Aluminum Pigments for Plastics

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SILBERLINE®
The Global Supplier of Effect Pigments℠

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Focus

The focus of this brochure is to educate aluminum pigment users on the safe and proper incorporation of our products in plastic applications. Silberline Manufacturing has been producing grades for the Plastics market since 1959 and has a wide array of aluminum pigments for polymer applications. The brochure includes aluminum pigment selections, formulating guidelines and common problems.

Introduction to Aluminum Pigments

The origin of the use of metallic pigments dates back to the age-old art of goldbeating. Egyptians working gold into very thin sheets could then overlay bone, wood or other materials with the precious metal. This art later spread to China, India and eventually Europe. As the ancient artisans plied their trade to produce the gold "leaf," the edges of the very thin foil would tend to break off. It was soon discovered that these loose particles, if placed in a suitable vehicle, could simulate the gold leaf. Carrying this process a step further, shredding the very thin leaf through fine screens would produce a gold powder that could be used for ornamental artwork or printing inks. Because of the prohibitive cost of gold, bronze and cooper soon became suitable substitutes, and eventually silver and tin were also used to make a "silver bronze" powder.

It was not until the middle of the 19th century that Sir Henry Bessemer, capitalizing on the high cost of gold bronze powders, developed a mechanical stamping process. As aluminum became more readily available through newly developed smelting processes, it was quickly adapted to the Bessemer process as a substitute for silver and tin.

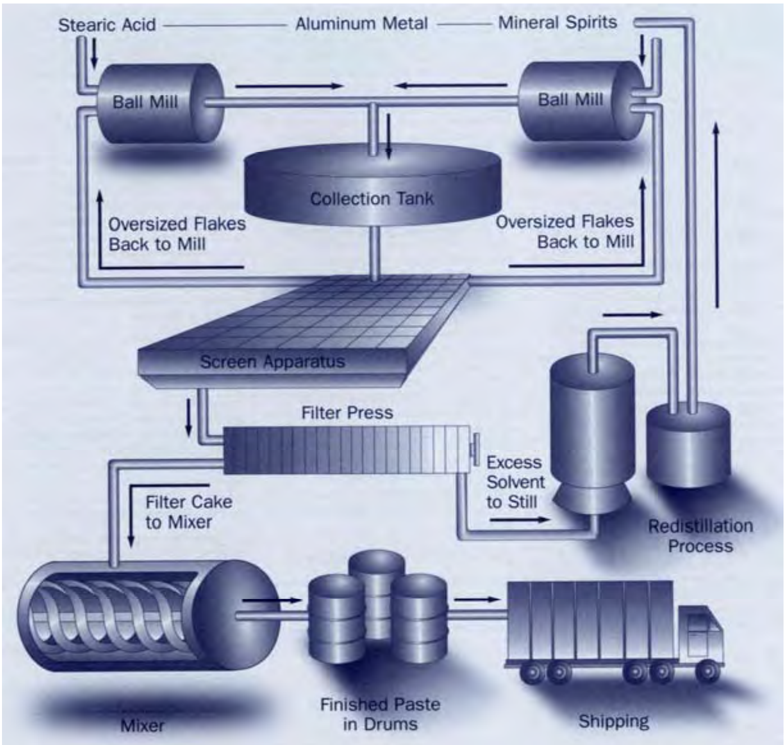
A safe, explosion-free manufacturing process did not evolve until 1930 when E.J. Hall of Columbia University developed the wet ball milling method. This process carries out the particle size reduction in the presence of a suitable lubricant and an aliphatic hydrocarbon solvent, producing a safer, far superior aluminum flake pigment. By eliminating the explosive characteristics of the Bessemer process, it became safe and economical to produce the finer aluminum flakes that find widespread use today. The importance of this was quickly realized, and as a result, the Hall process continues to be the principal manufacturing process for aluminum pigments used today.

Methods of Aluminum Manufacture

We, at Silberline, use the Hall process for both our leafing and non-leafing aluminum pigments. As indicated earlier, this process involves wet grinding of the raw material. Three raw materials are charged into the ball mill containing steel balls: aluminum metal, mineral spirits and suitable fatty acid, usually stearic or oleic acid. The mill is operated at a speed that will permit cascading of the balls onto the aluminum metal, thus flattening it and eventually breaking it into tiny flakes. The lubricant prevents cold welding of the metal and a sufficient amount of mineral spirits is charged into the formulation to maintain a wet slurry. The length of time for a ball mill operation depends on the grade being manufactured and the particle size distribution desired. Generally, a range from five to 40 hours is typical.

When the milling operation has been completed, the slurry is passed over an appropriate mesh screen, separating out the undesirable flakes. It is this process, along with the length of milling, that differentiates one grade from another. The oversized flakes are returned to the ball mill for further processing, while remaining aluminum flakes pass into a filter press. Excess solvent is removed in the process, resulting in a filter cake having a volatile content of approximately 20%. Products designed for the Ink and Plastic industries are processed further by removing the mineral spirit portion and replacing it with appropriate carriers.

