Inorganic Pigments

# IR Reflecting Pigments

Hot Pigments for Cool Solutions

heubach

COMPETENCE IN COLOR

## Hot Pigments for Cool Solutions

Jumping out of the box is an objective every pioneering and forward-thinking coatings chemist or engineer likes to achieve.

Modern and innovative coatings are striving for an apparent break-through effect that imparts the coating system an obvious added value. This ambition is driven by the general need for creating more and more cost efficient products without turning them into commodities.

To prevail it is essential to focus on the right raw materials. One of the most innovative options is the use of "smart" materials.

A smart pigmentation is a pigmentation that is capable to respond to changes in its environment or that may also exhibit an unexpected functionality.


## What does thermo controlling mean?

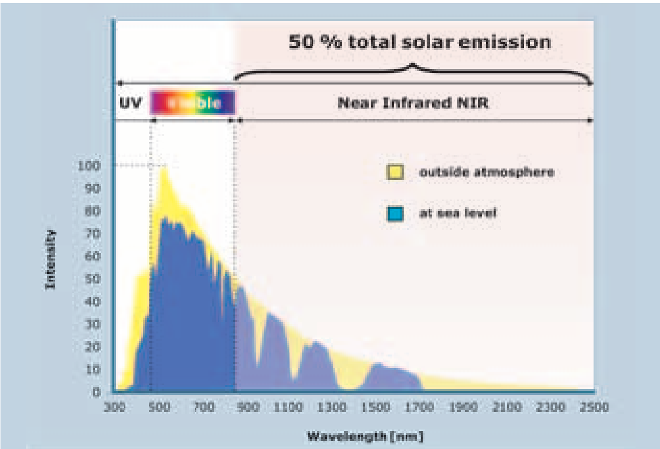


**Fig. 1** *Solar Spectrum*

It is well known, that a white surface remains cool, while a black one heats up. The reason for this is the interaction of the coated object with the near infrared-radiation (NIR) emitted by the sun (Fig. 1).

When radiation is absorbed light is physically converted into heat. A surface interacts not only by absorbing radiation but also by emitting in the far infrared region until the equilibrium at a certain temperature is reached. The sun emits almost 50% of its energy as NIR-radiation.

By using a conventional pigmentation this effect could result in a severe build-up of heat due to the unwanted absorption of radiation in the near infrared.

Black surfaces strongly absorb NIR- and visible light, while white surfaces are effective in reflecting NIR- and visible light.

