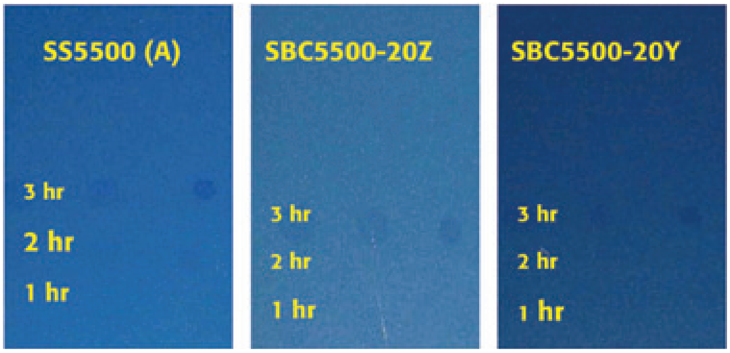
SilBerCote™—
New Dimensions in Performance

Silver has again captured the hearts and imaginations of consumers for the third year in a row! Today's technology-driven lifestyles demand products that not only perform but also appear "high tech"....and silver delivers! Color sells, and today's consumer items reflect colors that not only announce technical wizardry, but also provide what some stylists refer to as a neutral appearance that goes well with all colors. Whether for technical inferences, or neutral appealing colors, there is no question that silver leads the charge. In fact, it is the most popular color for automobiles worldwide. This popularity has carried over to many other consumer items, especially in the electronics and telecommunications areas.

While silver is considered an achromatic color, many shades and appearances can be generated. From soft, smooth gray appearances to very bright, sparkling, almost jewel-like tones, the palette is almost endless. The wide variety of shades is based on the very large number of aluminum pigment grades available on the market today. All are based on the same highly reflective metal, but differences in particle shape, size and particle size distribution contribute to the metallic effect we are familiar with. Probably the most unique aluminum pigment feature is that it is actually a flake, unlike most other organic and inorganic pigments. This morphology generates and supports the reflective nature of the pigment. Larger flakes will typically provide brighter, more sparkling appearances, while smaller flakes offer greater opacity, grayer appearances and smoother, less sparkling colors.

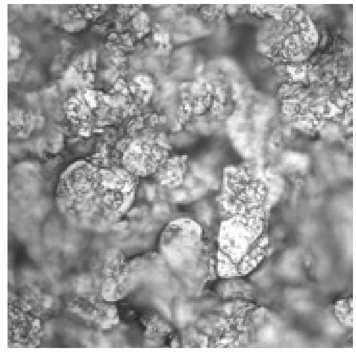
Aluminum pigments share many, if not all, of the properties of the metal itself and, when formulated into a coating, can enhance the performance in addition to

Figure 1/Acid spot test



By **Russ Ferguson**, Vice President of Global Technology/Silberline Manufacturing Co., Inc., Hometown, PA

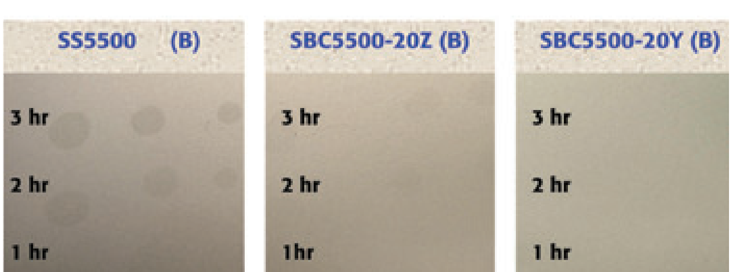
supporting the aesthetic function. They have been widely used for their performance features in many applications, ranging from roof coatings to auto-body putty, anti-corrosive coatings and reflective (heat, UV, IR) coatings. Some of the important performance properties shared between metal and pigment are excellent opacity; high reflectivity to UV, IR and visible light; barrier property performance; and heat reflectivity. While most of the properties shared between metal and pigment are positive, there are several that present challenges when formulating into coatings.



