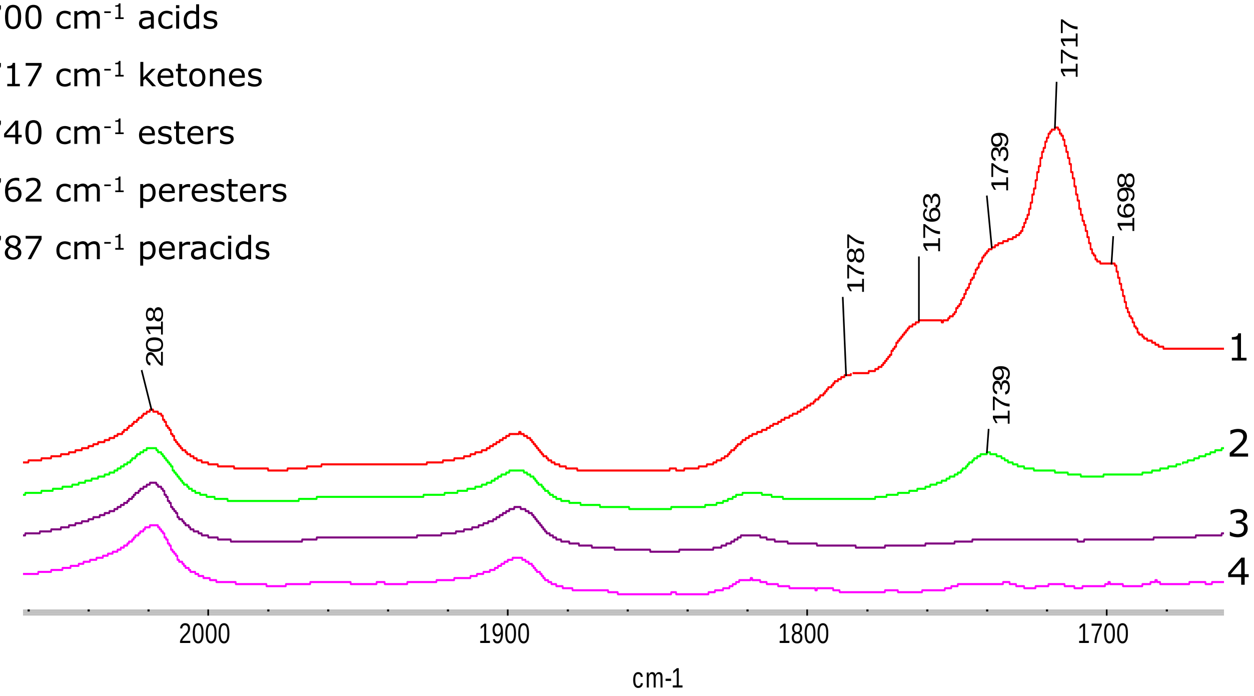
1700 cm^{-1} acids

1717 cm^{-1} ketones

1740 cm^{-1} esters

1762 cm^{-1} peresters

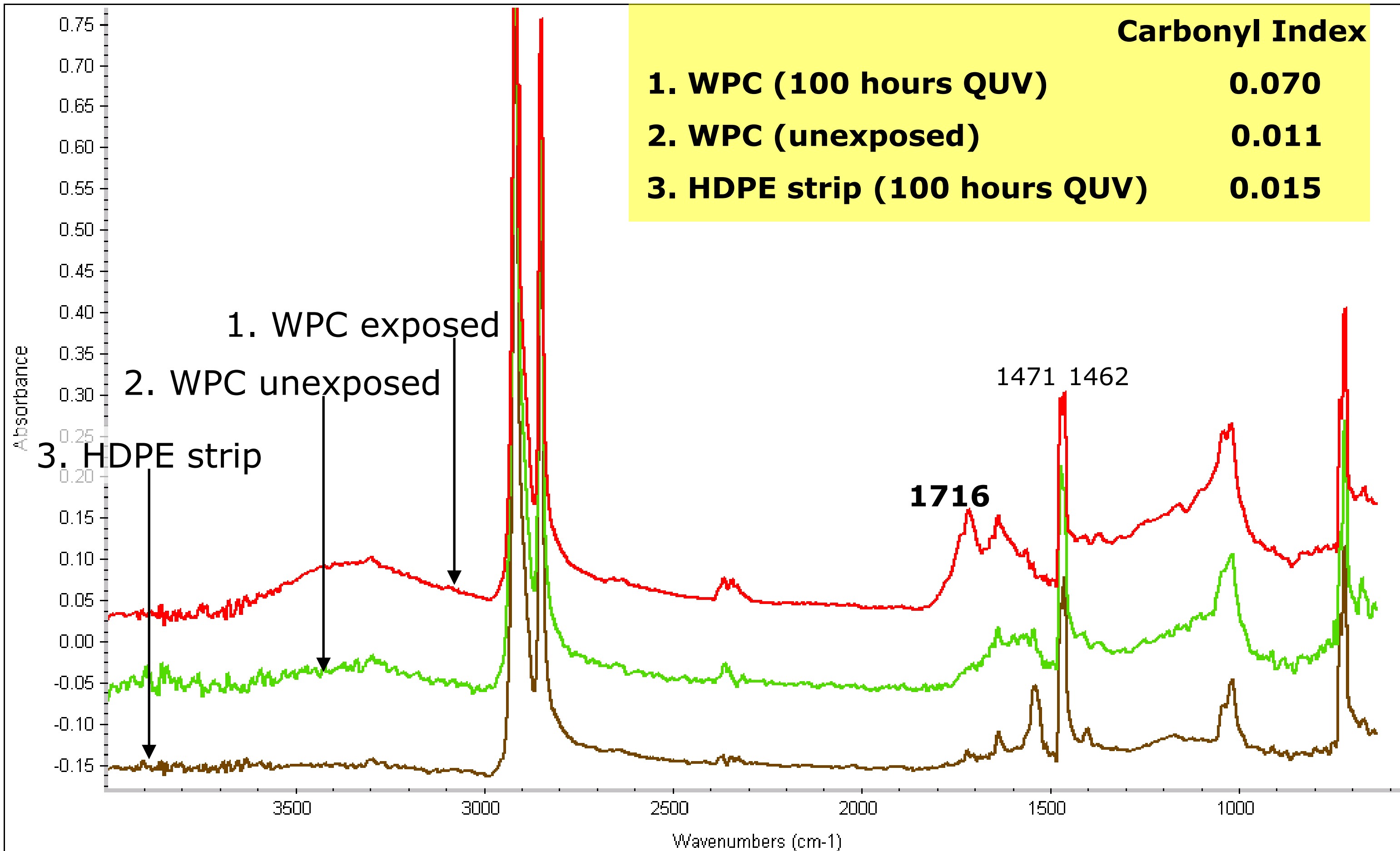
1787 cm^{-1} peracids



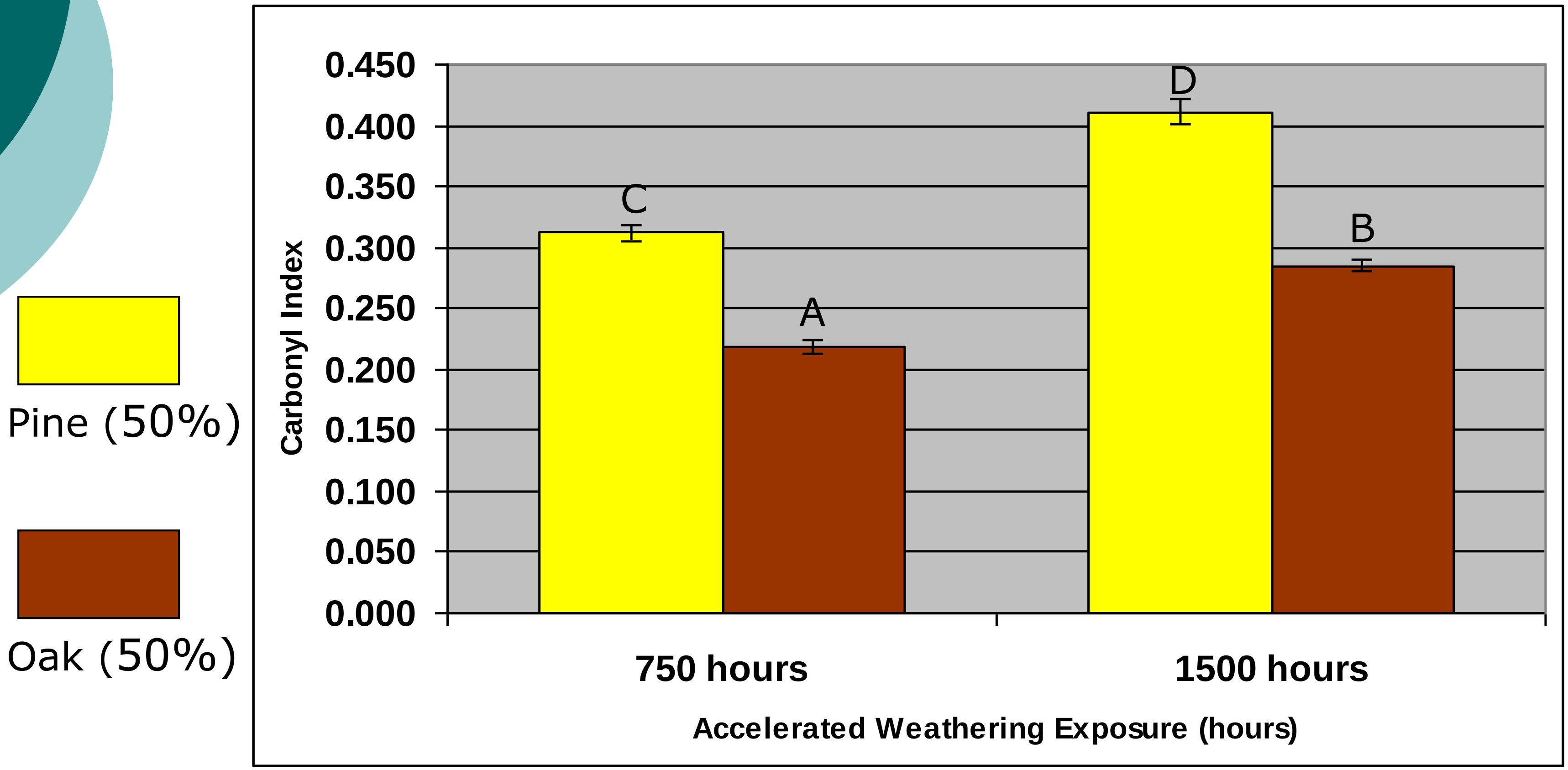
1. **HDPE recovered from WPC after exterior exposure**
2. **HDPE recovered from unexposed WPC**
3. **Recovered HDPE**
4. **Virgin HDPE**