Flow Diagram for Production of Aluminum Flakes



Safety and Handling

Dry aluminum flake, when suspended in air as a fine dust, has the potential for causing an explosion. Using a carrier to keep the aluminum pigment from becoming airborne is helpful. Other precautions, such as utilizing non-sparking tools and measuring scoops, keeping containers closed to prevent drying and proper grounding of the equipment to reduce static discharge are beneficial in reducing the chance of fire and explosion. The primary way to prevent an explosion is to make certain that the aluminum does not turn into a dry powder that becomes airborne at any point during the process. Once the aluminum pigment is wetted or melted into a polymer, this danger is greatly reduced. However, high shearing of the aluminum can produce new surfaces that can rapidly oxidize, thus creating enough heat to burn. When using Silberline aluminum pigments, contact the Technical Service department for proper incorporation methods and carrier recommendations.

Characteristics of Aluminum Pigments

Aluminum pigments are manufactured from pure metal with typical purity ranging from 99.30 -99.97% aluminum, depending on the grade being produced. When milled into a pigment, the most striking feature is the geometry of the particle. Aluminum pigments used for plastics come in three geometries: a flat cornflake, which somewhat resembles a breakfast cereal flake; a lenticular flake, which is a flat ellipse; and a spherical pigment, which resembles a very tiny sphere of aluminum with a bright surface. The aluminum pigment can be extremely dull or exceptionally bright, depending on the surface polish. The pigment's median particle size measured in microns varies from fine to coarse.

Measuring the particle size of a flat, thin flake is difficult. There are several methods used and even manufacturers of aluminum pigment may not agree on which is best. The median particle size tells only a small part of the story; however, the particle size distribution is very important. From a visual observation, an 85 micron aluminum pigment with a wide particle size distribution may seem similar in appearance (patina) compared to a 40 micron aluminum pigment with a much narrower particle size distribution. The best way to select a pigment is by examining some type of display, such as injection-molded step chips that would be close to the end use. Additionally, the aluminum pigment geometry and approximate particle size can be determined through microscopic examination of injection-molded step chips or displays.

The **hiding** (opacity) or tinctorial strength of aluminum pigments shares a direct relation with particle size distribution. In general, grades with the greatest hiding have the smallest average particle size. The converse is true of grades with larger particle sizes. Measurement of hiding differences between grades can easily be accomplished by visual comparisons of drawdowns in a clear vehicle or letdowns in a step chip using the desired resin system.

Color characteristics can be described as whiter, brighter, grayer or darker, all of which are related to the particle size distribution. The lightness or grayness is provided by the amount of light reflected from the surface of the flake. Generally, as the particle size distribution becomes finer, the color gets darker. Through particle size separation techniques and particle geometry, it has become possible to provide grades with a very small average particle size while maintaining a high degree of brightness.

The characteristic of **sparkle** is based on a visual assessment, which must be made in direct sunlight or incandescent light. The relation is particle size, shape and contour dependent, but coarser flakes generally provide more sparkle.

Plastic Grade Families

The vast number of available grades are grouped into nine families of pigments, dependent upon the starting aluminum flake. A description of each grade family is provided below.

Regular Grades

The Regular grades are based on leafing aluminum pigments. They have wide particle size distribution ranges and offer excellent hiding at low loading levels. They are often used as an economical way of producing a metallic appearance in plastics; however, even though they are based on leafing pigments, they will not produce leafing characteristics in most applications. These grades are well suited for application in blown film where pigment stability and high opacity are important. They are not recommended for use with colorants where clean, high chroma effects are desired.

Reflective Grades

The Reflective grades are based on medium non-leafing aluminum pigments with a particle size distribution more controlled than the Regular grades. These grades are better suited for systems pigmented with chromatic pigments and will offer cleaner, brighter effects than the Regular grades.

SPARKLE SILVER® Series

The SPARKLE SILVER grades are based on SPARKLE SILVER technology and are brighter and whiter than the Reflective grades. The SPARKLE SILVER series grades can be used with chromatic pigments to offer cleaner and brighter effects than the Regular or Reflective grades and are more economical than the SPARKLE SILVER Premier grades.

SPARKLE SILVER Premier Series

The SPARKLE SILVER Premier grades for plastics are based on automotive-quality lenticular pigments. They are characterized by a narrow particle size distribution range and will produce very clean colors when used in combination with various colorants. They are the brightest and whitest pigments based on their average particle size and will produce a very smooth patina.

SPARKLE SILVER ULTRA® Series

The SPARKLE SILVER ULTRA grades are highly refined lenticular pigments that are extremely bright for their particle size. They are capable of producing the appearance of solid metal, similar to the look of anodized aluminum. This appearance can be accentuated by the use of transparent pigments or dyes to produce colored effects with a brilliant metallic sheen.

Glitter Series

The Glitter grades are very coarse pigments that offer bright, high sparkle effects with very low opacity. Depending on the grade chosen, Glitter grades will offer aesthetics similar to chopped foil pigments. They produce high metallic sparkle and are well suited for systems that can be pigmented with various colorants, resulting in highly chromatic effects.