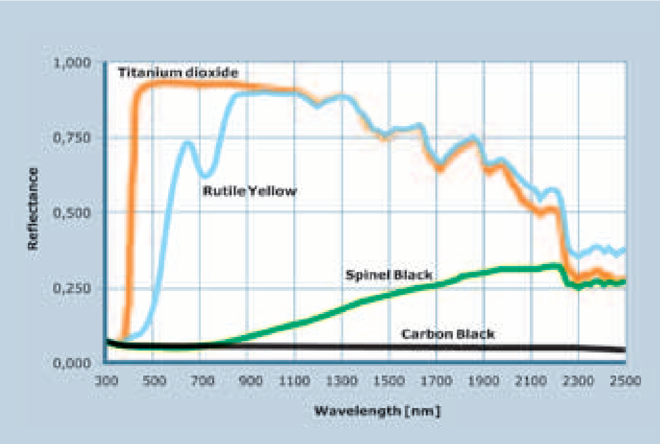


**Fig. 2** *Electromagnetic reflection profiles of different pigments*

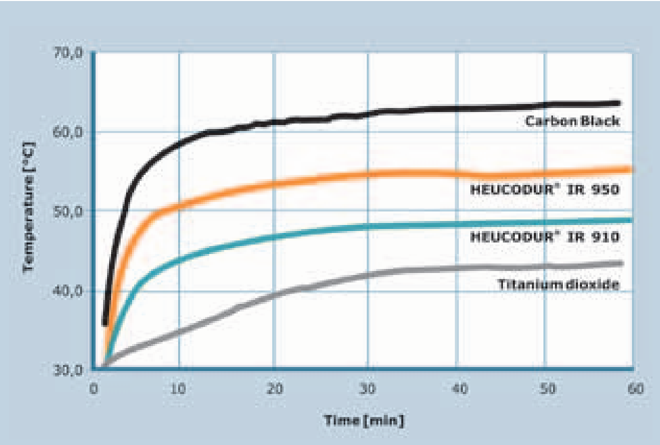


**Fig. 3** *Heat build-up profiles of different pigments according to ASTM D 4803-97*

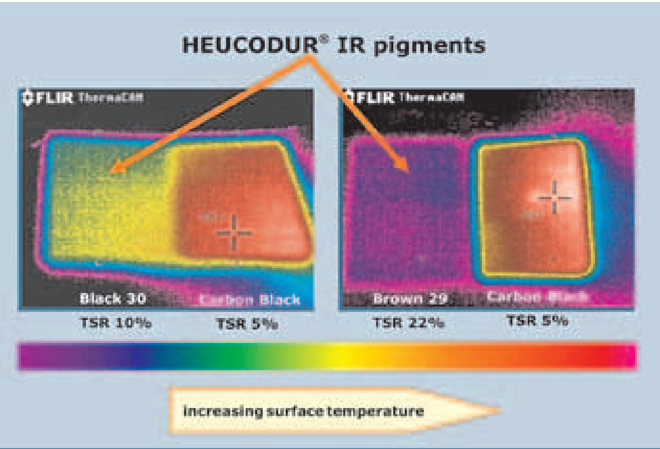


**Fig. 4** *Surface temperature visualized by a thermo imaging camera*

But white or pastel colors cannot always satisfy the consumer's demands.

Differently colored pigments exhibit different, specific electromagnetic reflection profiles as shown in Fig. 2.

Focusing on the IR-range (780-2500 nm) a pigment like rutile yellow exhibits the highest reflection followed by titanium dioxide. On the other hand carbon black benchmarks the lowest reflection. Compared to carbon black a considerable higher reflectance in the NIR-region of the solar spectrum can be achieved by a specifically designed IR-reflecting spinel black pigment.

These different and characteristic reflectance curves are also mirrored in different heat build-up curves shown in Fig. 3. In the heat build-up experiment a coated or pigmented object is exposed to artificial NIR-light in a closed box under defined conditions. The increase of temperature is measured in relation to the duration of exposure.

By reflecting the NIR-radiation more efficiently, this pigmentation gives coatings the ability to significantly reduce the surface temperature. This effect can be visualized by a thermo-imaging camera as shown in Fig. 4.

The thermo images show coated panels pigmented with different IR-reflecting pigments on the left side and with carbon black on the right side respectively. Afterwards the panels were homogeneously irradiated using an IR-lamp under defined conditions.

The advantage we can get from this approach is not only a reduction of the heat build-up that can be correlated with decreased energy consumption. The benefit is also an enhanced shelf life of the coating or the pigmented object.

Due to the significant reduction in surface temperature, thermal degradation of the polymeric matrix is reduced. In addition temperature differences between day and night, direct sunlight and shadowed areas etc. will also be levelled out. As a consequence thermal warping and thermal stress for instance becomes less effective.

This aspect of the use of thermo controlling pigments is very important, because this effect can be utilised for numerous other applications - not only housing, roofing and facades. This is the key reason, why this approach truly deserves the label SMART.

Not only because it contributes to a more environmentally aware use of resources, but also because of its exceptional ability to extend the shelf life of exterior coatings or polymers.

Hence it really is a tool to impart sustainability.

## Smart Complex Inorganic Colored Pigments

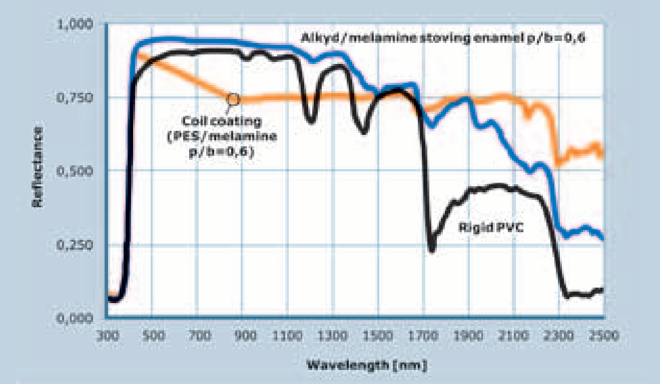


**Fig. 5** *Effect of different polymeric matrices on the reflectance of titanium dioxide pigmented systems*

We are looking for efficient IR-reflecting pigments offered in different color shades, exhibiting an outstanding durability to their intended use in exterior applications and available on large scale.

In order to select the right pigments we need to dig a little bit deeper into theory:

Comparing pigments regarding their influence on the heat build-up always depends on the polymeric matrix. Fig. 5 shows as an example the different reflectance curves of titanium dioxide in different matrices. As a consequence the characteristic absorption of solar radiation needs to be taken into consideration when designing an effective IR-reflecting coating formulation.