1. Luongo, J.P., *J Polymer Sci,* 1960. *42*: p. 139-150.

FTIR Spectroscopy of HDPE and WPC



FTIR Spectroscopy of WPC Made From Different Wood Species



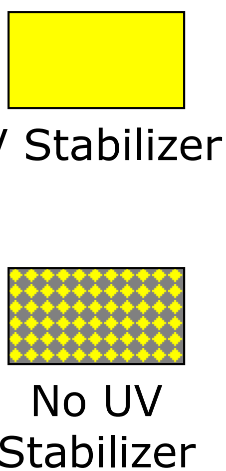
All samples contain UV stabilizer package

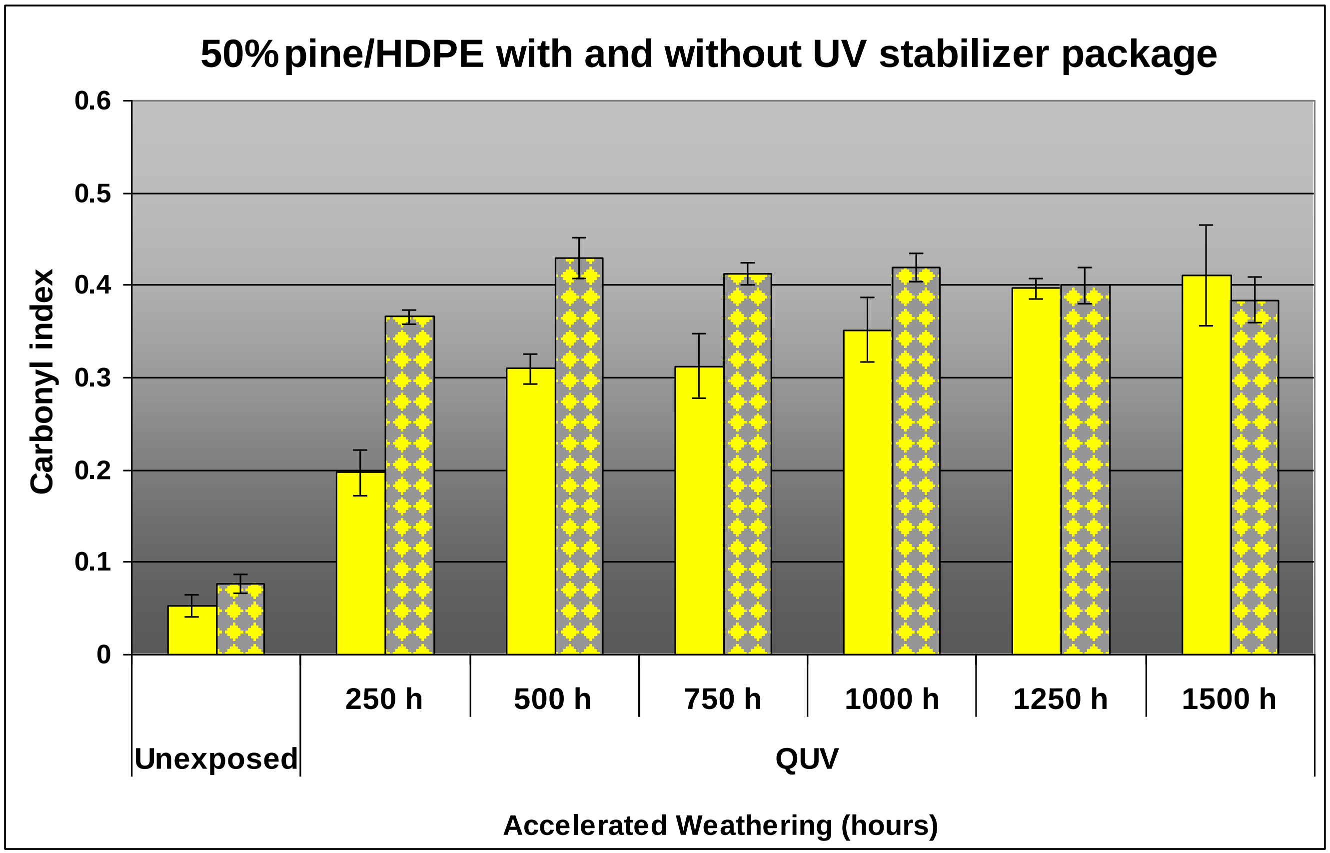
Error bars show standard error

Letters indicate statistically different values (t-test; 95% confidence)

