Monitoring of degradation process in automotive multilayer coatings

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Surely - there are different ways to protect your car against UV and weathering …

… but the most prospective way to go is to:

- Analyze and understand the degradation effects
- Then, secondly as a follow up, improve the coating formulation in a reasonable way

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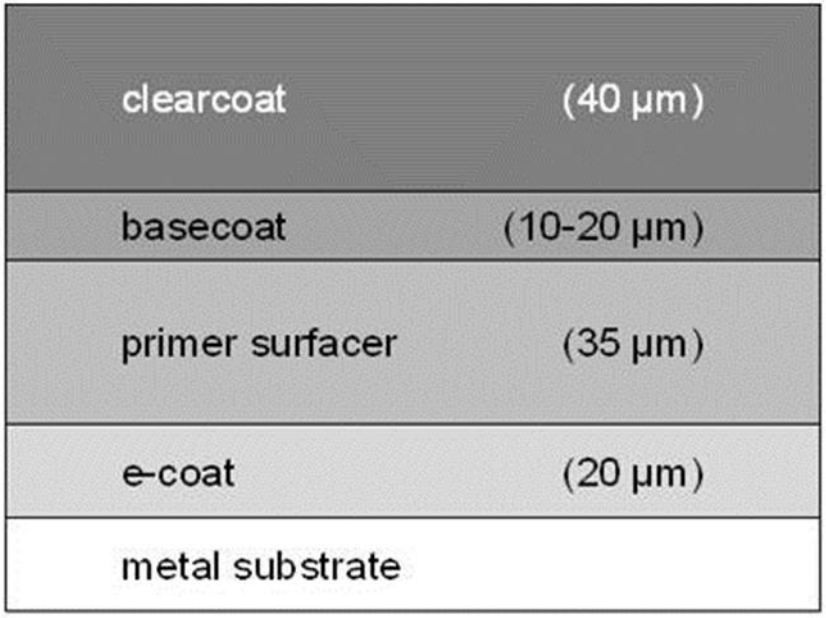
General aspects to be considered in the degradation process of multilayer coatings

- In multilayer systems the physical and chemical properties not only depend on the single layers, but also on their interfacial interactions, making the situation rather complex, if effects of outdoor weathering, for example on automotive coatings systems, are considered.
- It is generally accepted that the photochemical degradation of coatings is initiated by the absorption of UV light and that the e-coat in automotive multilayer systems is mostly endangered by this phenomenon.
- Unfortunately, mostly empirical data for automotive multilayer coating systems are available and therefore the degradation mechanism is still not fully understood.

Automotive multilayer coating system, used for the degradation experiments

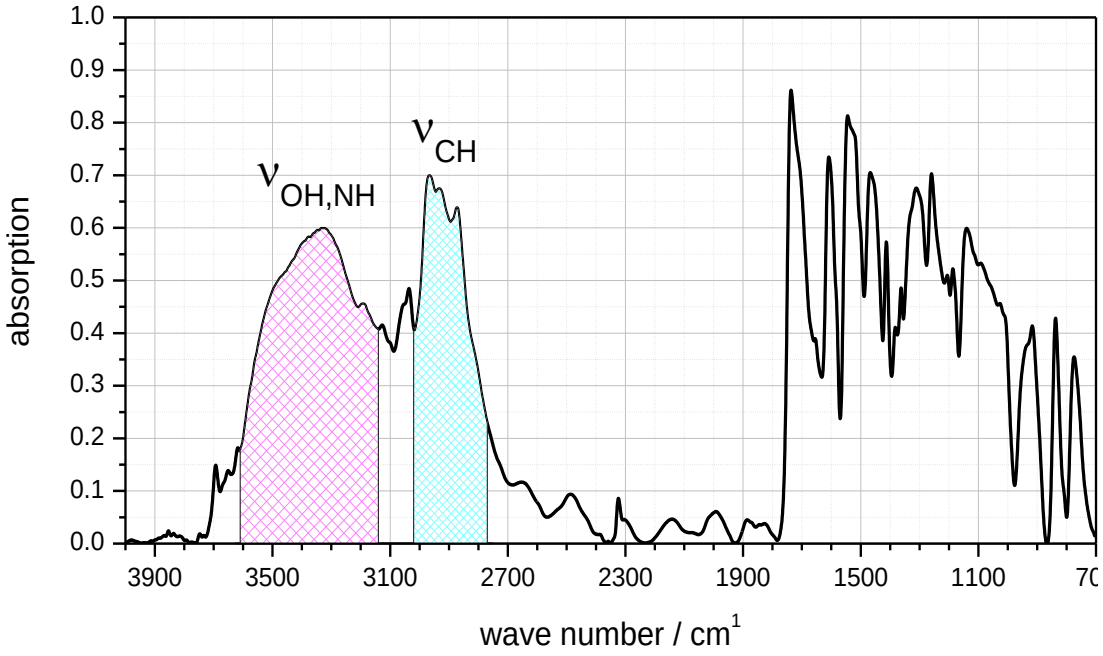


Todays automotive multilayer systems consist of an e-coat (mostly a cataphoretic coating), followed by a primer surfacer, a basecoat and a final clearcoat layer on the top.