High Sparkle Series

The High Sparkle grades are based on coarse to very coarse, non-leafing cornflake pigments that offer a bright, high sparkle appearance. They have broad particle size distribution ranges and, therefore, better hiding than the Glitter grades. However, like the Glitter grades, they produce high metallic sparkle and are well suited for systems that can be pigmented with various colorants, resulting in highly chromatic effects.

Extra Sparkle Series

The Extra Sparkle pigments differ from traditional lamellar metallic pigments because of their spherical or granular geometry. These pigments have very low opacity and can be used to impart pinpoint sparkle effects while allowing the primary polymer matrix color to remain dominant.

Metallescent Pigments

Metallescent Pigments can be used to provide colored pearlescent-like effects when combined with organic pigments and dyes. To create the Metallescent appearance, low concentrations of aluminum pigments in the range of 0.1-0.25% are used with transparent colorants. The "whiteness" of the pearl effect will be limited by the color of the aluminum itself so very white pearl effects cannot be matched. Such formulations are extremely cost effective, due to the very low concentrations required. The SPARKLE SILVER ULTRA series are a family of pigments well suited to provide metallescent effects.

Laser Receptive Pigments

The use of fine bright pigments such as those found in the SPARKLE SILVER ULTRA series are very suitable for laser marking. Aluminum pigments can be used by themselves or with a chromatic pigment. They function by imaging the polymer layer between the laser source and the aluminum flake below reflecting the laser energy and preventing further laser penetration as would occur without aluminum pigments.

SILCROMA® Iron Pigment

SILCROMA iron pigment is used to produce the aesthetic appearance of natural stone. SILCROMA iron pigments are stable at high temperatures and their black color will not bleed. This pigment also has the functional application of being magnetic or metal detectable by means of a ferrous metal detector.

Carriers for Plastics

After the appropriate grade of aluminum pigment is selected, a carrier should be chosen that would best match the incorporation method and process. Aluminum pigments are sold as dry powder, solvent-based pastes, plasticizer-based pastes, and solid carrier pellets or granules. Dry powder can easily become an airborne dust in normal mixing equipment and can be dangerous, so Silberline does not recommend its use in plastics.

Solvent-based aluminum pastes, sold to the Plastic market, are usually a combination of metal flakes and mineral spirits. They range in metal content from 60% to 85%, with the balance being solvent. Solvent-based pastes can be used for liquid systems such as plastisols, caulking and some two-part thermoset materials. The use of a solvent-based paste for liquid systems allows the pigment to be incorporated safely, without generating dust. The solvent will evaporate as the material cures, leaving the base polymer unaltered.

Introduced in 1959, aluminum pigments were wetted with a high boiling plasticizer carrier, which could be safely used with most thermoplastics processing. In SILVEX® grades, the most common carriers are mineral oil, Dioctyl Adipate (DOA) and Diisodecyl Phthalate Plasticizer (DIDP). These carriers are used because they boil at a temperature higher than many polymers are processed and are used from room temperature up to 430°F. They have fairly stable chemistries that are near neutral in pH, do not react with aluminum pigments and are clear and compatible with most polymers. The SILVEX products are designed as a damp powder with a high metal content. The metal content is typically 80% with some finer grades requiring a higher percentage of carrier. These carriers have a high flash point, which makes them much safer to work with around typical processing equipment. There are times when these products are mixed with resins having high oil absorption rates. This has the potential of generating dry aluminum flake through absorption of the carrier.

The use of DIDP and DOA carriers are common for PVC applications because of their compatibility with the base resin. The use of a plasticizer-based aluminum paste in flexible PVC may require the removal of a slight amount of plasticizer to keep the formulation in balance. In rigid PVC, a slight amount of plasticizer may not be desired because it could enbrittle the polymer. The use of a mineral oil carrier for rigid PVC may be a better choice in this case. The mineral oil carrier is recommended for most other thermoplastics. PVC processors have also reported problems with plate-out when using aluminum pigments. To reduce plate-out problems, customers have been using a special product blend of polymer treated aluminum flake carried in a plasticizer.

In 1982, a solid carrier was introduced, called SILVET®, which allowed aluminum pigments to be formed into solid pellets or granules. There are two advantages found when using SILVET: safety and cleaning. SILVET, in pellet or granule form, is safer because it is virtually dust-free. It is easier to feed to the processing equipment and to clean up after use. The SILVEX and solvent paste forms require substantial cleaning to change to another color. A small amount of residual aluminum pigment can affect a subsequent color.

The standard SILVET carrier is a modified polyethylene product with the carrier designated as “E” or “E1”. SILVET has a low melting point and is easy to incorporate with a wide range of thermoplastics. The metal content of SILVET grades is normally 70 -80%. SILVET grades are recommended for thermoplastics processed above 250°F, so that it is above the melting point of the SILVET carrier for proper incorporation. The carrier melting point is high enough to accept drying temperatures up to 200°F. It is recommended that the SILVET product be dried when the base resin requires drying. SILVET “E” and “E1” differ in the pellet compaction and process shear that is imparted to the aluminum flakes. SILVET “E1” is made with a low shear process that provides a brighter product with very easy dispersion characteristics. SILVET “E” and “E1” have limited compatibility when processed with PVC. SILVEX products are recommended for PVC applications.