Change of Carbonyl Index upon Exposure to UV

- Effect of UV stabilizer package



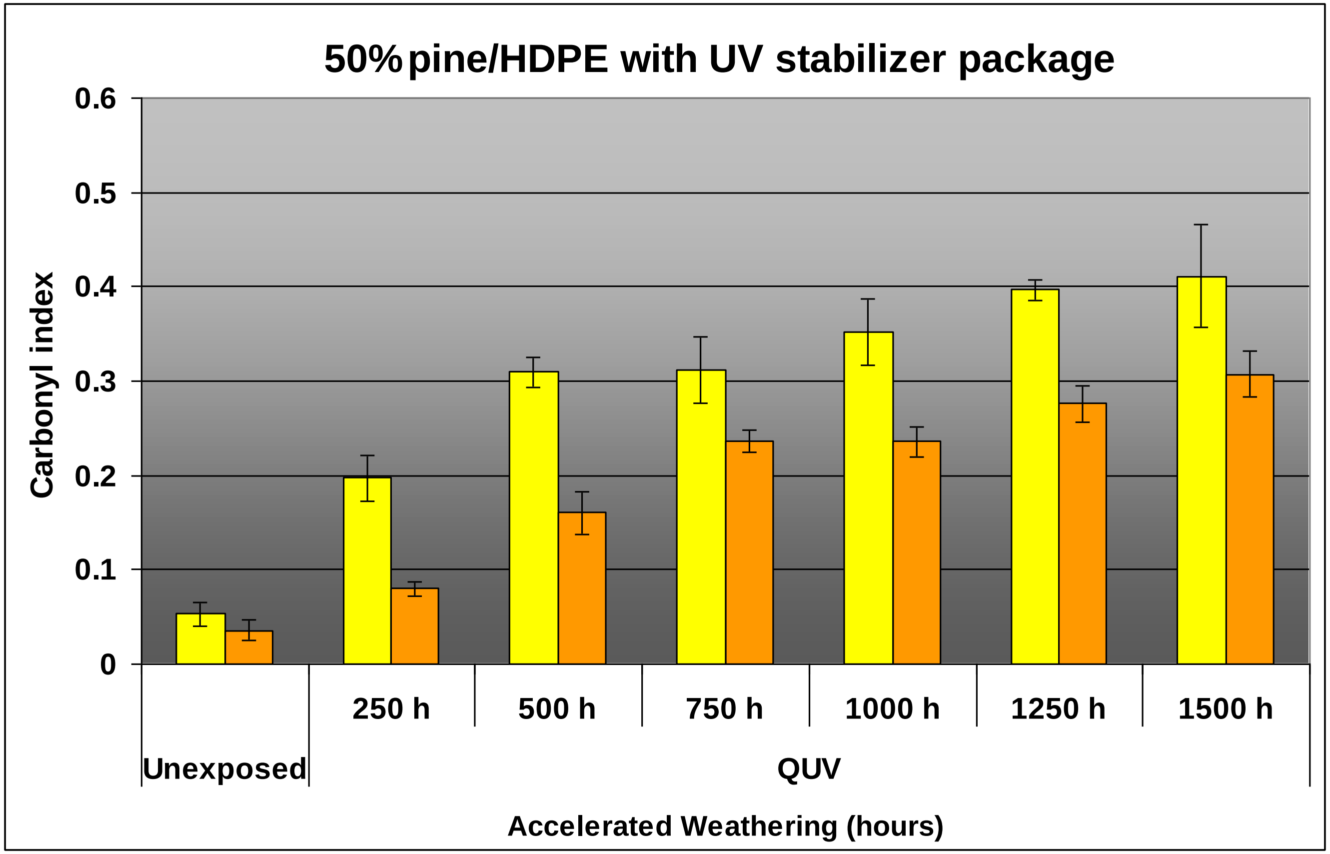


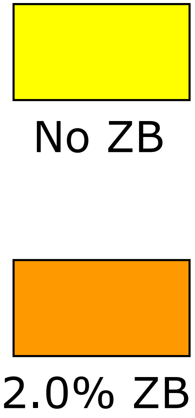
UV Stabilizer package contains HALS and UV absorbers

Error bars show standard deviation

Change of Carbonyl Index upon Exposure to UV

- Effect of other additives (zinc borate - ZB)





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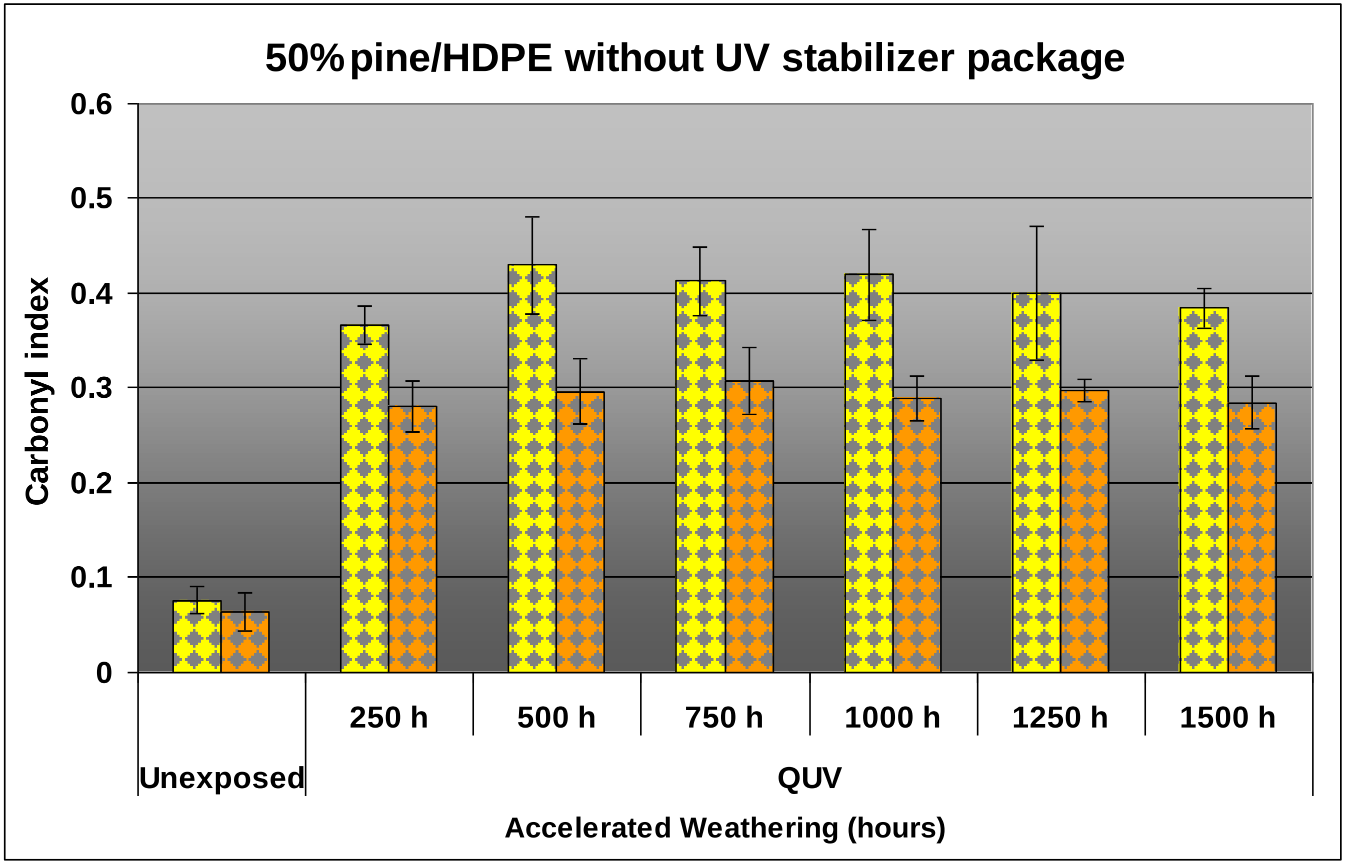
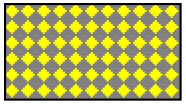
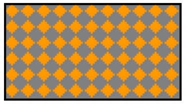




No ZB



3.0% ZB

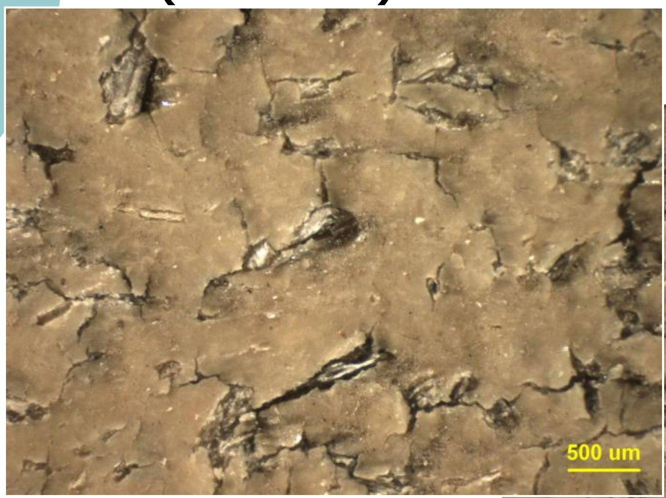
Error bars show standard deviation

36 Months' Exposure in B.C.

Carbonyl Index:

