

Applications of Waxes in the Coatings and Printing Inks Industry

Juan Segurola

English-language edition - 15 September 2026

Original publication: Pinturas y Acabados, July/August 2005, pp. 26-34.

Permanent concept DOI: <https://doi.org/10.5281/zenodo.22769067>

Copyright (C) 2026 Juan Segurola. All Rights Reserved.

Editorial note

This English-language edition reproduces the technical content of the Spanish article published in 2005. The presentation has been reset for legibility. In Table 1, the composition of Fischer-Tropsch wax has been corrected from "polyethylene" to "polymethylene". Fischer-Tropsch waxes are predominantly mixtures of long, linear paraffinic hydrocarbons and are distinct from polyethylene waxes produced by polymerisation of ethylene.

Abstract

Waxes are widely used in coatings and printing inks. They modify surface properties and can provide protection against scratching, abrasion, blocking and water, while also changing slip, gloss, touch and texture. This article reviews the definition of a wax, the principal natural, mineral, petroleum-derived and synthetic wax families, their origin and composition, their physical properties, the mechanisms by which they act at a coating surface, the main incorporation methods, and their use in printing inks, overprint varnishes, paints, powder coatings, metal coatings, wood coatings, waterborne systems and ultraviolet-curable systems. Particular attention is given to Fischer-Tropsch, polyethylene, polypropylene, polytetrafluoroethylene, amide, paraffin, microcrystalline, montan, carnauba and candelilla waxes, as well as to micronisation, particle size, migration, flotation and formulation compatibility.

What is a wax?

The definition of the word wax is relatively complex. For the purposes of this article, waxes are natural or synthetic substances that share several practical characteristics:

- they are solid at room temperature, taken here as 20 C;
- they usually melt above 40 C;
- immediately above their melting point, they are relatively low in viscosity; and
- their consistency and solubility are strongly affected by temperature.

Figure 1 summarises the approximate consumption of waxes by application sector in Western Europe during the final decade of the twentieth century. Micronised wax consumption is included in the data. Total annual consumption was estimated at approximately 43,000 tonnes, including about 8,000 tonnes per year used in inks and coatings; approximately 3,000 tonnes per year of the latter were micronised waxes.

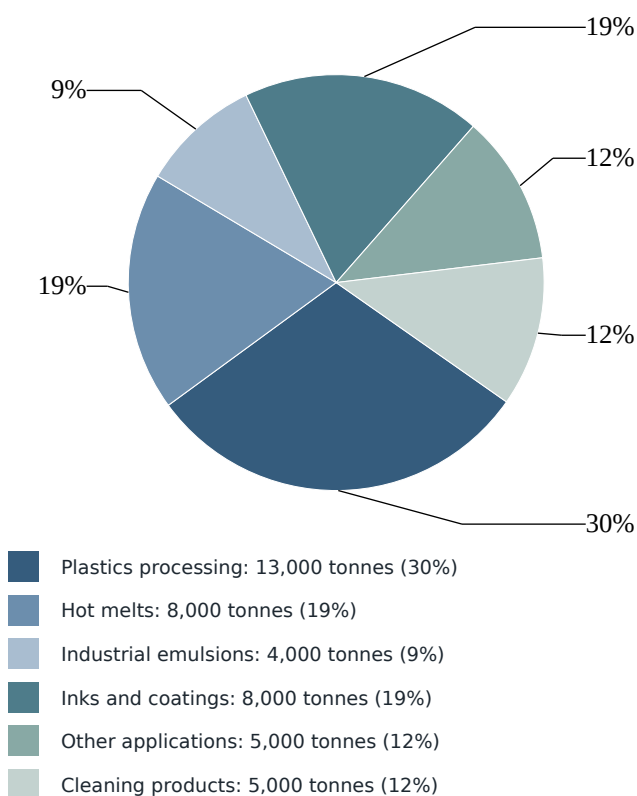


Figure 1. Approximate annual wax consumption by application sector in Western Europe during the final decade of the twentieth century. The 8,000 tonnes used in inks and coatings included approximately 3,000 tonnes of micronised wax.

