H24: Colorant Properties

Optical properties

The optical properties of pigments are introduced in this section. More complete descriptions of the standard methods of assessment are given in another section.

Transparency

The scattered light produced by pigment particles in a printed film when struck by light, reduces the transparency of the film. The scattered light can best be observed with a relatively black substrate, since this eliminates light reflected by the substrate. The transparency of printing inks and pigments is therefore usually measured with prints applied to a black substrate.

The transparency or scattering power of the printing ink depends on (a) the refractive index of the pigment and binder and on (b) the particle size of the pigment. Complete transparency is obtained when the refractive indices of the pigment and the binder are identical.

Transparent inks can be obtained with pigment particles that are smaller than half the wavelength of light. The particle size of highly transparent pigments is normally below 0.1 μm. Transparency slowly increases with decrease in particle size.

Hiding power

Hiding power of an ink is the ability of the ink to cover visually an underlying substrate. Hiding power is usually measured by applying the ink over a contrasting black and white substrate at a variety of coating thickness. Assessment of hiding power is made by comparing the colour of the layer coated over the black substrate with the colour of the layer coated over the white substrates, either visually or instrumentally. At the thickness where the contrast between the coatings on the black and the white substrates just disappears, the coating layer is considered to be opaque.

Tinting strength

Tinting or colour strength is the ability of a pigment to impart colour to a material in which it is dispersed. The tinting strength of a pigment can be measured by dispersing a set mass of the pigment in a standard white binder system, known as reducing white. The coloured pigment is usually mixed into the reducing white at a 1:20 or a 1:10 ratio. An opaque layer is coated onto a standard substrate and the colour properties of the dry layer are assessed. The colour depth achieved by the test pigment is compared to that of a standard pigment prepared in an identical way. The comparison provides a measure of the relative tinting strength.

High tinting strength is a very desirable property in pigments. From an economical point of view, the higher the tinting strength the smaller the amount of pigment that needs to be used to provide a specified degree of coloration in a system.

Stability and resistance properties

The stability of a pigment or a print is the ability to resist changes caused by the action of exterior factors. Different types of stability have been identified with respect to exposure to light, weather, chemicals, solvents and heat and there are standard methods to assess the fastness to many of these types of factors.

Stability can be measured in many ways, but common signs of poor stability are colour change, chemical degradation or change of physical appearance.

Light fastness

Light fastness is the ability of a pigment or a print to resist the action of daytime radiation. High light fastness is a very important property for all products that are used outside or have prolonged exposure to light. Inorganic pigments, especially oxides, have high light fastness, but the fastness properties of organic pigments vary with the pigment type. There is some form of relationship between the chemical constitution of an organic molecule and its light fastness, although few general principles can be determined. Trial and error still seems to be the main method of developing products with good fastness properties.

It is very important to note that light fastness is a property of the pigment coating system combination. The amount of colorant in the test panel is also critical, usually the higher the amount then the better the light fastness. Thus, in order to make good comparisons between pigments, a standard binder system containing a standard amount of colorant should be used for all the tests.

Light fastness is normally assessed using accelerated testing methods by placing test panels in an artificially high intensity of light from a xenon arc lamp whose spectrum is a reasonable simulation of daytime radiation.

The change in colour of the panel with the duration of the exposure may be assessed colorimetrically or by using the blue wool scale.

Blue wool scale

The blue wool scale is used to provide a comparative method of assessing the light fastness. The scale consists of 8 samples of dyed wool material. The blue colour of scale sample 1 fades most rapidly and the blue colour of scale sample 8 fades least rapidly. The fading of a scale pattern 7 is twice as fast as scale pattern 8 and the relationship is consistent down the scale so that

7 fades twice as fast as 8

6 fades twice as fast as 7 ....etc

2 fades twice as fast as 3

1 fades twice as fast as 2

A test panel is made and an opaque strip of material is attached to cover half of the area of the test panel so that one section of the panel is exposed to the light and the other is not. A set of 8 samples from the blue wool scale is made and an opaque strip is used to cover half of the width of the blue wool scale samples. The test panel and the blue wool set are placed side by side in the exposure cabinet.