0.237 (36 months)

0.140 (4 months)



Pine 50%

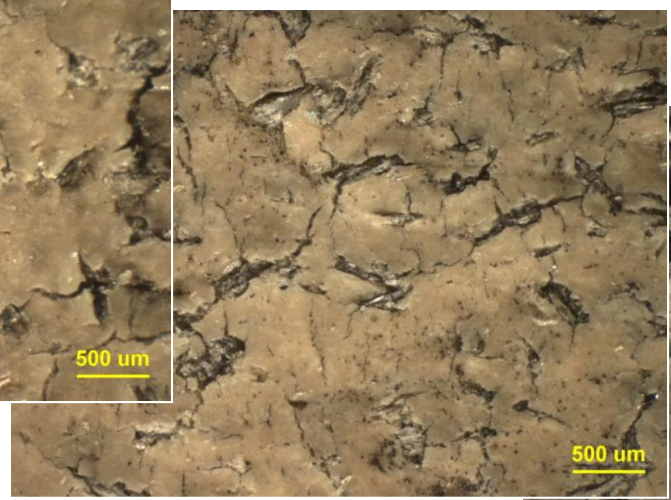
UV Stablizer

Zinc Borate 3%

Carbonyl Index:

0.244 (36 months)

0.179 (4 months)



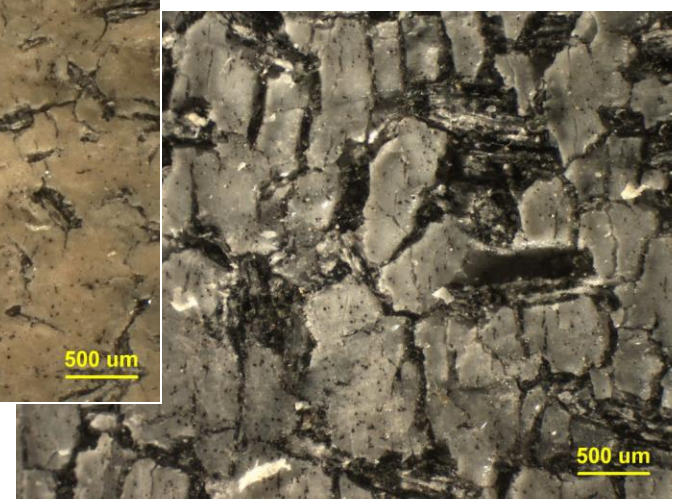
Pine 50%

UV Stablizer

Carbonyl Index:

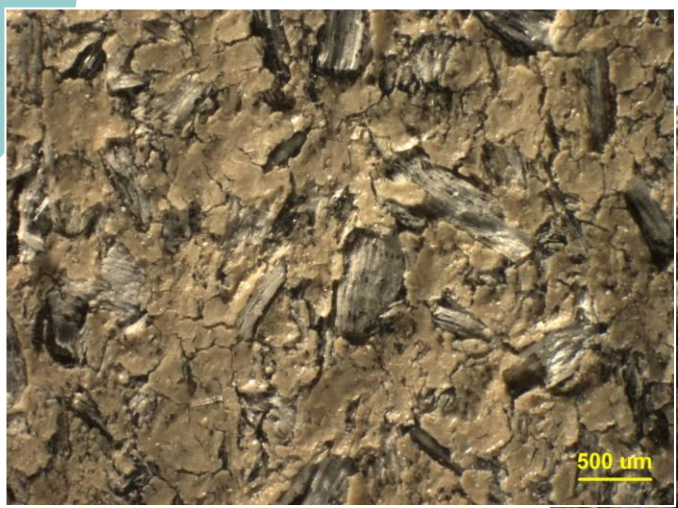
0.246 (36 months)

0.234 (4 months)



Pine 50%

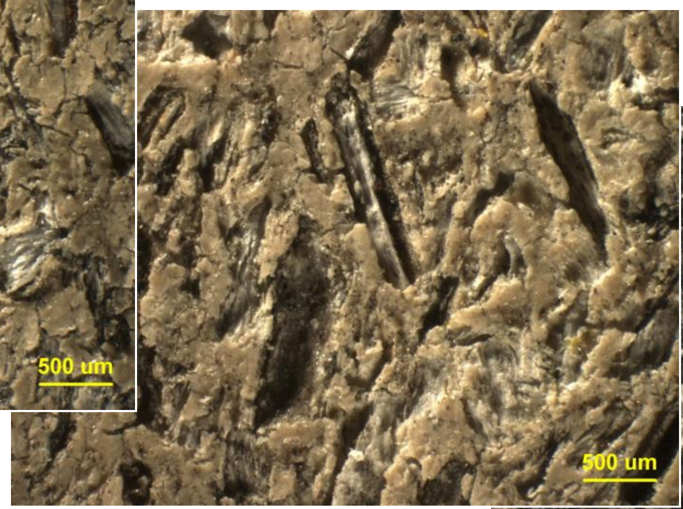
36 Months' Exposure in B.C.