Table 1 lists representative wax families, their origin, composition, method of manufacture, appearance, hardness and common applications.

Table 1. Wax types, origins, characteristics and applications.

Origin	Example	Composition	Production or source	Colour	Hardness	Applications
Animal	Beeswax	Long-chain fatty acids and esters	Beeswax	Yellow-brown	Brittle; plastic when heated	Cosmetics, candles, polishes, medicines, ointments and confectionery
Animal	Shellac wax	Mixture of esters	Secretions of selected insects	Brown	Hard and brittle	Insulating materials
Animal	Lanolin	Mixture of fatty esters, including cholesterol esters	Extraction from sheep wool grease	White to yellowish	Soft	Polishes, cleaners and leather finishes
Mineral	Montan and derivatives	Montanic acids and esters	Extraction from lignite; oxidation and re-esterification	Brown-black	Hard and brittle	Polishes, leather finishes, varnishes and inks
Mineral	Ozokerite	High-molecular-weight saturated and unsaturated hydrocarbons	Extraction from Miocene bitumen deposits	Yellow-brown	Soft to gypsum-hard	Polishes, cosmetics, creams, ointments, leather finishes, varnishes and inks
Mineral	Lignite wax	Mixture of esters	Extraction from lignite	Yellow-brown	Hard and brittle	Uses similar to montan and ozokerite
Vegetable	Carnauba	Mixture rich in long-chain esters	Extraction from leaves of the Brazilian carnauba palm	Yellow	Very hard and brittle	Floor, automotive, furniture and shoe polishes
Vegetable	Candelilla	Esters with hydrocarbons and resinous material	Extraction from candelilla leaves in Mexico and Texas	Brown	Harder than beeswax, softer than carnauba	Cosmetics, release agents and leather polishes
Vegetable	Ouricuri	Esters with resins	Extraction from leaves of the Brazilian ouricuri palm	Brown	Hard and brittle	Shoe polishes and release agents

Origin	Example	Composition	Production or source	Colour	Hardness	Applications
Petroleum	Paraffin, macro crystalline	Linear low-molecular-weight hydrocarbons	Separation from petroleum distillates	White-opalescent	Ductile and brittle	Polishes, furniture finishes, coatings, inks and water-barrier coatings
Synthetic	Fischer-Tropsch	Polymethylene; predominantly linear paraffinic hydrocarbons	Synthesis from carbon monoxide and hydrogen	White	Hard	Inks and coatings
Synthetic	Polyethylene	Polyethylene	Polymerisation of ethylene	White	Hard	Inks and coatings
Synthetic	Polypropylene	Polypropylene	Polymerisation of propylene	White	Hard	Inks and coatings
Synthetic	Amide and bis-amide	Fatty-acid amides and bis-amides	Condensation reaction	White-yellowish	Hard	Uses similar to carnauba and montan waxes
Synthetic	PTFE	Polytetrafluoroethylene	Polymerisation of tetrafluoroethylene and controlled degradation	White	Hard	Inks, coatings and special finishes

Waxes used in coatings and printing inks

The waxes most commonly used in coatings and printing inks are synthetic polyolefin and Fischer-Tropsch types, together with selected petroleum, mineral, vegetable, amide and fluoropolymer waxes. Their usefulness depends not only on chemical identity, but also on molecular weight, crystallinity, density, melting behaviour, particle size and shape, oxidation state, compatibility with the binder and solvent, and the manner in which the wax reaches the film surface.

Fischer-Tropsch waxes

Franz Fischer and Hans Tropsch developed a route for synthesising hydrocarbons from carbon monoxide and hydrogen at elevated temperature and pressure in the presence of metal catalysts. Industrial development of the process produced gaseous, liquid and solid hydrocarbons. The solid fractions used as waxes consist predominantly of long, linear, highly saturated hydrocarbon chains.