Engineering thermoplastics such as PC, ASA and PMMA have physical property, processing and color limitations when using SILVET “E” and “E1” products. The SILVET “P” carrier system, which is based on acrylic, is better suited for these applications. This product is manufactured in a low shear, easy to disperse pellet or granule. It provides much better clarity in clear engineering resin systems and improved polymer compatibility. There are additional SILVET carrier technologies under development that target specific polymers or FDA compliance applications.

Product codes for SILVET and SILVEX grades are a combination of five numbers and a letter. The first three numbers identify the family flake category, the next two numbers indicate the percentage of the carrier, followed by a letter to represent the carrier type. The SILVEX letters are “C” for mineral oil, DOA for Dioctyl Adipate and “D” for DIDP. The SILVET letters are “E” and “E1” for polyethylene and SILVET “P” for acrylic. An example of a product code is SPARKLE SILVEX® Premier 950-20-C (950 series flake, with 20% mineral oil carrier).

Formulating with Silberline Aluminum Pigments

Resin Compatibility

Aluminum pigments are used in a wide variety of thermoplastics to provide functional or aesthetic properties. The selection of the proper carrier system will allow the use of aluminum pigments with most polymer systems. The SILVET carrier is compatible with a wide range of high temperature thermoplastic systems such as ABS, nylon and PET. The SILVET “E” and “E1” carrier does impart some haze to very clear resins. Therefore, a SILVEX is selected in some applications to maintain clarity. SILVEX used in resins processed above 430°F, can have the carrier removed during compounding by heat and vacuum. The concentrate will have only the aluminum pigment in the polymer, which then has the least effect on physical properties. Aluminum pigments for plastics can be used in most plastic processes such as calendering, blown film, extrusion, injection and rotational molding. A functional use of aluminum pigments in a plastic system comes from the light and heat barrier offered to the plastic. The aluminum pigments are also selected for their aesthetics to provide a metal replacement effect or colored metallic appearance.

Proper Dispersion of Aluminum Pigments

Aluminum continues to make a large contribution to the realm of effect pigments in many areas of commerce. In these competitive markets, manufacturers and customers have come to expect reproducible aesthetics. As a result, it is desirable and cost-effective to achieve and maintain proper dispersion of aluminum pigments for consistent appearance and functionality. This is especially true in plastics and applies to commodity items, such as mulch film, as well as high-end applications like automotive components. As a leader in the special effect pigment market for Plastics, Silberline continues to develop and offer grades of aluminum products that are easy to use and provide good extension in a variety of thermoset and thermoplastic applications.

Most aluminum pigments sold to the Plastics industry are too concentrated for direct end-product use and must be reduced in an appropriate resin system. Typical grades are sold at 60-90% metal concentration, whereas levels are typically 0.1-5.0% in the final product. Obtaining a reduced metal concentrate requires a compounding step in which the master batch or color concentrate manufacturer reduces the loading to 10-20% in a compatible resin. If the final product requires a controlled metallic appearance, the processor may buy a "ready-to-shoot" compound to maintain the color more precisely. In any case, the use of pre-compounded materials helps the end-user achieve uniform color development in production runs.

Formulators use high shear mixing and fluxing equipment to obtain uniform hiding and color development when working with chromatic colorants. However, this type of equipment may alter the aesthetic effects of aluminum. When the flakes are exposed to high stress, they tear, shred and wrinkle, which changes their appearance. Aluminum pigment formulators use different techniques to decrease or eliminate the effects of aggressive mixing systems.

A slow-speed mixer, or kneading equipment with low shear blades, is recommended for dispersion of aluminum grades into liquid and paste compounds. To prepare these types of master batches, it is suggested that the pigment be pre-soaked in solvent, plasticizer or resin anywhere from a few hours to overnight. This will allow better dissociation of the flakes, making them easier to incorporate into the suspension. The viscosity of the dispersion will also determine how well aluminum stays mixed throughout the liquid or paste system. A low viscosity solvent may allow the flakes to settle, whereas a high viscosity paste can keep the flakes suspended. For some liquid color systems, suspension aids are available which can be used to reduce settling and make re-dispersion easier.

Compound manufacturers use ribbon blenders, drill mixers or tumblers for gentle distribution of colorants in dry pigment mixing. Aluminum grades are best introduced into these mixes at low speed to reduce stress on the flake. The blending should then be maintained at low speeds until the product is well dispersed. High intensity mixers for dry blending may damage aluminum pigments. The addition of the flake into a high intensity mixer should be completed during the last part of the cycle and, if possible, blended at a lower speed to reduce damage. If the resin is discharged into a medium intensity cooling mixer before further processing, the aluminum can be added at this step to avoid flake damage.