Pine 65%

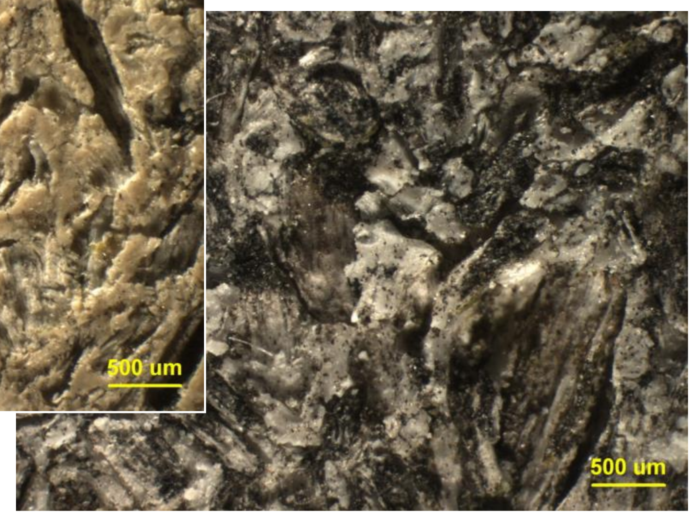
UV Stablizer

Zinc Borate 3%



Pine 65%

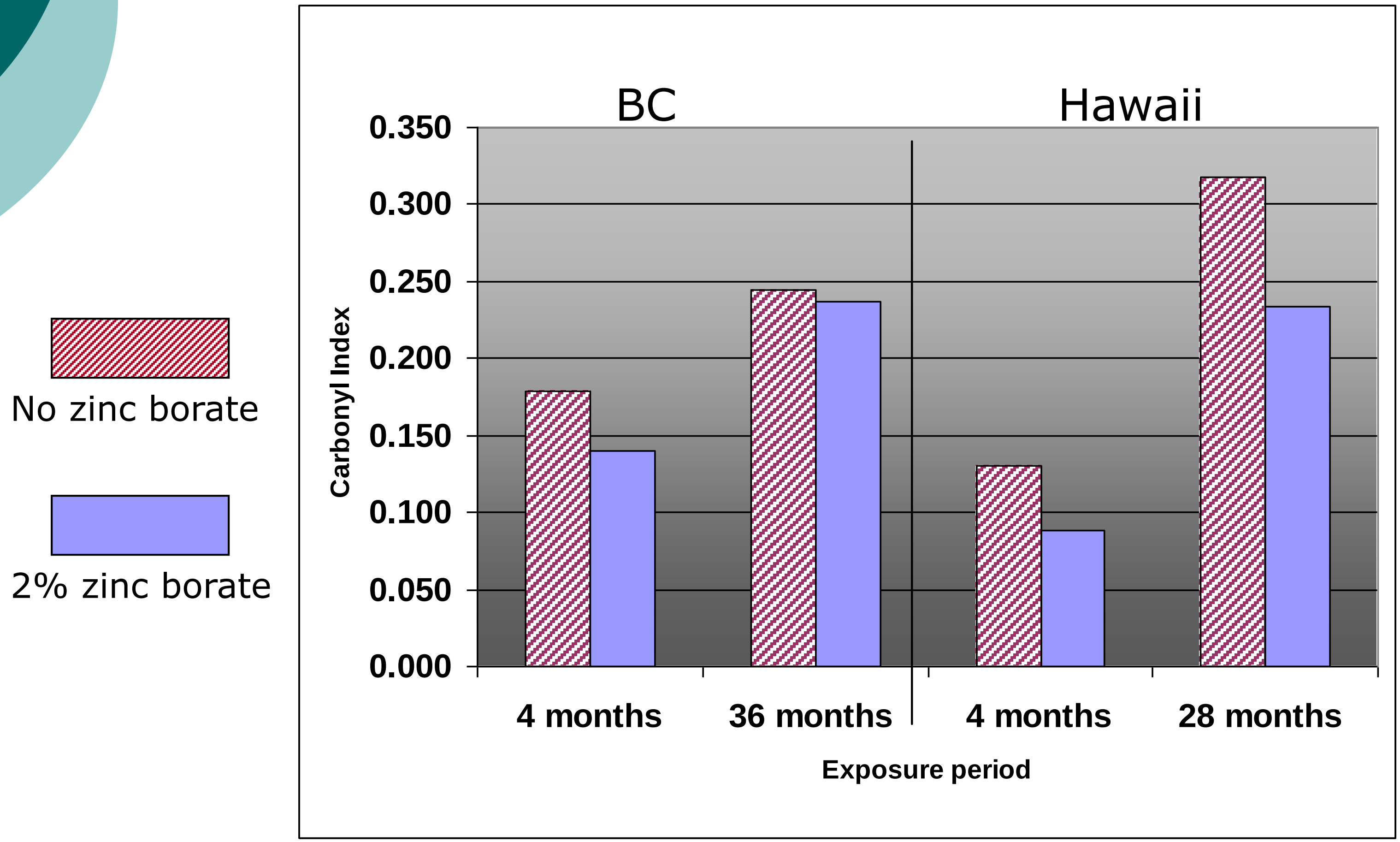
UV Stablizer



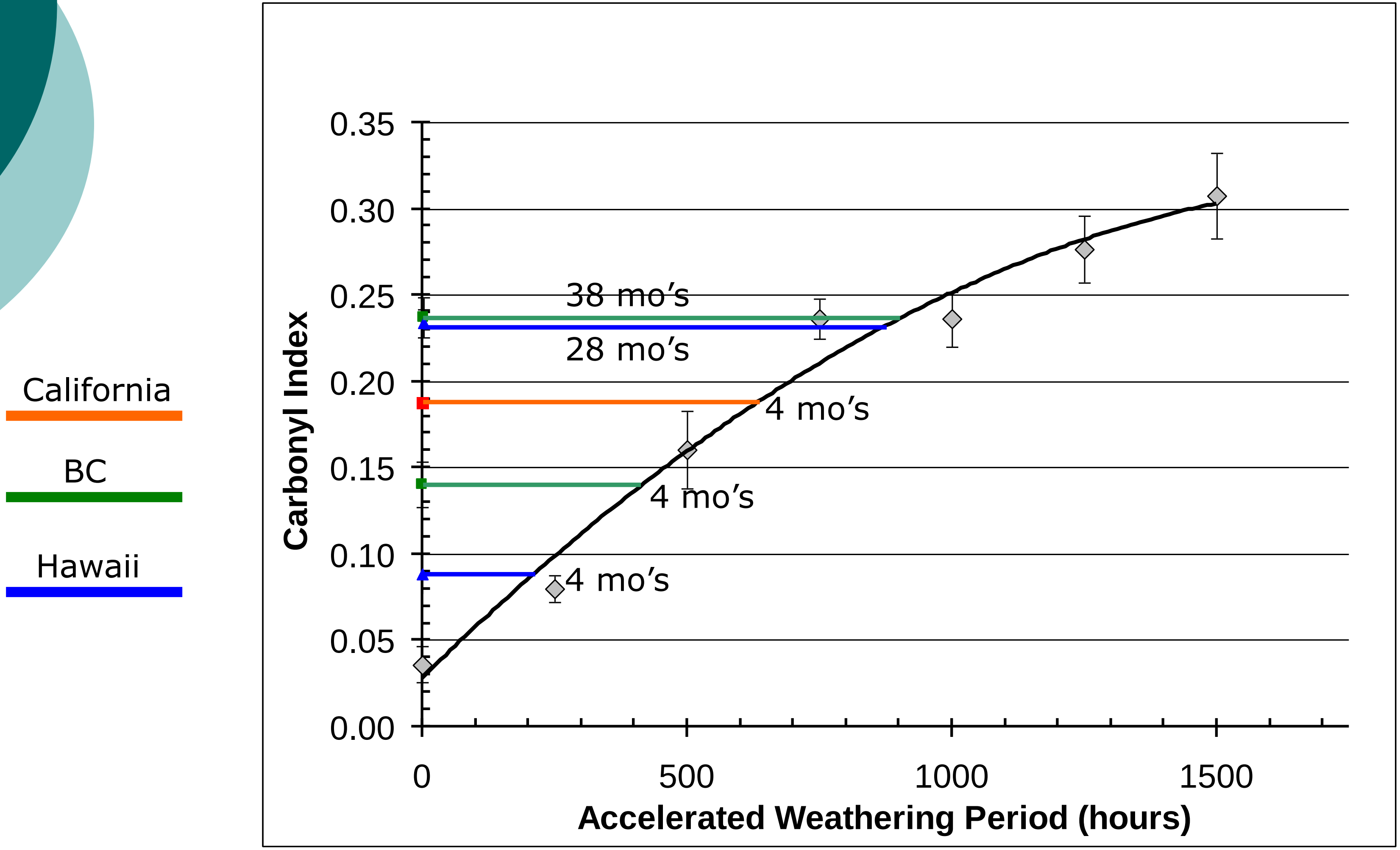
Pine 65%

Hawaii and BC Exposure

Comparison of oxidation of WPC with and without zinc borate exposed at different locations