Experimental aspects

- For the degradation experiments, OEM-formulations of e-coat, primer surfacer, basecoat and clearcoat were applied onto metal substrates. For the metallic basecoats, pneumatic application (air-only), electrostatic application (bell only) and mixed bell/air applications were performed.
- To evaluate the transmittance and absorbance properties, the multilayer coatings, applied on top of the e-coat layer, were prepared as free films and characterized using the UV-VIS-NIR spectrometer Lambda 900 from Perkin Elmer.
- The degradation experiments were performed by artificial weathering of coatings for 4500 h using a Weather-O-Meter equipment (WOM Ci 4000, Atlas Material Testing GmbH).
- For the evaluation of the photooxidation index (POI), a special kind of flat angle cross-sections was developed.
- The detected areas, which represent a depth profile of multilayer systems, were conditioned in vacuum and then analyzed with the FT-IR microscopic system Spectrum Spotlight 200 (Perkin Elmer).

Evaluation of the photooxidation index (POI)



$$POI_t^* = \frac{Q_t - Q_0}{Q_0} \cdot 100\,\%$$

with

$$Q_t = \frac{A_{variable}}{A_{internalstandard}}$$

$$\text{variable} = \upsilon_{OH,NH}$$

$$internal\ standard = \upsilon_{CH}$$

For the evaluation of POI, the integrated valency vibration regions of hydroxy and amino groups are related to the valency vibrations of alkyl groups, which are taken as an internal reference.

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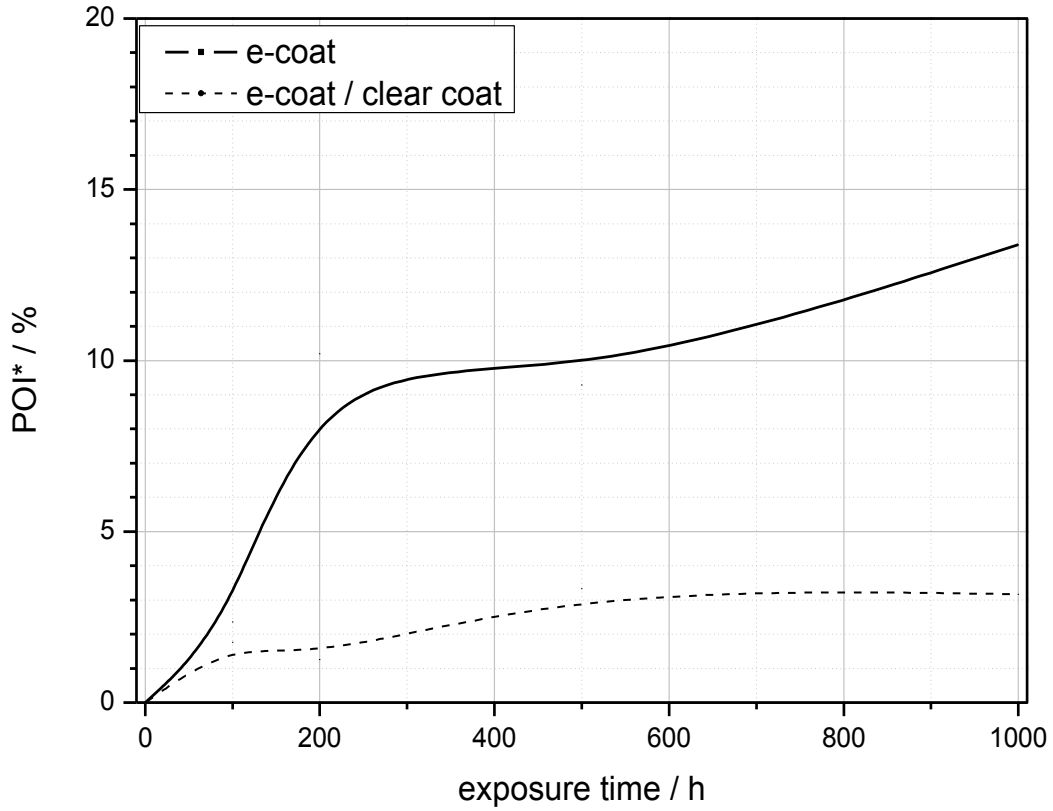
Changes of POI during UV and humidity loading of a single e-coat layer and an e-coat, overcoated with a clearcoat



- The e-coat is protected against degradation by the clearcoat.
- The evaluation of the influence of UV absorption properties of overcoating layers on the degradation of the e-coat seem to be highly interesting.