Fluxing of thermoplastic resins and colorants usually provides good dispersion of chromatic pigments, but care must be used when introducing aluminum grades. Co-kneading, Banbury or Farrel continuous mixers are often used since they provide dissociation with a low amount of shear. Single screw and twin screw extruders are also widely used to compound pigments, but caution is needed when adding aluminum products. In all cases, the pigments should be added toward the end of the mix cycle, or, in the case of extruders, incorporated via downstream addition for minimal stress. An additional factor for consideration is that aluminum pigments transfer heat much better than the surrounding polymer. When processing chromatic colorants in extruders, the barrel will require a certain heat profile to give good dispersion. When the same profile is used for aluminum, the flake may heat the polymer much faster and lower the viscosity of the flux. In this case, the product may not achieve proper extension in the batch. The use of aluminum requires that the overall melt temperature be decreased 10-40° F, depending on the loading level. If necessary, the use of a higher viscosity resin with aluminum pigments can achieve the same result at the original processing temperatures. Screen packs may also be used to aid dispersion; the selection will depend on the particle size. Additionally, dwell time of the colorants in either mixers or extruders is an issue with compounders. Too little dwell time can result in low pigment extension, while mixing too long may produce shear. A proper balance of residence time and dispersion needs to be determined on an individual basis.

Color matchers can anticipate the color changes and shear affects to aluminum products in their systems. One technique employs aluminum flake carried in a solvent, oil or plasticizer that has a lower viscosity than the host resin. Using this practice, the pigment flows and dissociates easily into liquids and pastes with little resistance. The same idea can be used with pellet versions where the carrier system used for the aluminum has a lower melt index than the master batch polymer. The formulator may be able to determine how much processing change will occur when comparing a sample created with laboratory equipment to one made with production equipment. Still another method is to use a slightly larger flake than desired, with the intent that the pigment will shear the aluminum only slightly without significantly increasing hiding.

Opacity

In many applications, a very fine aluminum pigment is used for making products, such as duct tape, shopping bags and agricultural films, really opaque. The opacity provided by aluminum pigments is related to their particle size. Very fine flakes provide extremely high opacity at low loading levels, whereas larger flakes provide much lower opacity.

Polymers that are exceptionally opaque can adversely affect the appearance of metallic colors. The SILVET carrier can cause clear polymers to become slightly opaque. The opacity of the polymer can mask the decorative flash, or sparkle, of the aluminum pigment. If an aluminum pigment cannot reflect light back to the observer, optimum metallic effects will not be achieved. The optimum metallic effects are obtained when the polymer is nearly transparent or just slightly tinted. If the base polymer is cloudy or contains chromatic colorants with high hiding power, more aluminum pigment must be added to have enough flakes near the surface to provide the desired metallic effect. When using metallic colors, formulate to the minimum opacity level in the thinnest section of the part, which will increase the visual depth of the polymer and show the optimum sparkle effect. However, as the opaqueness of the base polymer increases, the size of the aluminum flake and loading will need to be increased to maintain a similar metallic effect. A textured finish may require a coarser flake to match a smoother surface or to improve the visibility of flake sparkle.

Quite often, plastic parts are molded and then painted with metallic paints. Processors ask if the painted part can be matched as a molded-in, colored plastic part. Aluminum pigments that have been painted onto plastics appear very prominent. They align parallel to the surface and are flat in a thin film. In contrast, the aluminum flakes that are incorporated into a polymer are often bent and randomly arranged throughout the thickness of the polymer. To overcome this, the aluminum pigments selected for incorporation should be 10-100% larger in size (depending on the base polymer opacity) versus the size used in paints.

Leafing Effect

There are two types of aluminum pigments: leafing and non-leafing. The fatty acid employed in the initial milling of the aluminum flake will govern the orientation of the flakes. Leafing aluminum flakes use stearic acid and non-leafing aluminum flakes use oleic acid. The leafing phenomenon is where the aluminum flakes migrate to the surface of a liquid system. They form a bright film at the surface of aligned flakes.

Thermoplastics are too high in viscosity for any leafing effect to occur and the flakes have a more random orientation. In thermoplastic applications, leafing pigments are used to produce a gray color with excellent hiding power at low concentrations.

The leafing effect can occur in some liquid plastic systems, such as plastisol and silicone. Some SILVEX products are based on leafing pigments, but the process to make SILVEX reduces the leafing efficiency. If the customer still needs a SILVEX grade, a pre-shipment sample should be tested in the plastic system to make certain the leafing effect is sufficient. Using a leafing solvent paste, which is controlled for leafing, may be a better choice. In some systems, a solvent -based aluminum paste may be preferred, because the solvent can be baked off and not alter the softness of the base polymer. If a leafing effect is desired, one must be careful not to use polar solvents in the formulation, resulting in de-leafing.

When formulating with leafing pigments, the aluminum is only on the surface. When washed off, the underlying plastic is gray. This happens when a leafing grade is used for a fabric dip coating or plastisol ink. When the coated article is sold, the product is bright and catches the customer’s eye. After washing, however, most of the bright aluminum flakes on the surface are removed, leaving a gray color underneath. One solution to this problem of washability is to use bright, non-leafing pigments that do not change color when washed. Another solution is to use a clear top-coating over the leafing pigment.