Commercial Fischer-Tropsch waxes used in coatings typically contain chains of roughly 50 to 100 carbon atoms and have molecular weights in the approximate range 300 to 1,400. Their melting range is commonly about 85 to 110 °C. Because of their comparatively low molecular weight, some grades can partially dissolve in organic solvents and may recrystallise, particularly in aromatic-solvent systems. In waterborne formulations, their behaviour may be affected by mineral-oil defoamers.

Fischer-Tropsch waxes are among the lower-cost micronisable wax families and are offered in a wide range of particle sizes and densities, commonly around 0.92 to 0.96 g/cm³. They provide good slip, scratch resistance and economic performance. Typical uses include lithographic, flexographic and gravure inks, overprint varnishes, can and coil coatings, and coatings for wood, plastics and metals.

Polyethylene waxes

Polyethylene waxes are polyolefin products obtained from ethylene. They are usually linear polymers with varying degrees of branching and are manufactured by routes involving radical or transition-metal catalysis. Their molecular weights and melting points are generally higher than those of Fischer-Tropsch waxes. Typical melting temperatures are about 110 to 127 °C, with commercial densities commonly between 0.90 and 0.96 g/cm³.

High-density polyethylene waxes have closely packed chains, high crystallinity and densities of approximately 0.95 to 0.96 g/cm³. Their brittle fracture behaviour facilitates micronisation. They are not usually dissolved or dispersed by melting in solvents because they readily crystallise on cooling, even at high cooling rates.

Low-density polyethylene waxes, at approximately 0.90 to 0.94 g/cm³, contain more branching. Commercial grades vary considerably in molecular weight and crystallisation behaviour. The choice

between high-, medium- and low-density polyethylene waxes depends on the required hardness, particle formation, solvent resistance, slip and abrasion performance.

Oxidised and non-oxidised polyethylene waxes are used in solventborne and waterborne systems. Oxidised grades are particularly useful where better dispersion or emulsification is needed. Higher-molecular-weight grades generally provide improved scratch and rub resistance but may be more difficult to process.

Polytetrafluoroethylene waxes

Polytetrafluoroethylene, commonly known by the trade name Teflon, has the highest molecular weight among the micronised wax families considered here. PTFE waxes may be prepared from recycled tape and extruded products or directly from polymerisation of tetrafluoroethylene.

PTFE has excellent heat resistance up to its melting region near 320 C, a very low coefficient of friction and low surface tension. Because of its cost, it is frequently combined with other waxes in dry blends or melt blends. Its abrasion resistance is strongly associated with its low coefficient of friction rather than unusually high hardness. PTFE waxes provide excellent slip, scratch, rub and abrasion resistance and are used in high-performance coatings, powder coatings and metal decoration, often in combination with polyethylene or Fischer-Tropsch waxes.

Polypropylene waxes

Polypropylene waxes typically melt at about 140 to 160 C and often have a broader molecular-weight distribution than polyethylene waxes. They can provide good abrasion and temperature resistance and are effective in reducing blocking during stacking or winding. Their slip and scratch resistance may be less favourable than those of some polyethylene or PTFE systems.

Larger polypropylene particles can reduce gloss and clarity, which makes these waxes useful in satin and matt finishes. They are also used where resistance to marking by metal objects and anti-slip behaviour are required.

Amide and bis-amide waxes

This group includes fatty-acid amides and bis-amides such as ethylene bis-stearamide. They are readily micronised, can migrate to the surface by a blooming mechanism, and provide good slip. Typical melting temperatures are around 140 C. They may also provide clarity, rub resistance, heat resistance and anti-blocking performance.

In preprint and packaging applications, amide waxes can be useful where printed paper is subjected to friction and heat during bonding to corrugated board. Their selection must consider migration, surface adhesion and subsequent printability.