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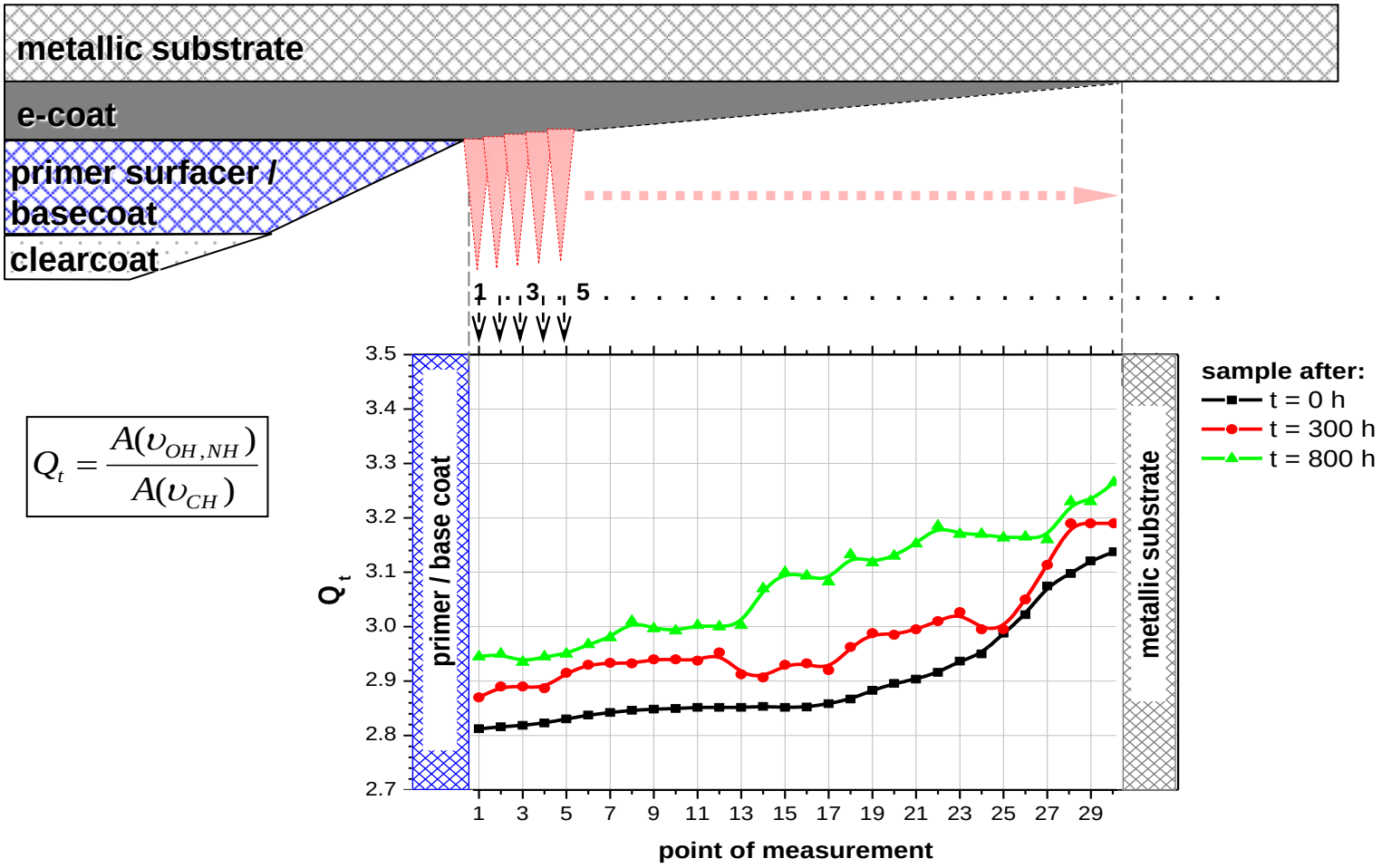
Changes of the Q_t values from the primer surfacer / e-coat-interfacial section to the metal surface system



