spe COLOR & APPEARANCE

CADNEWS®

WINTER 2022 NEWSLETTER

SAVE THE DATE
ANTEC 2023

RECAP
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TECHNICAL ARTICLE
A STEP-WISE APPROACH FOR COLOR MATCHING MATERIAL THAT CONTAINS EFFECT PIGMENTS
Dr. Breeze Briggs, BASF Colors & Effects USA LLC

2023 SPONSORSHIP PROGRAM
CADNEWS 2023

WINTER 2022 CHAIRMAN'S MESSAGE

Hello Color and Appearance, SPE members, and visitors to this next edition of the CADNEWS Letter.

To quote Earl Balthazar "RETEC 2022 - We're Back!". What a great show for our 60th Diamond year! Attendance was 352, up 100 from last year. Historically, attendance is around 450 so we look forward to RETEC 2023 in Columbus Ohio to reach this goal. Columbus Ohio is a near-centralized location for many division members and companies so hopefully attendance by formulators, laboratory experts, and especially new members of your companies can attend RETEC 2023 to see the valuable technical talks, make new contacts, and get involved with many aspects this conference has to offer. There were 60 tabletops representing 50 companies at this year's show. A sincere THANK YOU to all the sponsors and exhibitors this year.

I want to especially thank Mark Tyler Chair and Vice-Chair Alex Prosapio of this year's RETEC, as well as the entire conference committee for a job well done! Special shout-out to the Technical Program organizers Breeze Briggs and Andrew Smith, there were a lot of great talks and panel discussion.

The SPE Plastivan representatives attended this year as well. Eve Vital and Evan Morton hosted 41 local students ranging from elementary to high school along with many of their parents. The students worked together on the show floor while talking to company representatives. The students wanted to learn more about plastics and potentially make it a career focus. The parents stayed with the students the whole time and enjoyed watching their children develop a spark of interest in STEM through plastics and color. How exciting is this opportunity!

The CAD division was able to make another donation to the local Orlando area Habitat for Humanity. Thank you to all who participated in the Fun Run/Walk event. This year's donation was $1,150.

And lastly, I want to congratulate Jeff Drusda for being awarded this year's Terry Golding Outstanding Achievement Award for his exemplary work on the CAD Board over the past years and his continued work today.

I conclude with a recommendation to look for upcoming SPE events, programs, and educational series for your companies. And look forward to RETEC 2023 in Columbus Ohio! Thank you.

MICHAEL WILLIS
Color and Appearance Division Chair
michael.willis@sunchemical.com

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Milliken presents

Milliken: The Color Experts

Milliken & Company understands the power and value of color as it relates to branding. Humans are visual creatures, and color plays a key role in purchasing decisions, as it helps to inform, personalize and speak the brand language.

The company continues to tap into its vast experience in this space to develop solutions for a wide variety of end markets and end-use applications.

Milliken's color journey began in 1964, when it launched its proprietary Versatint® washable colorants for textile identification. In 1981, it introduced its Reactint® range of colorants for polyurethane (PU). Five years later, Milliken unveiled its ClearTint™ polymeric colorants for use in NX® UltraClear™ polypropylene (PP), which can be made only with its Millad® NX® 8000 clarifier.

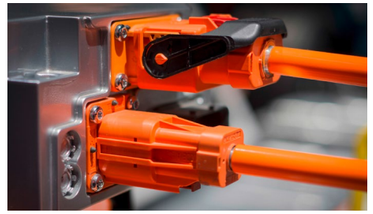
The year 2019 marked a major step forward, with the introduction of both its KeyPlast® products, as well as its KeyPlast RESIST™ high-performance colorants for plastics.

Milliken technology helps to color a vast range of sectors, including agriculture and turf; automotive and transportation; building and construction; coatings, paints and inks; home and laundry care; and plastics.

Milliken's KeyPlast RESIST colorants address another key challenge — coloring high-performance engineering polymers with bright and vibrant hues. These colorant are used in the high demanding applications such as high voltage connectors, control systems, structural parts and metal replacement.