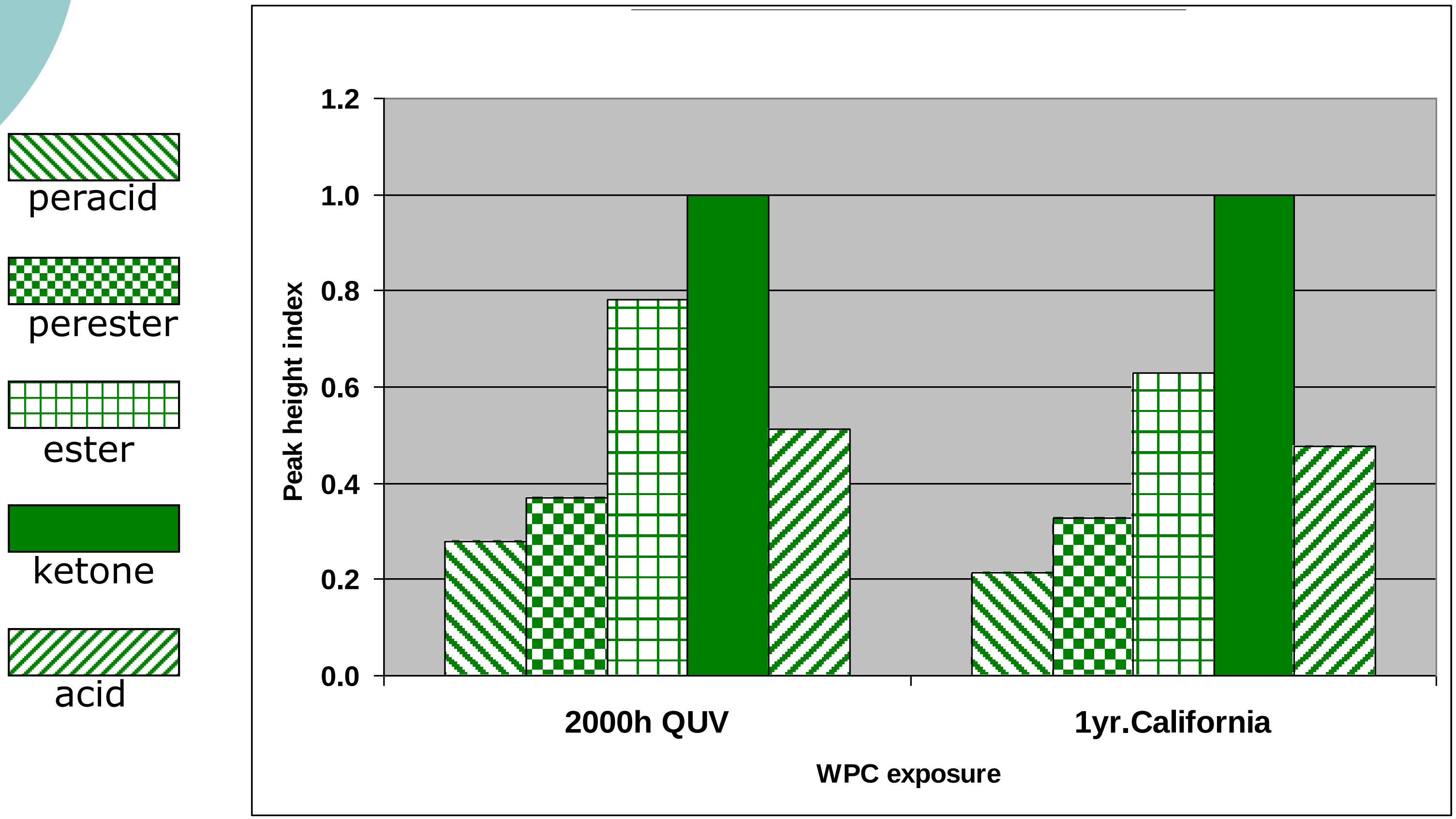


Correlation of Accelerated Weathering to Exterior Exposure



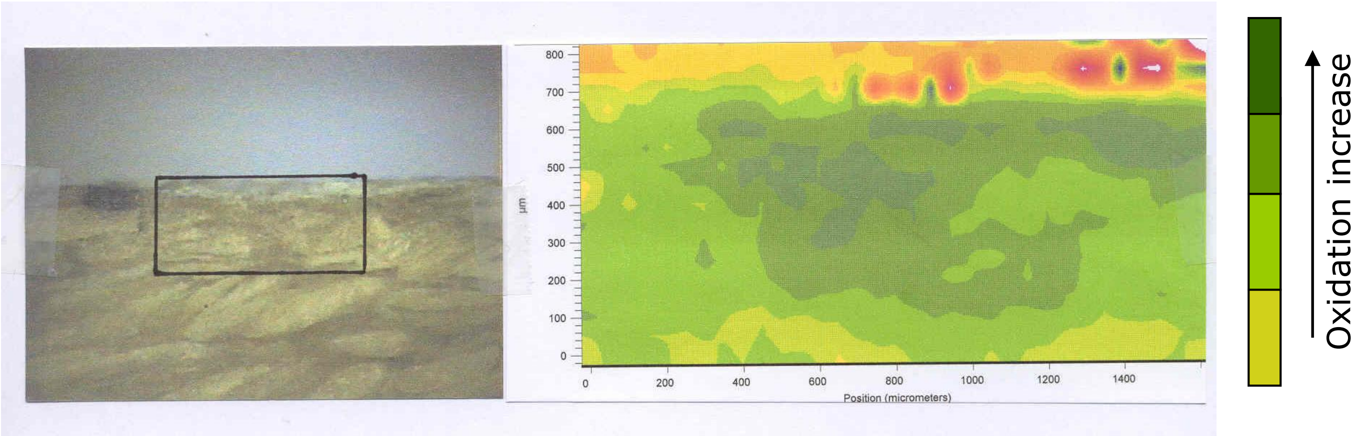
Carbonyl Peak Structure

- Intensity of absorption bands in carbonyl region for HDPE recovered from WPC after exposure to 2000h QUV and exterior conditions in California



Depth of UV Degradation 2000h QUV

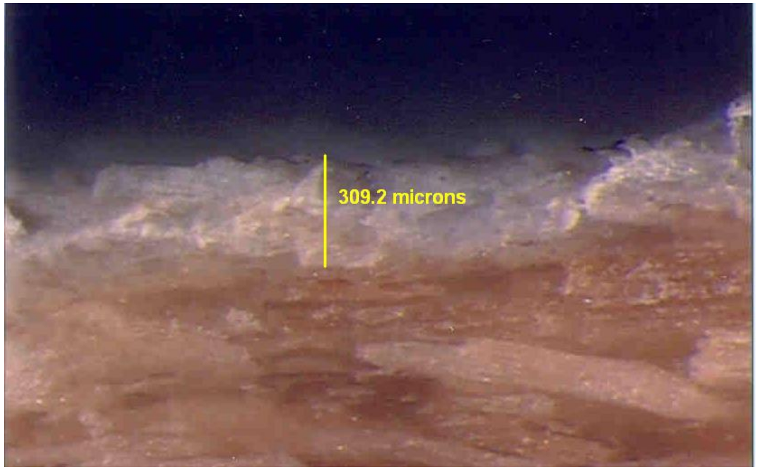
- Raman spectroscopy* oxidized HDPE layer thickness ~0.6 mm