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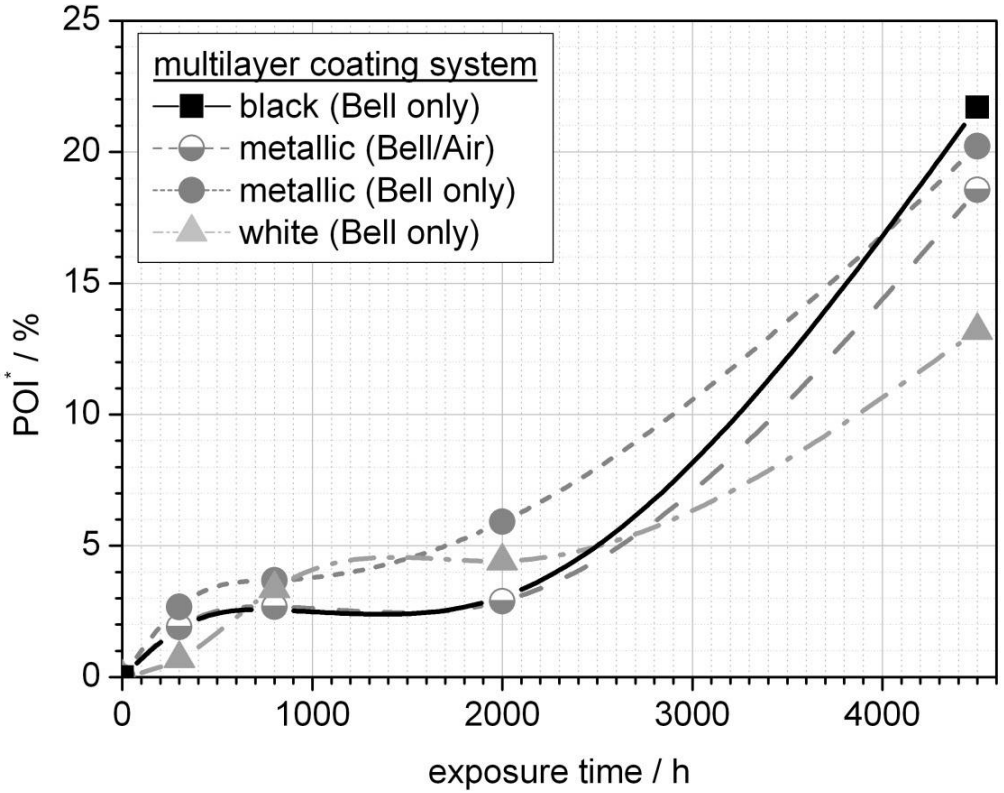
Changes of POI for the e-coat, overcoated with different multilayer systems, with increasing exposure times



After 4500 h of WOM exposure, the following ranking of changes in POI was observed (ordered from higher to lower degradation):

Black > Metallic (bell-only) > Metallic (bell/air) >> White

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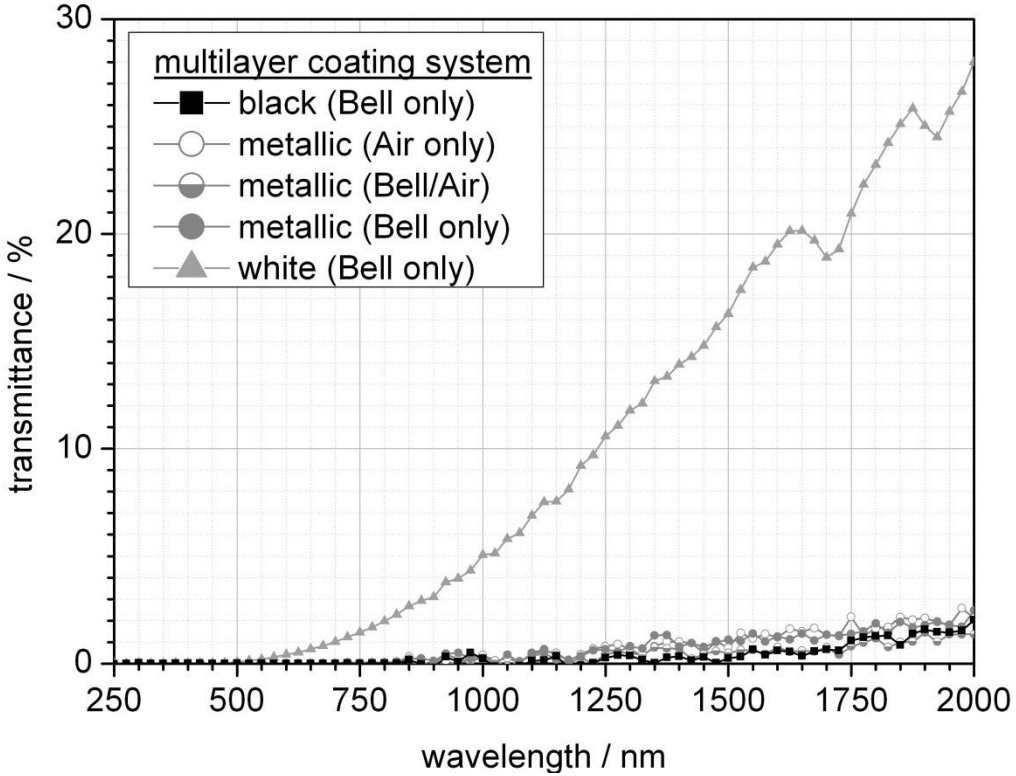
Transmittance of multilayer coatings applied on the top of the e-coat, in the UV-VIS-NIR range of light