Aluminum metal is amphoteric, reacting with both acidic and alkaline environments. Under certain circumstances, this metal flake can react with acidic or basic systems, potentially resulting in less-than-desirable performance. Aluminum metal also has the capability of reacting with water, which is not a serious concern when dealing with large, fabricated pieces. In this instance a slow reaction occurs with the generation of a thicker, benign oxide or hydroxide layer. This is also a positive feature and is especially useful when developing anodized colored coatings. However, in an aluminum pigment, where the volume of metal is so small and surface area so high, the reaction is no longer benign! The chemistry of this reaction generates large volumes of hydrogen gas, eroding the flake and converting aluminum to some form of aluminum hydroxide. In a coating system, this can be disastrous.

Figure 2/Acid-resistance immersion testing

Figure 3/Alkali spot test



Another feature of aluminum that is well understood, but not necessarily transferred to the pigment, is electrical conductivity. Under certain conditions and applications, aluminum-pigmented coatings will exhibit a degree of electrical conductivity, but in general it is not equivalent to that of the bulk metal. The reasons for this are very simple, but not well understood by many users. Even though aluminum pigments have a much higher surface area, they are covered by a thin layer of oxide and a thin layer of fatty acid lubricant. When formulated into a coating or plastic substrate, they are often separated by the vehicle or carrier. It is really the lack of metal-to-metal contact that lessens the electrical conductivity normally associated with aluminum metal. However, even though this is the case in most applications, there is still enough flake-to-flake contact to create concerns in certain special applications. Applications where this is of particular concern include plastic coatings that require a high level of electrical resistivity.

A final challenge that some coatings formulators face, particularly in specialized applications, is loss of adhesion, either to the substrate or intracoat. Adhesion properties are generally attributed to the greasy surface of the aluminum flake, which is not a deficiency of the metal, but rather of the process used to make the metal flake.

The pigment, accounting for its very popular use in coatings, inks and plastic applications has exploited almost all of the positive properties of the metal. Some of the physical, reactive and electrical properties however have, in some cases, imparted a roadblock to expanded use.....until now. Recognizing the many opportunities available to further market use, Silberline has engaged in several research initiatives to develop technologies to overcome the performance challenges presented by standard aluminum pigments. Probably the most pressing challenge, the aluminum/water reaction, has been and continues to be addressed through advances in inhibition chemistry.

In fact today, just about all aluminum pigment manufacturers have their own proprietary surface chemistry satisfying demanding customer needs. However the other pigment limitations, reactivity, conductivity and adhesion, especially on plastic substrates, were never quite satisfied until recently.

Table 1/Test methods

Test	Method
Acid-resistance test	Spot test using 10% HCL 24-hour immersion in 0.1N H_2SO_4
Alkali-resistance test	Spot test using 0.1 NaOH 3-hour immersion in 5% NaOH
Detergent immersion test	24-hour immersion in 5% Tide Detergent Sol'n
Adhesion test	Standard tape pulls over same location on sprayed panel
Electrical conductivity	Charge resistance measurement on sprayed panel.

Testing parameters/preparation:
- All coatings were prepared using acrylic-based polymer or polymer blend systems that are commercially available.
- The coatings were applied to two types of commercially available ABS polymer substrates using a spraymation air-applied system.
- Coarse, Medium and Fine non-leafing grades using two polymer chemistry systems were evaluated. Table 2
- In each of the Coarse, Medium and Fine categories, both acid-resistant, and non-acid-resistant aluminum pigments were evaluated. Table 2
- All testing was conducted under identical conditions and against a control (non-polymer treated aluminum flake).

Figure 4/Alkali-resistance immersion testing

Early research attempts to improve metal flake performance involved the encapsulation of aluminum flakes in a variety of polymers. Encapsulation techniques are not new, and have been practiced in a wide variety of industries for many years. These techniques, ranging from spray drying to spinning disk technologies, are well known. Equally well known is the unlimited number of available polymers. However, the recurrent challenge that was never solved, until recently, was the maintenance of individual flake identities throughout the encapsulation process. Although multiple flake encapsulation could provide the necessary barrier properties to the aluminum flake, it was not an acceptable solution. Loss of opacity, brilliance and seedy appearances could never be tolerated in functional coating/plastic systems.

Utilizing a unique thin slurry chemical process, and investigating a myriad of processing parameters, various monomer and polymer chemistries were evaluated. The list of candidate chemistries was gradually narrowed to include a family of organic polymers for flake attachment. The final chemistry and process for attachment maintained the original appearance of the aluminum pigment grade.