Petroleum-derived paraffin and microcrystalline waxes

Paraffin, or macrocrystalline, waxes are obtained from low-molecular-weight petroleum distillates. They are generally white, ductile, low in viscosity and relatively low-melting, commonly about 44 to 74 C. Typical molecular weights are around 350 to 420. Their relatively high proportion of linear chains gives them crystallinity commonly reported between about 80 and 90 percent. They are usually smooth but brittle and may create printability problems if they melt during pigment grinding or crystallise after application.

Microcrystalline waxes originate mainly from high-molecular-weight petroleum residues or waxy deposits associated with some crude oils. They normally melt at about 65 to 85 C and have molecular weights of approximately 500 to 800. A high proportion of branched paraffins, isoparaffins and cycloparaffins inhibits the formation of large crystals. Their crystallinity is typically lower than that of paraffin waxes, around 50 to 65 percent, and they tend to be more ductile and tacky. They are used in conventional offset inks because of their cost, slip and melting behaviour, and are often blended with other waxes.

Montan, carnauba and candelilla waxes

Montan waxes are mineral waxes extracted mainly from lignite deposits. Commercial grades are often chemically modified by oxidation, esterification and partial saponification to improve colour, dispersibility and emulsion performance. They are comparatively hard and are used in polishes, leather finishes, wood coatings, varnishes and inks.

Carnauba wax is one of the few natural waxes that can be micronised readily. It is obtained from the exudate on the leaves of the Brazilian carnauba palm and typically melts at about 80 to 86 C. As an agricultural product, its supply, colour and price vary with harvest and climate. It is a complex mixture rich in long-chain esters. Carnauba wax provides clarity, a smooth feel and water repellency and can be polished easily. It is used in floor, automotive, furniture and shoe-care products, clear varnishes and confectionery or pharmaceutical coatings. Commercial types are often classified by colour and exposure of the harvested leaves.

Candelilla wax is obtained from a shrub native to semi-arid regions of Mexico and Texas. It contains esters, hydrocarbons and resinous material and typically melts near 68 to 72 C. It is used in cosmetics, leather polishes and release applications. Because it is comparatively soft and tacky, it is less readily micronised than carnauba wax.

Table 2. Physical properties and applications of micronisable waxes in coatings and printing inks.

Wax	Molecular weight	Melting range, C	Density, g/cm ³	Principal properties	Typical coating and ink uses
Carnauba	340-820	80-86	0.99-1.00	Excellent slip, scratch resistance, clarity, smooth touch, polishability	Clear wood varnishes, automotive and coil coatings, wood coatings
Montan	360-850	82-86	1.02	Good slip; economical	Wood coatings, especially waterborne
Paraffin, macrocrystalline	350-420	44-74	0.90-0.93	Good slip and scratch resistance; low heat resistance; economical	Water-barrier coatings
Microcrystalline	500-800	65-85	0.92-0.93	Good slip and scratch resistance; economical	Heat-set lithographic inks
Fischer-Tropsch	300-1,400	85-110	0.92-0.96	Good slip and scratch resistance; economical	Wood, plastics and metal coatings; lithographic, flexographic and gravure inks; overprint varnishes; can and coil coatings
Polyethylene, including LDPE and HDPE	500-6,000	110-127	0.90-0.96	Good slip, scratch and rub resistance; economical	Wood, plastics and metal coatings; inks; overprint varnishes; powder, can and coil coatings
Polypropylene	2,000-7,000	140-160	0.85-0.89	Matting, heat and blocking resistance; sometimes anti-slip	Satin and matt finishes, anti-slip coatings, wood, plastics and metal coatings, can and coil coatings, powder coatings
Amide and bis-amide	275-790	68-145	0.80-0.89	Good slip, clarity, scratch, heat and blocking resistance; sandable	Kraft preprint inks and wood coatings
PTFE	10,000-100,000	315-340	2.15-2.20	Excellent slip, scratch, rub, abrasion, heat and blocking resistance	Combined with PE or FT in wood coatings, powder coatings, can and coil coatings and metal decoration

How waxes act in coatings

Waxes act through several basic mechanisms. More than one mechanism may operate in the same formulation.