## What is TSR?

When selecting an effective IR-reflecting pigment the most important factor is the TSR value. TSR means Total Solar Reflectance and is the integral total amount of solar energy that is immediately rejected by a surface material (e.g. coating). That means that it includes UV-, visible- as well as NIR-radiation and is thus a key figure to describe the heat build-up of surfaces.

Due to the fact, that the TSR covers the entire range of radiation between UV and NIR, e.g. black pigments show systematically lower TSR values compared to e.g. white pigments. Therefore only TSR values of similar pigments should be compared.

A high TSR value indicates efficient reflection - a low TSR value indicates a strong tendency to absorb NIR-light and therefore induce significant heat build-up. It is helpful to interpret the TSR value in relation to the matrix used and/or a reference pigment (e.g. titanium dioxide).

Furthermore it should be considered, that even small amounts of impurities can negatively affect the TSR of the coating. Even fillers, which are usually added to the paint, can potentially reduce the resulting reflectance in the near infrared.

## The Solution

To achieve maximum reflection of solar radiation a NIR-reflective pigmentation is required, that provides a high TSR value and the highest outdoor durability. All these requirements can be fulfilled by mixed metal oxide pigments, which exhibit specially designed reflectance characteristics whilst retaining their

| Pigment | TSR (absolute) Coil Coating (PES/melamine) | TSR (absolute) alkyd/melamine | TSR (absolute) rigid PVC |
|---|---|---|---|
| Titanium Dioxide | 76% | 85% | 79% |
| HEUCODUR® IR Black 940 | 24% | 24% | 23% |
| HEUCODUR® IR Black 910 | 22% | 21% | 21% |
| HEUCODUR® IR Black 950 | 10% | 9% | 10% |
| Carbon Black | 5% | 5% | 5% |

**Tab. 1** *TSR of different pigments in different matrices compared to titanium dioxide*

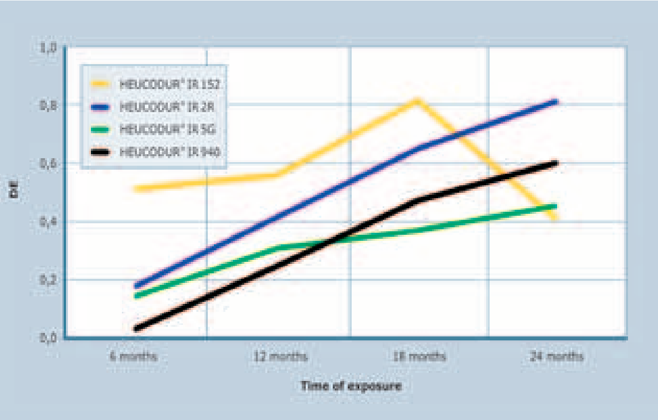


**Fig. 6** *Florida weathering results of IR-reflecting pigments*

excellent weather and light fastness (Fig. 6) as well as their exceptional temperature resistance. Looking at the thermo images in Fig. 4 the effect of different TSR values becomes apparent:

The difference in the TSR values of approximately 5% on the left panel and 17% on the right panel results in a drastically stronger heat build-up of the carbon black pigmented coil coating.

These novel, IR-reflecting complex inorganic colored pigments offer a wide range of color shades from yellow to black. They allow the formulation of not only architectural, building and construction coatings, tiles, plasters etc., but also automotive exterior and interior applications like dash-boards, fuel tanks, etc.

Because of the reduced surface temperature the use of these pigments extends the shelf-life of the polymeric matrix through a minimization of thermo induced degradation effects and of course substantially reduces the heat build-up. This smart effect is not only possible in chromatic formulations but also especially in the achromatic range convincing effects can be achieved.

As mentioned above titanium dioxide is one of the best performing pigments in terms of TSR value. But on the other hand carbon black or iron oxide blacks are on the contrary the lowest performing pigments in terms of TSR.

But what happens when titanium dioxide and carbon black are blended to create grey color shades?

The effect of carbon black on the heat-build-up of grey objects is significant and in the context of maximizing TSR it can be seen as a matter of „contamination". Implementing even small amounts of carbon black or iron oxide blacks drastically reduces the NIR reflectivity of the entire system leading to higher heat build-up effects.