Assessment of performance gains was based on well-established testing protocols used in the industry (Table 1).

Test Results

The results of this comprehensive test program were quite revealing and indicated significant performance improvements when the aluminum flake was chemically modified with a polymer treatment.

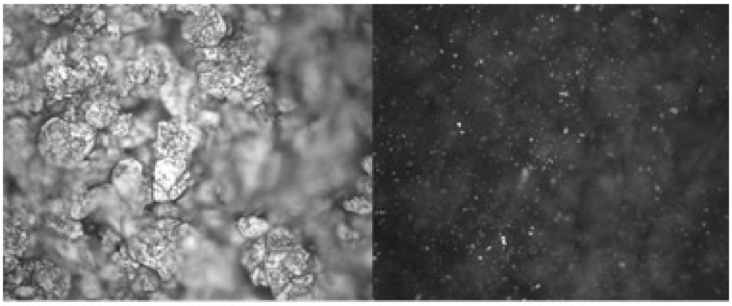
Acid Resistance

Acid resistance has long been a requirement of many OEM coating systems. Prior to the introduction of polymer surface treatments, a degree of acid resistance was achieved through the use of high-purity aluminum alloys. Standard metal purity is 99.3 – 99.7% aluminum, while high-purity alloys are closer to 99.97% aluminum. The most common alloying ele-

Table 2/Aluminum pigments tested

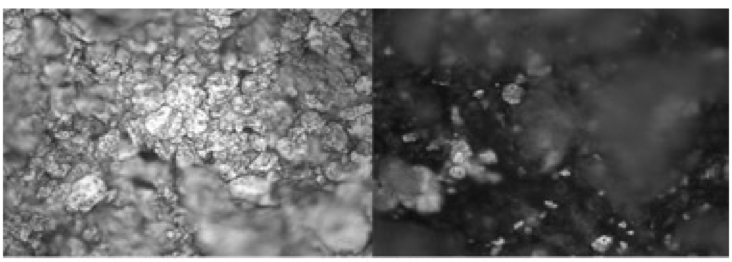
Aluminum Pigment Grades				
Control Untreated Grade	Description	Median Particle Size (D 50)	Polymer-Treated Grade: Z Organic Polymer	Polymer-Treated Grade: Y Organic Polymer
SSP 303AR	Coarse	21	SBC 303-20Z	SBC 303-20Y
SSP 353	Coarse	24	SBC 353-20Z	SBC 353-20Y
SS 5000AR	Medium	13	SBC 5000-20Z	SBC 5000-20Y
SS 5500	Medium	13	SBC 5500-20Z	SBC 5500-20Y
SS 7000AR	Fine	7	SBC 7000-20Z	SBC 7000-20Y
SS 7500	Fine	11	SBC 7500-20Z	SBC 7500-20Y

Figures 5-7/Visual observations - 400 X optical microscope



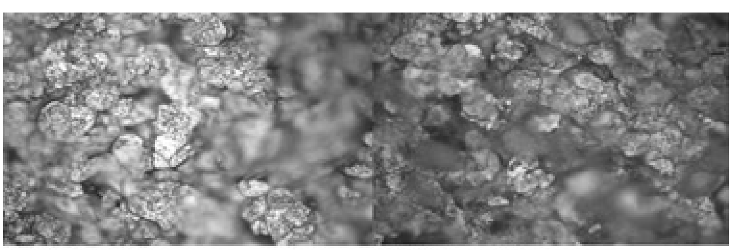
SS5500 Not Immersed **SS5500 Immersed in 5% NaOH**

Figure 6



SBC5500-20Z Not Immersed **SBC5500-20Z Immersed in 5% NaOH**

Figure 7



SBC5500-20Y Not Immersed **SBC5500-20Y Immersed in 5% NaOH**

ments, iron and silicon, contribute to the reactivity and subsequent loss in metallic appearance. In this series of tests, two different mineral acids were employed, one through a spotting test and the other in an immersion test. Results from both test procedures indicated that polymer treatments significantly improved the resistance to attack and subsequent color change, regardless of the purity of the alloy used in producing the flake. The spotting test shown in Figure 1 demonstrates the resistance to a 10% HCL solution over a 3-hour period. While difficult to see in this picture, both the "Z" and "Y" polymer technologies are more resistant than the untreated grade. The acid immersion test (Figure 2) clearly reveals improvements in resistance to H_2SO_4.