The test panel is checked regularly during the exposure until the contrast difference between the exposed and the unexposed parts of the test panel is judged to be the same as the contrast difference between two greys on the standard grey scale 3. The fading rating is given by the number of the blue wool scale sample that shows a similar level of contrast between the exposed and unexposed sections.

Typical ratings for several types of coloured material are:

➢ Publication Inks	2 to 4
➢ Packaging inks and decorative paints	5 to 7
➢ Automotive paints	8+

Colorimetric methods

A spectrophotometer is used to measure any colour change. L*, a* and b* values between the exposed and unexposed sections the CIELAB colour difference values are calculated. A standard method is available for calculating a grey scale rating value from the colour differences.

Weather fastness

Weather fastness is the ability of a pigment dispersed in a system to resist changes caused by the combined action of the earth's atmosphere and daytime radiation.

Weathering combines the action of rain, humidity, light, pollution, salt and other climatic conditions, so is very difficult to measure accurately. Weathering also affects the pigment and the binder (in fact, all components) in a coating system causing problems such as colour changes and reduction of gloss. Weather resistance can be tested naturally or artificially and there are standard methods for both types of test. Natural weathering tests simply use the earth's natural atmosphere, and are dependent on the time of year and location of the study; therefore, they can be very slow and difficult to repeat. Accelerated testing procedures are carried out in controlled weathering cabinets that simulate daytime radiation with a filtered xenon arc, rain and humidity with water sprays and with temperature control.

The level of weather fastness can be assessed by colour change, measured using a spectrophotometer before and after the weathering procedure, or by the change in the gloss of a coating.

Chemical resistance

Chemical resistance is the ability of a pigment dispersed in a system to withstand changes caused by the action of chemicals. There are a number of chemical resistance tests that attempt to assess the performance of a pigmented coating by exposure to a standard environment containing chemicals; these may be short, medium or long-term tests. The results of testing for chemical resistance are often assessed visually but the colour change can be measured instrumentally. There are a few important and frequently used tests, but generally the chemical resistance test devised will be specific to an industry. The following example tests are based on the German DIN standards.

Sulphuric acid

An approximately 20 mm wide strip of a 2% full shade offset print is placed between filter paper that is moistened with a 1% sulphuric acid solution. This assembly is then placed between two glass plates, wrapped round with waterproof film and weighted with a 1 kg weight. After keeping this sample at room temperature (20° C) for 24 hours the discoloration of the filter paper or a colour change of the print is evaluated.

Caustic soda

The test is carried out as described above in the paragraph "Sulphuric acid" except that a 2.5% caustic soda solution is used to moisten the filter paper, instead of water. This method is more stringent than most caustic soda tests and corresponds more exactly to practical conditions. Results are assessed visually by noting the degree of colour transferred to the filter paper.

Spittle or sweat

The resistance of a coating to spittle or sweat is important for print that is likely to come into contact with children. The tests provide information about the amount of pigment that could be transferred into a child's mouth or onto skin after chewing or some other contact.

The test is carried out as described above in the paragraph "Sulphuric acid" except that the strips of filter paper are wetted with sodium hydrogen carbonate and with salt solutions. Results are assessed visually by noting the degree of colour transferred to the filter paper.

Lactic acid

The test is carried out as described above in the paragraph "Sulphuric acid" except that a 10% lactic acid solution is used to moisten the filter paper. The values obtained for the resistance to lactic acid together with the resistance to butter allow conclusions to be made as to the resistance to contact with cheese.

Soap/detergent

Strips of soap gel are prepared by dissolving 25 g of soap in 75 g of boiling water. The solution is poured into a flat dish and, after cooling and setting, cut into pieces of approximately 50 x 20 x 5 mm. A full shade offset print is brought into contact with the soap gel, with the printed side touching the soap. The print is then wrapped in waterproof film and stored for 6 hours in a closed container at room temperature (20° C). Any staining of the soap gel or change of colour of the printed sample is assessed.

Butter

A Petri dish is half filled with butter. The printed side of a full shade offset print is pressed firmly onto the butter and kept at 20° C for 24 hours. Subsequently the dish is placed in a refrigerator for 1 hour and finally the print sample is removed from the hardened butter. Any staining of the butter or change of colour of the print is assessed.