Therefore an optimal pigmentation strategy avoids the usage of carbon black or iron oxide blacks and introduces the special NIR reflective HEUCODUR® IR pigments. The results of brightness adjusted exchanges of carbon black versus HEUCODUR® IR 950 are displayed in Tab. 2.

Only by using NIR reflective blacks maximum TSR values and minimum heat build-up effects could be accomplished. By that they take care for the customer's comfort as a result of reducing the heat build-up and thus his electricity bill.

| Brightness L * | 49.5 | | 62.7 | | 78.0 | |
|---|---|---|---|---|---|---|
| Pigmentation | P.Bk. 7 | HEUCODUR® IR Black 950 | P.Bk. 7 | HEUCODUR® IR Black 950 | P.Bk. 7 | HEUCODUR® IR Black 950 |
| TSR (%) | 14 | 21 | 23 | 34 | 41 | 54 |
| Max. Temperature (%) | 71.7 | 63.0 | 73.5 | 64.0 | 73.0 | 58.3 |

**Tab. 2** *TSR values and maximum object temperatures after 30 minutes exposure to artificial NIR radiation of different adjusted formulations based upon titanium dioxide and varying amounts of carbon black or HEUCODUR® IR Black 950 respectively.*

| Name | Full Shade | Reduction | Pigment | Color Index |
|---|---|---|---|---|
| **Nickel and Chromium Rutile Pigments** | | | | |
| HEUCODUR® PLUS IR Yellow 150 | | | Nickel Antimony Titanium Yellow Rutile | P.Y. 53 |
| HEUCODUR® IR Yellow 152 | | | Nickel Antimony Titanium Yellow Rutile | P.Y. 53 |
| HEUCODUR® IR Yellow 3R | | | Chrome Antimony Titanium Buff Rutile | P.Br. 24 |
| HEUCODUR® IR Yellow 256 | | | Chrome Antimony Titanium Buff Rutile | P.Br. 24 |
| HEUCODUR® IR Yellow 259 | | | Chrome Antimony Titanium Buff Rutile | P.Br. 24 |
| **(Inverse) Spinel Pigments** | | | | |
| HEUCODUR® IR Blue 550 | | | Cobalt Aluminate Blue Spinel | P.B. 28 |
| HEUCODUR® IR Blue 2R | | | Cobalt Aluminate Blue Spinel | P.B. 28 |
| HEUCODUR® IR Blue 5-100 | | | Cobalt Chromite Blue Green Spinel | P.B. 36 |
| HEUCODUR® IR Blue 4G | | | Cobalt Chromite Blue Green Spinel | P.B. 36 |
| HEUCODUR® IR Green 5G *) | | | Cobalt Titanate Green Spinel | P.G. 50 |
| **Browns & Blacks** | | | | |
| HEUCODUR® IR Brown 869 | | | Chromium Iron Oxide | P.Br. 29 |
| HEUCODUR® IR Black 910 | | | Chromium Iron Oxide | P.Br. 29 |
| HEUCODUR® IR Black 940 | | | Chromium Iron Oxide | P.Br. 29 |
| HEUCODUR® IR Black 945 | | | Chromium Iron Oxide | P.Br. 29 |
| HEUCODUR® IR Black 950 | | | Chrome Iron Nickel Black Spinel | P.Bk. 30 |

*) *In accordance with CLP Regulation No. 1272/2008 this product is classified as dangerous substances with Hazard Classes and Category Codes: Skin Sens. 1; H317 / Carc. 1A; H350i / STOT RE 2; H373*

| TSR [%] [1] | Oil Absorption [ml/100g] [2] | Heat Resistance [°C] [3] | Automotive Coatings | Industrial Coatings | Coil Coatings | Powder Coatings | Decorative Coatings | Concrete, Plasters | PVC | PO | Engineering Plastics | Fibre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| 72 | 16 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● |
| 72 | 17 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● |
| 68 | 20 | 600 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● |
| 64 | 17 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● |
| 62 | 16 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● |
| | | | | | | | | | | | | |
| 51 | 30 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | |
| 47 | 30 | 600 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | |
| 41 | 17 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | |
| 43 | 15 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | |
| 33 | 17 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | |
| | | | | | | | | | | | | |
| 28 | 25 | 700 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | |
| 26 | 17 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | |
| 31 | 22 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | |
| 22 | 20 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | |
| 14 | 17 | 800 | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | ●● | |

●● Our recommendation

[1] powder pellet [2] according to DIN EN ISO 787/5 [3] AA10/CIC/104

® = Registered trademark of Heubach GmbH



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