Alkali Resistance

The need for alkali resistance in metallic coatings, especially for general industrial applications, has grown in recent years. Much like acid resistance, the purity of the aluminum alloy can enhance resistance, but does not achieve the desired level of performance required for many of today's demanding coatings. Spot and immersion testing using a NaOH solution proved very aggressive for standard, untreated controls (Figure 3). The same immersion and spot testing applied to the "Z" and "Y" polymer-treated grades again showed dramatically improved results (Figure 4). These polymer treatments, while not completely impermeable, greatly slow down the rate of reaction and dramatically reduce aluminum flake degradation and darkening in the finished coating system.

Microscopic evaluation of the alkali-immersed panels was carried out in an effort to support the flake integrity/color change relationship. As can be clearly seen in Figures 5, 6 and 7, the visual color change noted in the before and after immersed panels is the direct result of flake integrity. Untreated SS 5500 aluminum flake is almost completely destroyed after immersion, resulting in a severe darkening of the panel. The "Z" and "Y" polymer treatments demonstrate well-defined improvements in color retention, and the photomicrographs of these flakes indicate much less flake damage.

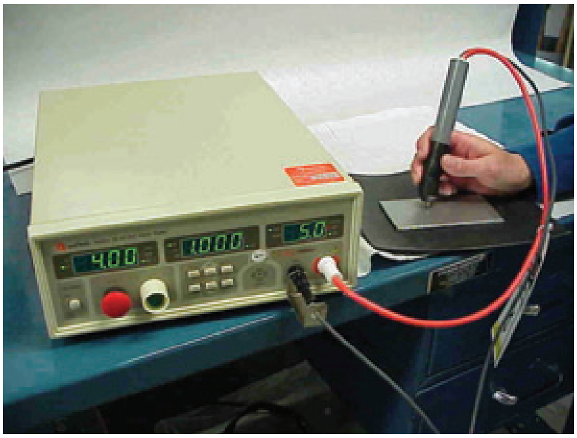
Adhesion Testing

One of the challenges of formulating metallic coatings for plastic substrates is good adhesion. Both inter-coat and intra-coat adhesion failure can occur, depending on the formulation and the formulation components. The fatty acid sheath surrounding aluminum flakes is often the culprit because of its greasy nature. Chemically modifying the surface of these flakes through the polymerization process has the positive effect of improving the adhesion character of the formula. A standard test method based on the cross hatching of the cured coating followed by "tape pulls" was used to qualify the improvement. In all grades tested, from coarse to fine, the polymer surface modification improved the adhesion properties of the aluminum flake, however the coarser grades in general possess slightly poorer adhesion properties. This improvement was most notable with the "Y" polymer chemistry.

Electrical Conductivity

A requirement for much of today's electronic and telecommunication equipment is a coating system that is basically non-conductive. Standard aluminum flake metal unfortunately does not possess good resistive characteristics in paint films, and especially does not meet some of the specifications established for coatings on plastics. One of the standard test methods in the industry employs a meter capable of measuring the conductivity of a coating (Figure 8). Two electrodes are placed on the coated substrate 10 mm apart; applying a 4 KV DC potential, the conductivity is measured between probes. Less than 1 milliamp of current is deemed acceptable.

Figure 8/QuadTech Sentry 25



Summary and Conclusions

The need to improve the chemical and functional properties of aluminum pigments in coatings systems has been a well-recognized requirement for many applications. While some success has been achieved in the past, maintaining the aesthetic properties of the flake has always been the last and most difficult hurdle to cross. The development of the SilBerCote™ technology has allowed us to not only leap this hurdle, but also to exceed expectations in the improvement of functional properties.

This new capability of putting a "barrier coating" on individual aluminum flakes is opening many new doors for applications where aluminum flakes were not formerly acceptable. As this technology is further explored and expanded we expect to further enhance the physical, chemical and functional properties and uses for aluminum pigments. ◍

For more information, call 800/348.4824, or visit www.silberline.com.