Mock Pearlescent Effect

The use of aluminum pigments as a replacement for pearlescent pigments can be accomplished in some cases. Aluminum pigments for plastic applications offer larger sizes and better shear resistance than pearlescent pigments. Pearlescent pigments bend the light while aluminum pigments reflect it. Aluminum pigments, therefore, give much higher hiding power and a dark flop, while pearlescent pigments have less hiding and a lighter flop. The flop phenomenon is called metallic travel. In a flat, painted surface this effect shows that the aluminum pigments have a bright face color and dark flop as the surface is rotated from a vertical to horizontal position. In metallic coatings, this phenomenon is often desirable because it produces a color change associated with a polychromatic effect. The best aluminum pigment to offset pearlescent pigment is the Metallescent series, used at a low dose, to allow the light to pass deeply into the polymer. The next best product families are the SPARKLE SILVER Premier series and SPARKLE SILVER ULTRA series, both of which are very bright. The lighter flop can be developed, to some degree, using a low dose of TiO_2 or Ultra-Fine TiO_2 in combination with a low dose of aluminum flake, to allow light into the polymer. Pearlescent and aluminum pigments are often mixed together to combine the benefits of the hiding power of aluminum pigment and the brighter flop of pearlescent pigment.

Imitation Gold and Copper from Aluminum

Copper and brass flakes are easily tarnished by moisture, which causes them to change color. The use of aluminum pigments to make imitation gold and copper colors is very popular. Aluminum pigments can be combined with yellow, orange and red transparent chromatic pigments or dyes to produce an imitation gold or copper. To achieve this effect, the aluminum pigment loading must be low enough to allow the light to be reflected through the transparent chromatic pigments. Aluminum pigments have a tendency to make a bright yellow appear slightly green, which requires a low loading of red or orange colorant to compensate. The use of coarse aluminum flakes with yellow colorants produces poor metallic gold colors. This combination appears as aluminum glitter flake in a yellow background.

Common Problems

Agglomeration/Aggregation

Unlike most chromatic pigments used for plastics, aluminum pigments do not have an unlimited shelf life and may agglomerate or aggregate over time. The agglomeration can be very slight to severe. This is the number one complaint from aluminum pigment users in all industries. The problem occurs when the aluminum flakes stick to each other with such a strong bond that normal mixing techniques cannot break them apart. Consequently, the plastic processor may see a loss of hiding power, color shift, difficulty in dispersion or seediness. Proper storage of pigments, such as keeping drums sealed, maintaining reasonable storage temperatures and preventing carrier evaporation will extend the life of the product. Agglomerated aluminum pigments may look usable in the drum, but this can be deceiving. As a result, the problem may not be found until used in production. If the aluminum pigment is being formulated to achieve hiding, the loading level can be increased to match the required opacity. However, if the aluminum pigment is used for aesthetic purposes, it may be very difficult to correct. The only solution may be to use fresh aluminum pigment.

Silberline lot numbers contain the year and month of manufacture, so the age of the pigment can be determined, thus, ensuring proper rotation of inventory. A very common problem occurs when the color matching laboratories use old stock of aluminum pigment that has agglomerated. If an agglomerated pigment is used to prepare a color standard, subsequent production problems can occur. It will be almost impossible to match the laboratory-generated formulation using fresh aluminum pigment. Try to keep the laboratory pigment stock fresh. If an aluminum pigment has been in inventory for a long time, it should be compared to a standard before use.

The use of aluminum pigments with certain polymers, chromatic colorants or additives can also cause agglomeration. One of the most common reactions occurs when using aluminum pigments with certain polyethylene resins. This is of great concern because aluminum pigments are used extensively in color concentrates containing polyethylene. The problem generally occurs with a color concentrate containing an aluminum pigment loading over 20% in low density polyethylene that has been stored in a hot warehouse or truck. To determine if there is a potential problem, take the color concentrate and place it in an oven at 200°F for two weeks. After heat-aging, disperse the heat-aged concentrate into a natural polymer and determine if dispersion is equivalent to an unaged sample of concentrate. If dispersion is poor, the potential for agglomeration may occur. Silberline offers a SILVET product containing a stabilizer to prevent this problem. The stabilizer is typically effective for at least one year or longer.

Chromatic colorants and additives can also react with aluminum pigments. It is well known that aluminum will react with water, acids and alkalis. Chromatic colorants and additives that have these substances as part of their chemistry may cause agglomeration or adverse reactions. One should be concerned about the use of strong oxidizing colorants, like chrome and moly oxides, and using aluminum with chlorinated solvents and halogenated compounds. In many cases, there is no compatibility data available for these products when used with aluminum pigments, since each compound blend is unique. Caution should be exercised in each case.

