"A Philosophy is gaining Momentum"
By Dr. Thomas Sowade

Influence of Solar radiation on Pigments

Pigments interact with the solar terrestrial radiation described in Figure 01. Possible interactions are absorption (transmission), reflection and scattering.

The interaction of color pigments with the visible part of the electromagnetic spectrum (380 – 780 nm) is obvious in form of our color impression. Pigments can additionally interact with UV-radiation (250 – 380 nm) and/or NIR (near infrared; 780 – 2500 nm) radiation. While the (detrimental) influence of the UV-radiation is well known in form of e.g. pigment fading, the interaction with the NIR-radiation is its poor invisible cousin, although the integral energy of the NIR-radiation accounts for approx. 50 % of the total integral energy of solar radiation.

Influence of Solar radiation on Pigments

The pigment with the highest reflection ability is based on TiO₂, while the pigment with lowest reflection is based on Carbon Black. If from aesthetical point of view one likes to stay with a dark color instead of white, there is the choice to use dark Inorganic Complex Pigments like P.G. 17 (Chromium Green Black) or P.Bk. 30 (Chrome Iron Nickel Black Spinel) as IR-reflecting option. These pigments show higher TSR values compared to Carbon Black and are an excellent choice for e.g. grey color shades while in mono pigmented systems the TSR-value is higher but the jetness is lower compared to Carbon Black.

The following graphs demonstrate TSR values of different pigmented topcoats (Figure 02) with the corresponding heat build-up measurements (Figure 03).

Heat build-up effect of different Pigments in a Multi-Layer-System like Car Refinish

Although the usage of black Inorganic Complex Pigments with higher TSR-values compared to Carbon Black is unlikely in full shade Car Refinish or OEM-TopCoat due to missing jetness there is still some room for it in the total Multi-Layer Setup: Conventionally pigmented topcoats (high performance organic pigments) are transparent or at least partially transparent to NIR-radiation. As consequence the NIR-radiation passes through the TopCoat and the IR-reflectance ability of this Multi-Layer-System is then determined by the behavior of the next layer, in this case the primer. Primers are available in different colors, including light grey and dark grey, to support the color of the Topcoat e.g. in case of scratches. We modified a conventional white primer to a light grey and a dark grey primer, one
modification with carbon black, the other with inorganic IR-reflecting black. Both modifications were tinted to the same coloristic values.

Due to the better tinting strength of carbon black a higher amount of inorganic black was necessary to achieve the similar coloristic result (Figure 04).

The light grey and the dark grey non-NIR primer show an appr. 8˚C higher end temperature compared to the white or the NIR primers. Remarkable is especially the very small difference in between the white and the two NIR primers which proof the efficiency of using IR reflecting inorganic blacks (Figure 05).

In practice a red basecoat is more likely to be combined with a light or dark grey primer, but a blue basecoat is more likely to be combined with a white or light grey primer while a red basecoat is more likely to be combined with an inorganic IR-reflecting black. Both modifications could be observed in our lab with non-NIR-reflecting and NIR-reflecting modified samples (Figure 10).

The darkness of the applied plaster on the EPS is limited as it may suffer from thermal / thermomechanical stress especially at the interface between Plaster and EPS layer. Therefore thermal insulation Systems are only offered to a certain point of luminosity values, indicating the darkness of the plaster.

Using IR reflecting pigments, the heat build-up on the composite thermal insulation is reduced, with expected positive impact on prevention of premature failure (Figure 07). As a consequence using (dark) grey products with lower luminosity values is becoming reality.

In a lab experiment grey plasters with a 1/3, 1/9 and 1/25 standard depth were formulated using for each sample a different pigment chemistry (PBk. 7, PBk. 11, PBk. 30 and PG. 17) and applied as thermal insulation system.

In heat build-up tests for all standard depths the systems with PBk.7 and PBk.11 show a higher equilibrium temperature compared to the systems using PBk. 30 or PG. 17 (Figure 08 showing the example for 1/3 standard depth).