Protrusion or ball-bearing effect

Wax particles can protrude above the coating surface. This is common when particle diameter is similar to, or slightly greater than, the dry-film thickness. Protruding particles reduce the true area of contact and can change slip, scratch resistance, gloss and touch.

Migration or flotation

Wax particles may migrate or float toward the surface. The outcome depends on wax identity, particle size, film thickness, the relative densities of wax and liquid coating, solvent evaporation, temperature, drying rate, viscosity and solids content. Particles less dense than the coating tend to float.

Solvent-evaporation microcurrents can also contribute to transport during drying.

Rapidly cured coatings, including radiation-curable systems, may not allow enough time for particles to migrate before gelation. Bis-amide waxes can also migrate at the molecular level through blooming: wax molecules partially dissolve in the medium and subsequently concentrate at the surface.

Migration can occur both toward the air interface and toward the substrate. It need not reduce adhesion to the substrate, but a wax-rich surface can impair intercoat adhesion or overprintability when another layer is applied.

Filtration effect

On a porous substrate, binder and solvent may be partially absorbed, leaving wax concentrated at the surface. This filtration mechanism can alter the surface independently of density-driven flotation.

Properties imparted by waxes

Waxes may provide scratch and abrasion resistance, slip or anti-slip behaviour, water resistance, chemical resistance, heat resistance and anti-blocking. Some also create matt, textured, silky or soft-touch finishes. In combination with matting silicas, selected waxes can reduce settling.

Because waxes migrate or protrude at the surface, they can either lower or raise the coefficient of friction. Carnauba, Fischer-Tropsch, PTFE and selected amide waxes are common choices for high-slip surfaces. The formulator must balance slip against adhesion, overprintability, gloss, clarity, particle settlement and cost.

For matt finishes, protruding particles scatter incident light and reduce reflected gloss. Relatively large particles usually have greater matting power, and polypropylene waxes are frequently selected. For abrasion resistance, particle hardness, particle size, the number of contact points and coefficient of friction are important. Fischer-Tropsch, high-molecular-weight polyethylene, PTFE, blends of Fischer-Tropsch/PTFE or polyethylene/PTFE, and amide waxes are common choices.

Anti-blocking is promoted by hard particles that reduce the true contact area between adjacent films. High-molecular-weight polyethylene, polypropylene, polyethylene/PTFE blends and amides are frequently used. The best choice is application-specific and depends on cure, film thickness, pressure, temperature and storage conditions.

Incorporating waxes into coatings

Wax performance depends strongly on the form in which the wax is introduced. Four methods are widely used.

1. Waxes melted in solvents

Wax can be dissolved or melted into a hot solvent and then rapidly cooled under shear to precipitate fine particles. This is one of the oldest incorporation methods. The solvent boiling point must normally exceed the wax melting point, unless pressurised equipment is used. Particle-size distribution is highly sensitive to cooling rate, shear and seasonal process-temperature variation, which can cause batch inconsistency.

The method is unsuitable for very high-melting waxes such as PTFE. Its advantage is that very fine particles, sometimes below 2 micrometres, can produce transparent and clear systems. Despite the hazards and toxicity associated with heating aromatic solvents, the method has historically been used in some paste inks and in formulations intended to give high clarity.

2. Waxes in aqueous emulsions

Wax emulsions are generally produced by melting the wax and emulsifier, then adding hot water under strong agitation. A second approach melts the wax in solvent before emulsification and later removes the solvent under vacuum. Emulsifiers, pH and oxidation level must be chosen to provide adequate stability and compatibility.

Compared at the same wax-to-resin solids ratio, emulsified waxes often preserve gloss better because of their small particle size, but they may provide less slip, hardness, scratch resistance and abrasion resistance than micronised particles. Highly hydrophilic surfactants can reduce water resistance. Oxidised waxes or pre-dispersed emulsions are therefore commonly selected for waterborne coatings.