Plate-Out

Aluminum pigments have been reported to plate-out on calendering rolls and extruder screws. The problem on extruder screws is sometimes related to improper dispersion, where lumps of plasticized aluminum paste stick in the feed, or metering sections, and then break loose causing an aluminum streak. Plate-out, occurring after the pigment is fluxed in with the polymer, may cause surface defects or reduce gloss. A special blend based on aluminum flakes with a polymer surface treatment combined with plasticizer can reduce this problem.

Plate-out or surface migration can also occur from the liquid carriers used in SILVEX. If the loading level of carrier is too high, surface migration may result. A SILVET carrier is a better choice in this instance.

Hardness and Wear

A common question asked about aluminum pigments is whether or not they cause excess wear on plastic processing equipment because the flakes are metal. The answer is that no excessive wear is found because aluminum pigments are very soft and ductile. The Moh’s hardness of aluminum is 2.0-2.8, which is very comparable to 2.8 for pearlescent pigments. Most processing equipment is made of hardened steel, which have a hardness around 4.0-5.0, so the aluminum pigment is not hard enough to even scratch the equipment. TiO_2, with a hardness of 6.0-7.0, and glass filler, with a hardness of 5.0-6.0, will be much more abrasive.

Lensing or Air Voids

This is a term used to describe thin areas or voids that are evident in an extruded or blown film, and are caused by gassing. The thin areas appear as spots of reduced hiding when aluminum pigments are used. The number of spots is determined by the concentration of the volatile and its pressure, relative to the process temperature. In film processing, the most common cause is moisture, which can come from numerous sources, including condensation in bulk storage. Another contributing source of volatiles in these films can be the use of aluminum pigments. Aluminum paste in a solvent carrier, if used for this application, will exhibit lensing because the solvent generates a gas in the polymer melt. The use of plasticized paste, which has the solvent exchanged for a high boiling liquid, provides a great improvement. Although there may be some residual solvent in plasticized products, which may cause lensing, the problem can be easily solved by vacuum venting the extruder. It is best to do this during the manufacturing process of a color concentrate or during the manufacture of the film. Elimination of solvents and moisture may not guarantee a reduction in lensing. Plasticizer carriers can become volatile at 430°F, turning them into a gas. A solution to this problem would be the use of a solid carrier, which does not turn into gas, even at higher processing temperatures. For films that are very sensitive, requiring resin drying before processing, the aluminum pellets should also be dried a minimum of one hour at 200°F.

In injection molding, volatile gas can show up as a splay mark. It is important to determine if a splay mark is coming from volatiles, improper injection or the decompression cycle. In the injection cycle, proper injection speed and packing should be used so the part is not under-filled and the injection rate is not too fast to entrap air in the melt front. In the decompression cycle, make certain that air is not drawn in, or entrapped, when refilling the screw. If the splay mark is still present, drying the material before processing might reduce or solve the problem. If this does not help, the aluminum pigment carrier may be volatilizing or may have blocked the mold vents. The solution can then be found with proper carrier selection.

Flow and Weld Lines

Aluminum pigments used in injection molding often exhibit problems associated with flow and weld lines. Weld lines are caused when a part has an interruption or thinning section and the polymer flows around this section faster than the aluminum flakes, which makes a lower aluminum flake concentration line. A flow line will develop from direction changes that allow the aluminum pigment to adopt a vertical orientation, with respect to the polymer surface. This shows only the dark edges of the aluminum flakes, not the bright surfaces, disrupting randomized orientation. There has been literature published and some suggestions have been made for minimizing this problem.

By careful mold design of new tooling, the occurrence of flow and weld lines can be reduced. The use of large gates (preferable fan, tab or round) will provide the best delivery of material, preventing jetting and providing the most random pigment distribution. The gate area should be at least three times the median particle size of the coarsest metal pigment to be used. The part should be gated in an area that is not a face surface. The number of gates that allow molten flow fronts to meet within the part should be reduced. The mold should be designed with the least amount of restrictions and interruptions as possible, even to the point of post-machining some openings into the plastic part, after molding. Finally, the use of surface texturing can also reduce unwanted flow and weld lines.

An injection mold that is not designed for metallic pigments may show flow and weld lines that are difficult to overcome. If the mold cannot be modified, selecting proper aluminum pigments may reduce the appearance to a level that is acceptable. A suggested first step may be to use a coarse aluminum pigment, while still achieving the desired appearance. Coarser aluminum pigments tend to align less at flow fronts and appear more randomly distributed. A second suggestion is to examine the amount of aluminum pigment loading needed to achieve the desired effect. The use of a high loading makes a very strong, narrow weld line but makes flow lines more pronounced. A low dose of aluminum allows more space between flakes, reducing the flow line, but the weld line is wider. Loading that gives a low level of hiding, but still allows light to pass through, gives the best balance of flow and weld line hiding. Another suggestion would be the selection of an aluminum pigment with a narrow particle size distribution, reducing the number of fine flakes that darken the flow and weld lines. The last consideration is to use a background color to reduce the appearance of the flow and weld lines by contrasting the darker areas.

Aluminum pigment geometries may have an affect on helping to reduce the flow line appearance. Spherical aluminum pigments, which are tiny spheres of aluminum with a bright surface, may help brighten a flow line when used in combination with aluminum flake pigments.