Using KeyPlast RESIST colorants compounders and resin producers, offer a vast spectrum of stable and reproducible colors suitable for use with a wide range of resins such as Polyamides, PPA's, Poly Sulphones and other high heat polymer blends and alloys.

Additionally, Milliken continues to keep its finger on the pulse of end-user and market trends, which it documents each year in its ColorDirection report that forecasts the key shades and hues for the coming year. In doing so, it offers a palette of carefully curated colors, while providing the stories behind the inspiration and motivation driving their popularity. Brand owners can leverage this expert information to help capture the mood of consumers through effective branding and personalization.



Milliken's diverse portfolio of colorants can enable product makers to realize their aims to deliver on those colors that will help drive and shape consumer preferences in the coming year.

From the R&D lab to the production floor, Milliken's Chemical Division stands ready to help customers leverage color to design new products, reinvigorate existing products, and create opportunities to grow in new markets and applications.

For more details and information please contact us or visit us online at ***chemical.milliken.com***

EUROPE : eurochem@milliken.com | **NORTH AMERICA** : millichem@milliken.com
LATIN AMERICA : lachem@milliken.com | **ASIA** : asiachem@milliken.com

The 2022 RETEC® Committee and Color and Appearance Division Board of Directors would like to thank this year's exhibitors.

2022 CAD RETEC® TABLETOP EXHIBITORS

3V Sigma USA	Lintech International
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MAKE A SPLASH WITH COLOR II

CAD RETEC® 2022

CAD RETEC® 2022 SPONSORS

The 2022 RETEC® Committee and Color and Appearance Division Board of Directors would like to say a huge Thank You to this year's RETEC® Sponsors.

Registration fees for attendees are kept low in part by the generous donations of these corporate and individual sponsors.

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CALL FOR BOARD OF DIRECTORS CANDIDATES

2023 - 2026 TERM

The Color & Appearance Division of the SPE will be conducting its annual Board of Directors elections April 2023.

SPE CAD BOARD OF DIRECTORS

The election is open to current SPE members with CAD as their primary division. Time commitment would be for four meetings per year for 3-year terms. One of the meetings will correspond with RETEC where you will participate in CAD activities and initiatives. Members of the Board participate in the planning, organization and running of CAD activities including ANTEC programs, RETEC programs, Technical Programs, Scholarship Programs & Funding, as well as offering guidance and advice to other SPE members interested in coloring plastic resins.

To be listed as a candidate or have questions about becoming a candidate, please email or call **Chair Elect Alex Prosapio**. Please Email a picture of yourself, educational background, employment (current and prior), and why you wish to be a candidate to:

Alex Prosapio
PH: 845-641-0596
aprosapio@sudarshan.com

All candidates must be identified and have all their information to SPE CAD BOD by March 19th, 2022

Visit SPECAD website for more information.

SPE COLOR & APPEARANCE DIVISION MISSION STATEMENT:

The Color and Appearance Division of SPE strives to educate, train, inform, and provide professional interaction opportunities to the global community involved in visual performance and aesthetics of plastics.

Society of Plastics Engineers

Color & Appearance Division

Endowment Scholarship Program

The Endowment Scholarship Program offered by the Color & Appearance Division of the Society of Plastics Engineers awards multiple scholarships each year to students who have demonstrated or expressed an interest in the coloring of plastics industry. The students must be majoring in or taking courses that would be beneficial to a career in this industry. This would include, but is not limited to, plastics engineering, polymer science, coloring of plastics, chemistry, physics, chemical engineering, mechanical engineering, industrial design and industrial engineering. All applicants must be in good standing with their colleges. Financial need is considered for most scholarships.

Undergraduate and graduate scholarships range up to $3,000 annually. Scholarships are awarded for one year only, but applicants may apply for a re-award for each year they are enrolled in school.

Scholarship Eligibility

1. Applicants for these scholarships must be full-time undergraduate students in either a four-year college or a two-year technical program or enrolled in a graduate program.