3. Wax dispersions

Wax dispersions are produced by milling wax into a liquid carrier or by dispersing a previously micronised powder. Ball mills, bead mills and three-roll mills can be used, provided the process temperature remains below the softening point. Sufficient shear improves wetting and distribution, but excessive heat can soften particles, change size distribution or cause reagglomeration.

4. Micronised waxes

Micronised waxes are solid products whose compatibility problems are limited because the same grade can be used in solventborne, waterborne, solvent-free and UV-curable systems. They can be added directly during manufacture or supplied as pre-dispersions in resin or solvent.

The particle size is normally determined during manufacture, so grinding in the final coating is not always necessary. Nevertheless, moderate milling below the wax softening temperature can improve dispersion. Practical incorporation commonly uses medium shear, approximately 1,000 to 1,500 rpm in a Cowles or Silverson-type mixer.

Production of micronised waxes

Jet micronisers use high-pressure air streams to accelerate wax flakes or granules, often around 10 mm before processing, and fracture them by high-velocity particle-particle collisions. The resulting particles are commonly irregular and about 2 to 12 micrometres in size. A wax must be sufficiently brittle under pressure to be processed efficiently; soft, tacky materials such as candelilla wax are poor candidates.

Spray micronisation is an alternative in which molten wax is atomised and solidified as approximately spherical particles. It is applicable only to waxes with suitable melting temperature and melt viscosity.

General applications

Waxes are supplied in different physical forms for direct or indirect incorporation. Selection must consider the application method, dry-film thickness, target particle size, gloss, transparency, coefficient of friction, abrasion, scratch resistance, blocking, compatibility and the need for subsequent printing or coating.

Printing inks and overprint varnishes

Micronised waxes are common in lithographic, letterpress, screen, flexographic and gravure inks and in overprint varnishes. They improve surface properties in systems that dry by oxidation, solvent or water evaporation, absorption, or UV radiation.

In multicolour printing, wax concentration and choice are particularly important because an excessive wax-rich surface can reduce adhesion between successive colours. Particle size can be as important as chemical type. As a general rule, particle diameter should be below the dry-film thickness unless a deliberate protrusion effect is required.

Waxes with low moisture-vapour transmission are used in food-packaging varnishes to preserve the intended moisture content of the packaged product. Historically, carnauba and paraffin waxes and

some plasticised chlorinated hydrocarbon waxes were used; polyolefin polyethylene waxes increasingly replaced these materials in many applications.

Paints

Waxes can create satin or matt paint finishes. Mineral fillers are often used as matting agents and extenders, but their high absorption increases the pigment volume concentration and may reduce binder effectiveness, wet and dry rub resistance, scratch resistance and related properties.

Micronised waxes do not consume binder in the same way and can act as efficient secondary matting agents while improving surface properties. Silica is often more powerful as a matting agent, but it can settle and can polish under rubbing. Combining silica with wax can reduce settling, improve slip and scratch resistance, and create softer tactile effects. Hydrophilic silicas must be assessed carefully because they can contribute to cratering or interfacial water penetration in solventborne coatings.

Powder coatings

Micronised waxes are used in powder coatings to improve scratch resistance, abrasion resistance, water resistance and slip. Slip is important where cured appliance or insulation foams must release cleanly from coated metal parts. Suitable waxes reduce damage and claims associated with poor release.

Metal coatings

Coatings for automotive components, structures, metal furniture, shelving, containers and cans use waxes to improve slip, reduce scratching on high-speed filling and handling lines, and increase service durability. The wax must not compromise the printability or adhesion of protective varnish over exterior printed inks.

Inside food cans, waxes can improve cleanability through water repellency and can assist the release of food contents. Selection must meet the applicable regulatory and food-contact requirements.