Additional work on flow and weld lines has shown that some improvements are possible with changes in mold and processing temperatures. The aluminum flakes have a tendency to orient parallel to the mold surface when filling, which provides brightness. In a cross section of the part, the flakes are random in orientation except where variations in concentration and orientation make flow and weld lines more visible. Increasing the mold temperature and/or the stock temperature seems to provide some improvement. Once that optimized point is hit, there is no additional improvement from increasing mold or stock temperature. Fast injection speed and higher pressure also provide improvement in flow and weld line appearance.

Orientation

Aluminum pigments will orient to the process direction. The degree of orientation depends on the aluminum pigment loading and particle size. As the particle size of the aluminum flake decreases, directional orientation problems increase. Generally, as the loading of aluminum pigment increases, directional orientation problems increase. Flat sheet extrusion, calendering and plastisol web coating processes frequently show the directional orientation problem, due to the linear process direction. This orientation problem makes the product look like two different colors when the sheet is turned horizontally 180 degrees. In plastics, process orientation occurs when the flakes align with the process direction, giving a brighter face. The opposite direction will show more dark flake edges. When components are seamed together or cut into smaller items, such as credit cards, the process orientation makes these items appear to have color variation. Processes that provide mono and biaxial stretch orientation, after extrusion or injection molding, can produce an increase in the proportion of the flakes orienting to the surface, which may have the effect of brightening the object or film.

Color Measurement

The instrumental measurement of metallic colors in plastic can be difficult, but not impossible. The typical single-angle colorimeter, used for most pigments, often provides results that are very confusing and misleading when measuring metallic color. The best color-measuring instrument currently available is the goniospectrophotometer, which measures metallic colors at several angles. This instrument, which measures reflected light at different angles, offers valuable colorimetric data. Metallic colors present measurement problems when the plastic process orients the aluminum pigments in one direction. There will be one set of color values in the process direction and a completely different set when the sheet is rotated 180 degrees. Color measurement instrument manufacturers recognize that metallic pigments are difficult to measure and are always searching for improved methods.

When processes orient the flakes in a linear, non-parallel direction, it is recommended that a visual standard be used. The visual standard should be prepared in the same polymer, formulation and surface texture and then marked in the direction of processing. When moving from a lab match to production, it is important to make certain that the part opacity, aluminum pigment loading level and particle size are correct before starting. Finally, always try to compare the colors in the direction of orientation.

Silberline Technical Service Support

The aluminum pigments for plastics have technical support from the Technical Service centers in Tamaqua, Pennsylvania; Leven, Fife; Suzhou, China, and Singapore locations. These support services provide customer visits, grade and carrier recommendations and aid in problem solving. Their main goal is to have the aluminum pigment safely provide the customer's desired effect. The Technical Service representatives also attend many of the major Plastic trade shows worldwide in an effort to help answer customer inquires. Additional product information is also available on the Silberline website at www.silberline.com.

References

Recommendations for Storage and Handling of Aluminum Powder and Paste – TR-2, Third Edition, The Aluminum Association, 900 19th Street, N.W., Washington, DC 20006.

Aluminum: The Useful Pigment by George Kern, presented at the Coloring of Plastics – XVI RETEC, for the SPE Color and Appearance Division, October 4-6, 1982, McAfee, New Jersey.

Metallic Direct Pigmentation, Coloring Plastics with Aluminum Pigments by John Kerr and Bernard Klein. Special Reprint from Kunstoffe Plast Europe, August, 1995.

Replacing Metallic Painted Plastics by Mass Pigmentation by Ian Wheeler, presented at the Intertech Conference, "High Performance Pigments," October 27-29, 1997, Chicago, Illinois.

A Bad Day of Color Matching is Often a Great Day of Unique Effects by Robert Schoppe, presented for the SPE Color and Appearance Division RETEC, September 27-29, 1998, Cleveland, Ohio.

Eliminating Flow and Weld Lines in Metallic Pigmented Mouldings by Ian Wheeler, presented at High Performance Pigments, October 5-7, 1998, Barcelona, Spain.

Styling with Metallic Pigments by Ian Wheeler, presented for Colorants for Plastics Asia 2000, June 14-16, 2000, Hong Kong.

Metallic Pigments in Polymers by Ian Wheeler, Rapra Technology Limited, 1999, Shrewsbury, Shropshire, United Kingdom.

Aluminum Pigment Distribution Techniques, Retention of Color & Brightness in Metallic Plastics Through Control of Mixing, Shear and Pigment Wet-Out by Michael Sanchez, presented for the SPE Color and Appearance Division RETEC, October 1-2, 2002, Toronto, Canada.

Weld Lines? What Weld Lines? Getting Better Appearance from Metallic Pigmented Mouldings by Ian Wheeler, presented at Addcon 2003, Vienna, Austria.

Recommendations for Flow and Weld Line Mitigation Using Aluminum Pigments by Robert Schoppe and Eric Ringan, presented at ANTEC 2006, Charlotte, North Carolina.

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