Solvent fastness

Solvent fastness is the ability of a pigment in a coating to resist changes caused by the action of solvents. The definition of a pigment is one of an insoluble substance, so any indication of solubility indicates a non-ideal pigment. In reality many organic pigments have low fastness to one or more types of material. The level of their solubility in a binder depends on a number of conditions: choice of solvent, chemical constitution of pigment, particle size of pigment and temperature. There are a number of affects that can be seen when a pigment has poor solvent fastness:

Migration

Migration is the movement of pigment dissolved in a medium to the surface of that medium or into contact with an adjoining medium. Migration of a pigment leads to blooming and bleeding.

Blooming

Blooming usually occurs when a part of the pigment content has dissolved in one or more components of the material and formed a super saturated solution next to the surface. A layer of pigment crystals may start to form on the surface, this can take a number of years to become apparent. Bloomed pigment crystals can be brushed away but will continue to form until the concentration of dissolved pigment falls below a certain level. The surface crystallisation of pigment is a function of pigment solubility, temperature and concentration.

Bleeding

Bleeding is the migration of dissolved pigment from one medium into an adjoining medium in which it causes discoloration. Industrially this is very important because it affects the ease with which a coating can be over-varnished.

Solvent fastness of a print

A 15 mm wide strip of a 2% full shade offset print is dipped in a test tube filled with 20 cm^3 of solvent. The sample is removed after 5 minutes and dried. Any discoloration of the solvent and associated change of colour of the print is assessed.

Solvent-fastness of the pigment powder
0.5 g pigment is placed in the centre of filter paper (Whatman No. 6). The paper is folded to form a parcel, closed with a thin thread and suspended for 24 hours in a test tube filled with 20 cc of solvent and kept at a temperature of 20° C. Subsequently, the parcel is removed from the solvent. The degree of staining of the solvent is assessed.

Improving solvent fastness
It is usually very important industrially to improve the solvent fastness of a pigment as much as possible, in some high temperature applications organic pigments are not sufficiently fast and only inorganic pigments can be used. However, where the lifespan of the product is short, this may not be an issue.

The solvent fastness of an organic pigment can be improved by:

- Increasing the pigment molecular mass
- Avoiding solubilising groups in the pigment molecule
- Forming metal complexes.

The best way to avoid problems with poor solvent fastness is to test a pigment/binder/solvent combination thoroughly over a wide temperature range before use.

Heat stability

Heat stability is the ability of a pigment dispersed in a binder to resist changes bought about by elevated temperatures. Thermal stability is a system dependent property so it is a function of the chemical constitution of the pigment and of the binder, processing conditions, pigment concentration, degree of dispersion, the presence and nature of any additives and on the type and duration of heat applied.

Many organic pigments are not thermally stable at high temperature and may:

- decompose to form new compounds;
- chemically interact with the medium or other pigments;
- melt and re-crystallise in a new crystal form or with a different particle size distribution.

Influence of particle size

Flow properties

The surface area of a pigment powder has the units of m^2 per gram of pigment. Surface area is an important pigment property because it provides a guide to how much binder a pigment will require to be wetted out in a formulation. Pigments with high surface areas will absorb a greater amount of binder in a formulation and so the formulations will become more viscous.

Optical properties

a) Tinting strength

As particle size decreases the tinting strength of an organic pigment in an ink tends to increase to an optimum value, and then decreases again.

b) Opacity

As the particle size of the pigments in an ink decreases the opacity of a print decreases and it tends to becomes more transparent because less light is scattered by the pigment particles.

c) Colour undertone

As the particle size of the pigments in an ink decreases the colour undertone of the print becomes yellower and as the particle size increases the undertone of the print becomes more blue.
Gloss: As the particle size of the pigments in an ink decreases, the gloss of a print is seen to increase.

Fastness properties

d) Light fastness

Light fastness of a pigmented material decreases as the particle size decreases.

e) Weather resistance

The resistance of a pigment in a binder to the effects of weathering decreases as the particle size decreases.

f) Solvent fastness

The solvent fastness of a pigment in a formulation often decreases as particle size decreases. This in turn can cause a higher incidence of pigment migration and the bleeding and blooming phenomena.