* Courtesy Thermo Nicolet

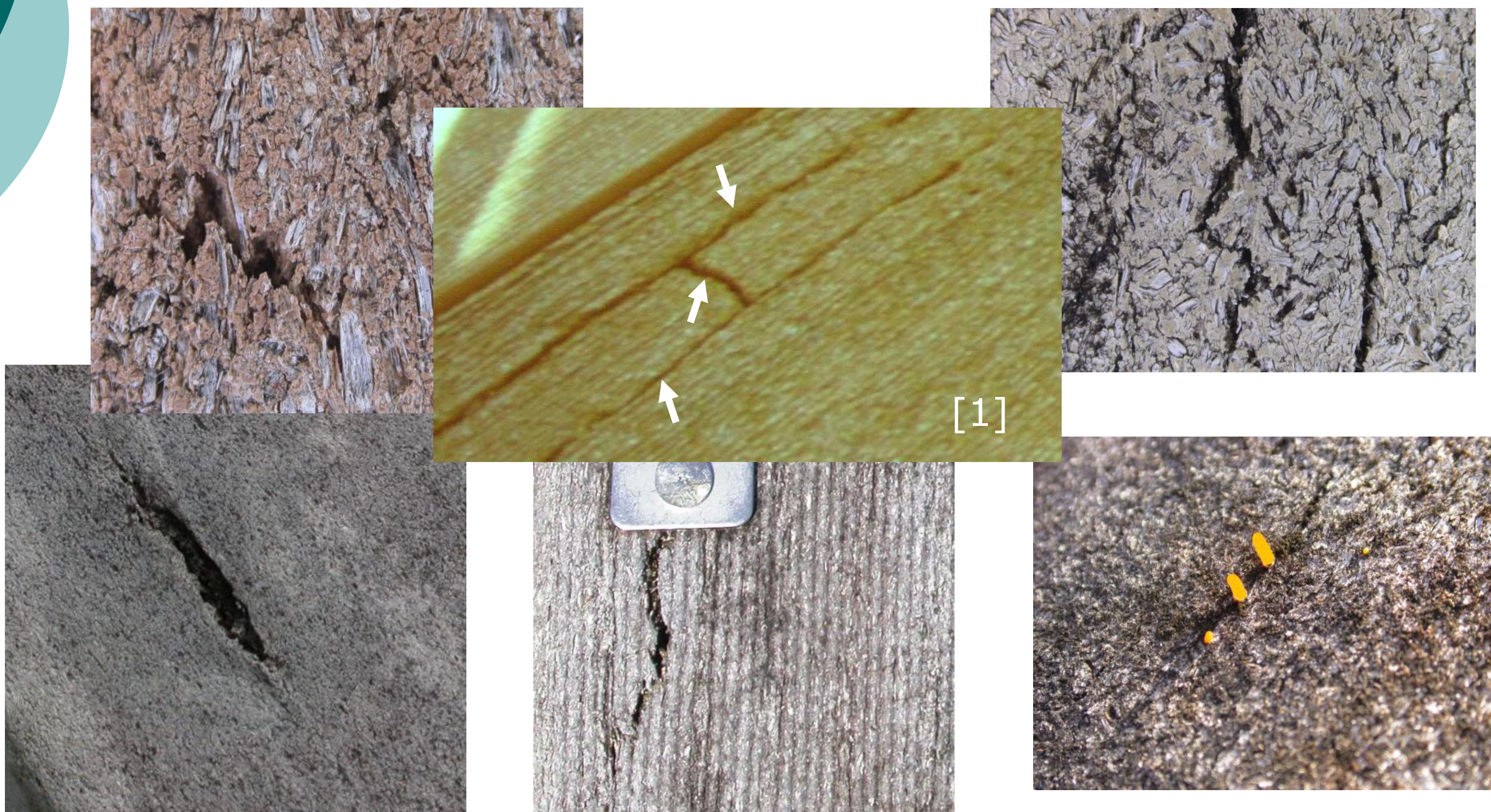
- Microscopy

heavily degraded layer thickness ~0.3 mm



Heat Induced Degradation

- Deep fractures appear in WPC after exposure to full sun in hot climates such as Florida, Arizona, or Hawaii



[1] Dr. Anatole Klyosov, “Oxidative Degradation and Lifetime of Composite Building Materials”, Progress in Wood & Biofibre Plastic Composites 2006 International Conference, Toronto, ON, May 1-2, 2006

Analysis of Surface and Interior of WPC Exposed for Over 10 Years in Florida

- Segment used for evaluation

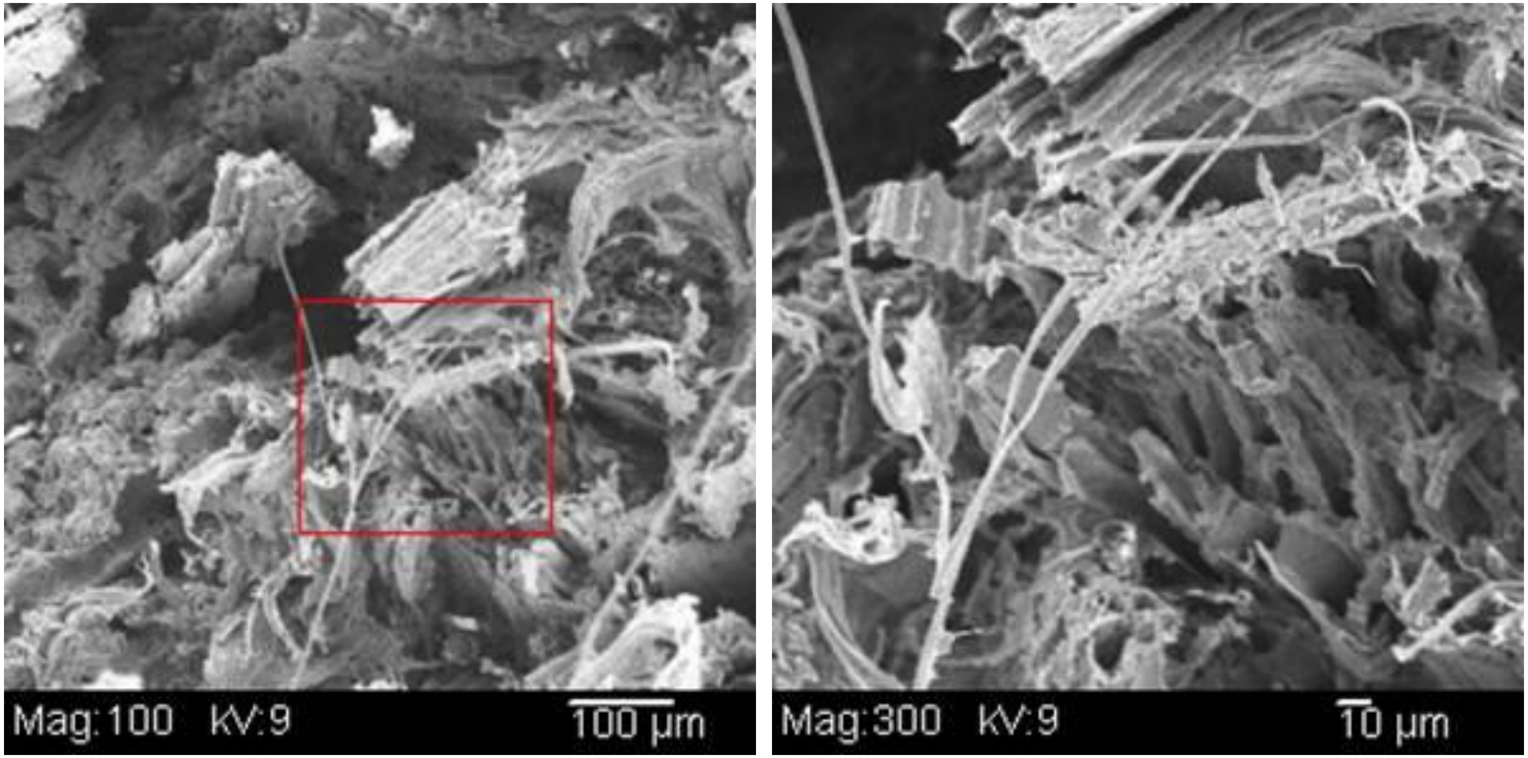
Analysis of Surface and Interior of WPC Exposed for Over 10 Years in Florida

- Wood content in Florida WPC sample

Sample Description	Distance from Surface mm	Wood Content %
Reference	NA	50 - 55
Florida sample surface	0 – 2	14
Florida sample interior	2 – 6	3

Analysis of Surface and Interior of WPC Exposed for Over 10 Years in Florida

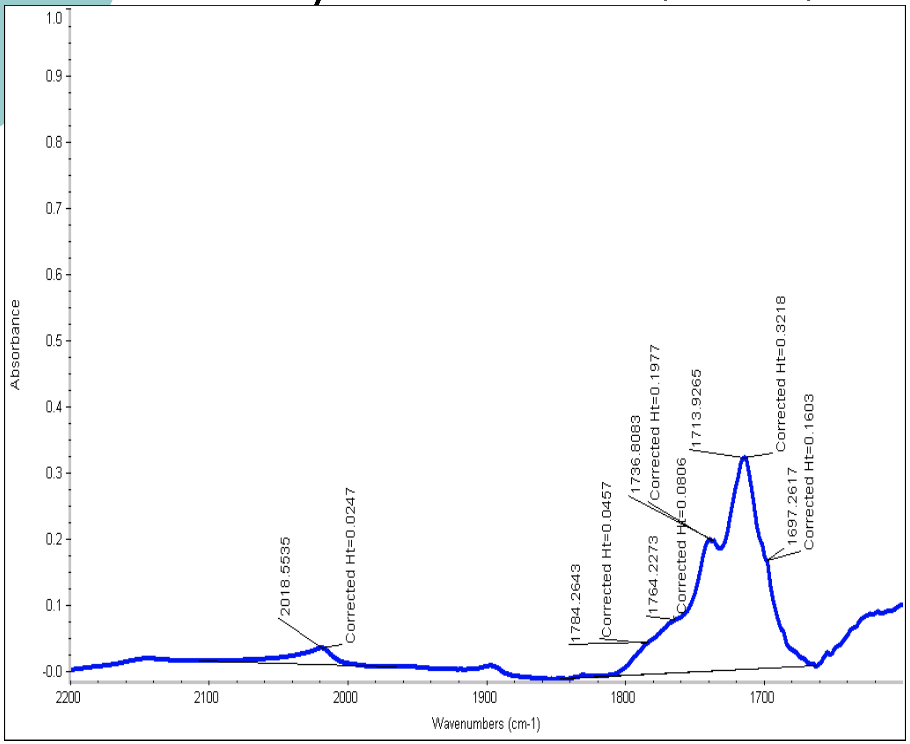
- Scanning Electron Microscopy of WPC Interior