Because the observed transmittance is very small, the UV transparency of overcoated layers cannot be the only parameter, which influences the photooxidative degradation of the e-coat.

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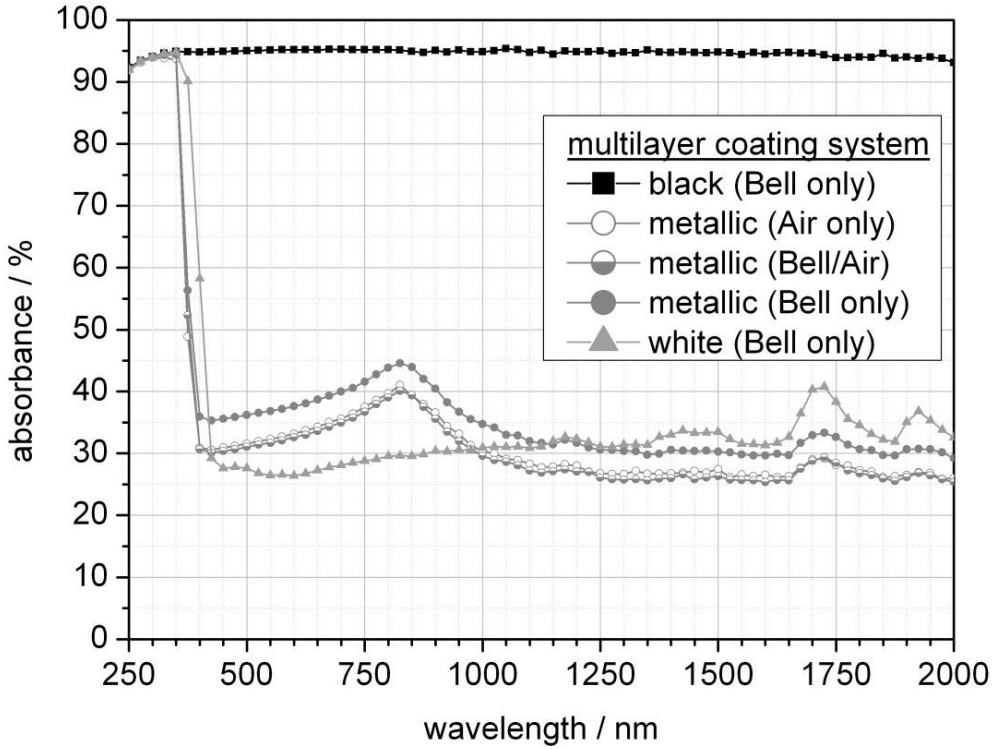
Absorbance of multilayer coatings applied on the top of the e-coat in the UV-VIS-NIR range of light



Whereas the white coating showed a low absorption in the wavelength range between 250 and 1000 nm, the absorption of the black system was very high, with values above 90 %. The metallic coating system, in comparison to the white coating, showed a slightly increased absorption, dependent on the kind of spray application.

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Conclusions and possibilities to diminish the degradation process in todays automotive multilayer coating systems

- The obtained results prove that for the tested different coating systems, the transmittance of UV light is not the only important factor which influences the degradation stability of the e-coat.
- The observed stronger degradation of e-coats, coated with black or other highly light absorbing coatings, can be interpreted in terms of a thermocatalytic effect, which accelerates the photooxidation process.
- For automotive coating systems, the color range of basecoats, which dominates the energy absorption and heating up of the coating system, is determined by customers, so the possibilities to decrease the heat uptake and depress the thermocatalytic effect of photooxidation are certainly limited.

Nevertheless, coating concepts that allow an increased UV and/or IR reflection on the coating surface and the use of less IR absorbing pigments in basecoats should be intensively considered.

Acknowledgements

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Thank you for your Attention …

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