Following these lab findings tests in outdoor exposure have been performed: During an extraordinary warm summer day (38°C maximum temperature) samples colored with PBk. 30 and PBk. 7 at 1/3 STD and PG. 17 and PBk. 7 at 1/9 STD were placed in the sun in Germany/ Langelsheim (51.9’N, 10.3’E) facing south. While the non-NIR reflecting samples reached surface temperatures of around 100 °C the NIR-reflecting modified samples stayed appr. 10 °C cooler (see setup of experiment in Figure 09 and summary of results in Table 02).

Considering the thermal form stability of EPS (depending on compressive stress by load) to be 75-85 °C in long term and 100 °C in short term many manufacturers of EPS recommend to keep temperatures < 75 °C. The above findings show an extraordinary warm summer day (38˚C maximum temperature) samples colored with PBk. 30 and PBk. 7 at 1/3 STD and PG. 17 and PBk. 7 at 1/9 STD were placed in the sun in Germany/ Langelsheim (51.9’N, 10.3’E) facing south. While the non-NIR reflecting samples reached surface temperatures of around 100 °C the NIR-reflecting modified samples stayed appr. 10 °C cooler (see setup of experiment in Figure 09 and summary of results in Table 02).

The TSR values including the maximum temperatures of the heat build-up measurements of different multilayer combinations are listed in the following table (Table 01). In both cases (red & blue basecoat) the modification of the standard grey primers (containing Carbon Black) with Inorganic IR-reflecting Black Pigments shows a significant effect for the Multi-Layer-Setup in total performance.

**Table 01**: Matrix of test results (TSR and maximum temperature) for multilayer Car Refinish systems

<table>
<thead>
<tr>
<th>Primer</th>
<th>Red Basecoat</th>
<th>Blue Basecoat</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-NIR Light Grey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-NIR Dark Grey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NIR Light Grey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NIR Dark Grey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSR [%]</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>Max. Temperature [°C]</td>
<td>50.0</td>
<td>56.0</td>
</tr>
</tbody>
</table>

**Figure 05**: Heat build-up measurements on white, light grey and dark grey primer

**Figure 06**: Multilayer set up of refinish coating with different primers and a red respectively a blue basecoat

**Figure 07**: Temperature profile of composite thermal insulation with and without IR-reflecting pigments

**Figure 08**: Comparison of surface temperatures on the surface of composite thermal insulation for four different pigments at 1/3 STD depth
The main difference compared to products which typically show such high TSR-values can be seen in the visible part of the spectrum, especially in between 650nm – 800nm. Here the reflection is significantly lower resulting in a more neutral color shade (Figure 12) and a higher jetness.

While in full shade the new pigment is more neutral compared to PG 17 or PBr 35 (figure 12) this behaviour can be found also in the 1:1 reduction (see figure 13). To achieve this color shift to the more neutral side while staying with the high TSR-value a lower tinting strength needs to be accepted.

Conclusion

Besides the well known application of IR-reflecting Pigments in coil coatings possible benefits in two other areas have been found and a new inorganic black pigment combining jetness and high TSR-value was developed:

- In Multilayer systems it is possible to formulate brilliant surfaces combining the brilliance of an NIR-transparent topcoat (organic pigments) with the NIR-reflection ability of the below primer layer (NIR-reflecting pigments instead of carbon black) to reduce heat build-up of the whole system. Such Multilayer systems can be found e.g. in automotive OEM or Refinish as well as in other industrial coatings applications. Although in car industry research is focussed at the moment to optimize the window glazing due to its higher influence on heat build-up in the car interior, it can be expected that the attention will turn back to the coating once the research for glazing is finished and the contribution of the car body/reflective coating gets higher again in relation.

- Positive findings for lower heat build-up of thermal insulation systems using IR-reflecting black pigments instead of carbon black or black iron oxide have been reported for lab and outdoor tests. Detrimental effects on dimensional integrity of the expanded Polystyrene insulation layer can be seen under real outdoor conditions which can be minimized using IR-reflecting Pigments. All in all one can expect a lower energy consumption for cooling the buildings interior as well as an enhanced lifetime of the thermal insulation system reducing thermomechanical stress at the interface EPS/Plaster.

- A new inorganic black pigment has been developed combining jetness and a neutral colour shade in reductions with an extraordinary IR-reflecting ability bridging the gap between existing products.

Note: All in this paper cited TSR-values have been determined in 20% pigmentation in Alkyd/melamine. The powder pigments itself show even higher TSR-values.