Analysis of Surface and Interior of WPC Exposed for Over 10 Years in Florida

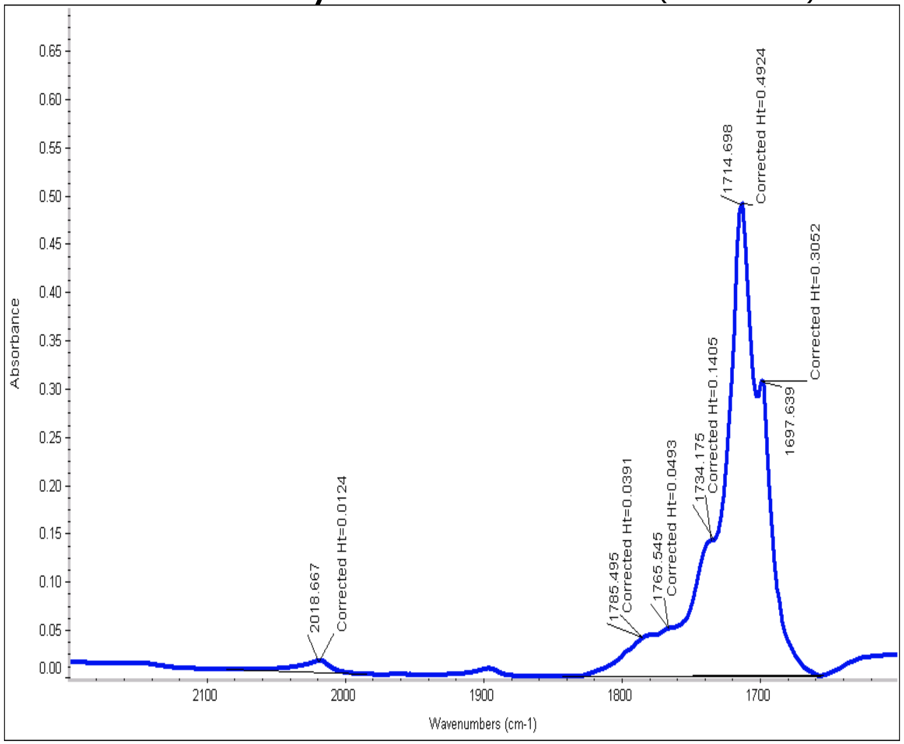
- FTIR Spectroscopy

Carbonyl Index **14.5** (2018 cm^{-1})



Surface

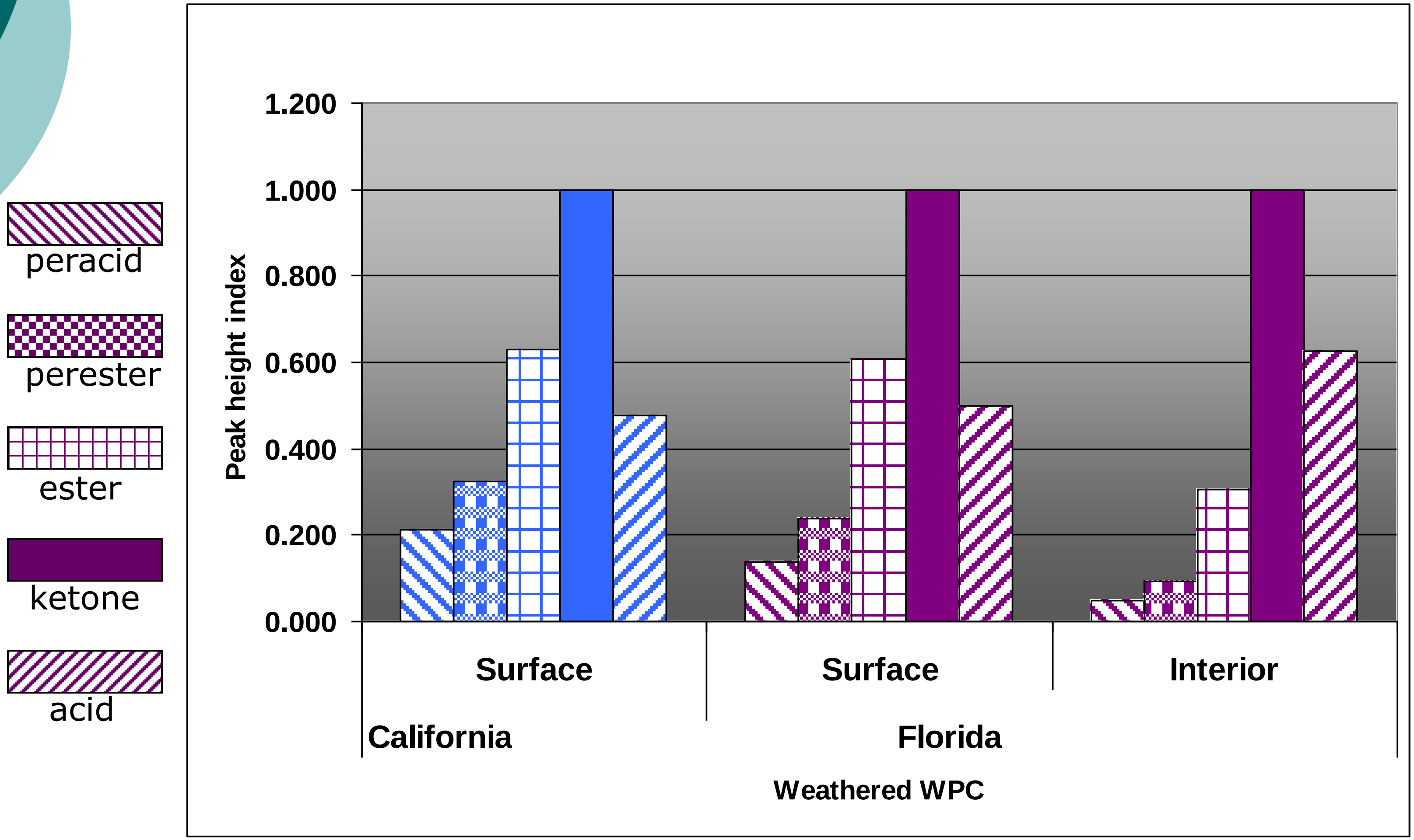
Carbonyl Index **42.0** (2018 cm^{-1})



Interior

Analysis of Surface and Interior of WPC Exposed for Over 10 Years in Florida

- FTIR Spectroscopy



Analysis of Surface and Interior of WPC Exposed for Over 10 Years in Florida

- Differential Scanning Colorimetry

Sample Description	Heat of Fusion of Polyethylene J/g
PE Reference	100.0
Florida sample surface	110.8
Florida sample interior	142.0

Conclusions

- **Various FTIR techniques** can be used to track oxidative degradation of polyethylene binder in WPC. Analysis of FTIR spectroscopic data can be used for assessment of the relative progress of weathering and the effect of different additives.
- **Wood can accelerate photo-oxidation** of polyethylene in WPC. The intensity of the process seems to be related to wood species.
- Some **additives** commonly used in WPC may have a positive or negative effect on polyethylene photo-oxidation. Zinc borate can be seen as an example of a biocidal additive which also inhibits photo-oxidation.
- Samples of polyethylene based WPC exposed to fluorescent lamp induced accelerated weathering or exterior conditions develop very similar patterns of oxidative degradation by-products. This indicates that the **weathering process seems to be similar** in both cases.

Conclusions 2

- WPC degradation by UV light seems to be only a **surface and shallow subsurface phenomenon**.
- **Heat induced stress cracking** of WPC seems to be a weathering process capable of reaching further into the composite. Stress cracking in older materials may be associated with further composite degradation.
- The mechanism associated with WPC degradation in the field seems to be not fully understood. **Further study is required**, particularly related to subsurface degradation.

Acknowledgements

- PEC personnel Beverly Start and Christine Mah for contributions and assistance.
- Washington State University Wood Materials & Engineering Laboratory for assistance with sample preparation.
- Thermo Nicolet for Micro Raman Spectroscopy.