Wood coatings

In wood finishes, waxes improve durability, slip, scratch and abrasion resistance, and resistance to wet blocking during drying and stacking. Blends of Fischer-Tropsch or polyethylene wax with PTFE can perform particularly well in abrasion tests because PTFE lowers the coefficient of friction.

Density must be controlled: a high PTFE fraction increases the blend density and can promote sedimentation, leaving less wax at the film surface. The effect is more likely when particle diameter is much smaller than film thickness. Polyethylene, Fischer-Tropsch, polypropylene and amide waxes can also be used alone where their hardness and abrasion resistance are sufficient. Polypropylene wax combined with silica is useful for matt or satin, soft-touch finishes.

Water-repellent waxes are used in exterior wood stains and lacures to extend coating life and reduce moisture-related wood degradation.

Waterborne and UV-curable systems

Micronised waxes in waterborne systems

Waterborne systems require easily incorporated oxidised waxes or pre-dispersed emulsions. At the same wax/resin solids ratio, wax emulsions often retain gloss better but give less scratch and abrasion resistance than micronised waxes. The difference reflects their small particle sizes and the effects of surfactants.

An appropriate wax can balance slip, scratch and abrasion resistance while controlling gloss. A common high-performance approach combines polyethylene and PTFE waxes. The blend ratio must be selected to reduce sedimentation of dense PTFE. Melt blending can lower the effective particle density, improve dispersion and help the particles remain near the surface. Polyethylene also helps distribute PTFE and reduces the tendency to reaggregate.

Micronised waxes should remain substantially inert and insoluble so that particle shape and size are retained. Low-molecular-weight Fischer-Tropsch waxes can be partially solvated or swollen in some aromatic-solvent or waterborne systems. Certain mineral-oil defoamers may also attack these waxes. If neither wax nor defoamer can be changed, pre-diluting the wax into the defoamer before addition may reduce incompatibility.

Visible flotation or sedimentation does not necessarily indicate poor wetting. A correctly dispersed particle may still move because its density differs from that of the liquid formulation. Stability can be improved by increasing viscosity, matching wax density more closely, reducing particle size, or ensuring adequate remixing before use. The simplest practical remedy is often to stir the product thoroughly and select a wax designed for the formulation.

Micronised waxes in UV-curable systems

A frequent challenge in UV-curable coatings, especially transparent wood varnishes, is obtaining a strongly matt yet transparent finish. UV coatings are often high-solids systems, typically around 90 to 100 percent solids, and form relatively thick films. Crosslinking can create a smooth, level surface that reflects incident light efficiently and therefore appears glossy.

High additions of silica and wax may be needed to reduce gloss, which can cause excessive viscosity, difficult deaeration, poor curtain-coating behaviour or insufficient levelling in roller application. In suitable cases, combining polypropylene wax with silica helps achieve mattness while controlling application properties.

Some waxes can inhibit cationic UV-curing reactions. The effect may arise from anionic groups introduced by oxidation or present in the wax composition, which can interact with propagating cations. Compatibility and cure response must therefore be checked in the complete formulation.

Conclusions

Waxes are functional surface-control materials rather than interchangeable fillers. Their chemical family, molecular weight, crystallinity, density, melting behaviour, oxidation state, particle size and shape, dispersion route and capacity to migrate jointly determine performance. A wax that improves slip in one formulation may reduce adhesion, gloss or overprintability in another. The most reliable selection is made by matching the wax and its physical form to film thickness, cure mechanism, application conditions and the required balance of scratch resistance, abrasion resistance, blocking, water resistance, appearance and cost.

Acknowledgements

The author sincerely thanks Ewold Kensbock, Steve Kensbock and Paul Upton of Kromachem, and Warren Pushaw of Micropowders, for their suggestions.

References

1. Schrenk, V. Paint & Resin International. 1995; 3:8.
2. Pushaw, W.; Gittleman, D.; Kensbock, E. Polymers Paint Colour Journal. 1999:18-21.
3. Bennett, H. Industrial Waxes. New York: Chemical Publishing Co.; 1975.