2. All applicants must be graduates of public or private high schools.

Scholarship Criteria

1. Applicants must have a demonstrated or expressed interest in the coloring of plastics industry.

2. Applicants must be majoring in or taking courses that would be beneficial to a career in the coloring of plastics industry.

3. An applicant must be in good academic standing with his or her school.

4. Preference is given to student members of SPE and also to students who have a parent(s) as a member of the Color & Appearance Division of the SPE.

4. Financial need of an applicant will be considered for most scholarships.

Application Procedure

To be considered for a scholarship from the Color & Appearance Division Endowment Scholarship Program, applicants must complete an application and return it to the address specified on the application by June 5, 2023. All applications submitted must include:

1. A completed application form.

2. Three recommendation letters: two from a teacher or school official and one from an employer or non-relative.

3. A high school and/or college transcript for the last two years.

4. An essay by the student (500 words or less) telling why the applicant is applying for the scholarship, the applicant's qualifications, and the applicant's educational and career goals in the coloring of plastics industry.

For more information, visit www.specad.org or contact Ann Smeltzer at (412) 298-4373 or e-mail at ann.smeltzer@clariant.com

All scholarships will be paid directly to the recipients' schools. The Color & Appearance Division Endowment Scholarship Program will not award scholarships to applicants who are not qualified and reserves the right to not award a scholarship in a given year if it so chooses.

CALL FOR CANDIDATES

COLOR & APPEARANCE DIVISION
BOARD OF DIRECTORS

WE NEED YOUR HELP – CONTINUE THE EXCELLENCE!

- Interested candidates for the 2023 Board of Directors should contact Alex Prosapio or any Board Member, or indicate your interest on the questionnaire
- We will be soliciting candidates through the end of 2022
- Biographies due February 2023
- Elections will be conducted in Spring 2023
- If elected, term is 3 years (serve until 2026)
- There are 4 Board meetings per year to attend: Spring, Summer, CAD RETEC®, and Winter meetings
- Candidates must be members of SPE in good standing and members of the Color and Appearance Division

COLORFUL COLUMBUS

CAD RETEC® 2023

CALL FOR PAPERS

HYATT REGENCY | COLUMBUS, OHIO

SEPTEMBER 18 – 20, 2023

DEADLINE FOR ABSTRACTS IS FEBRUARY 2023

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Color and Appearance Division

spe CAD RETEC® Columbus, Ohio • September 18-20, 2023 Presented by SPE Color and Appearance Division

SPE CAD NEWS

HABITAT FOR HUMANITY

SPE CAD-RETEC has been supporting HfH since 2005 when Hurricane Katrina struck the Gulf Coast causing catastrophic damage from central Florida to eastern Texas. That year, SPE CAD-RETEC was held in Charlotte, North Carolina and in support of the vast rebuilding that would take place, SPE CAD-RETEC donated 25% of the profits from the event to HfH. Since that time the relationship between the two organizations has grown.

For the last 16 years, DCL has supported the Habitat for Humanity in their mission to bring people together to build homes, communities and raise hope through sponsorship of the 5K Fun Run. This past September we were in Orlando, FL and DCL once again hosted the annual 5K Fun Run. It raised $1150. We are grateful to the runners who helped make this possible, as well as the matched donation made by the Society of Plastics Engineers Color and Appearance Division.

Here in this photo, we have Frank Lavieri (DCL, EVP Sales and Marketing) presenting the cheque to Mary Alice Fish (Habitat for Humanity).

TERRY GOLDING OUTSTANDING ACHIEVEMENT AWARD

This year's recipient for the Terry Golding, Outstanding Achievement Award went to Jeff Drusda. Jeff is an active member of the Color and Appearance Board of Directors where he is a past chair and contributes on several key Committees.

Jeff's work on setting up and developing the new CAD Website was a tireless task and Jeff was undaunted and unfazed by the magnitude of the venture. There were several others who helped along the process, but it was Jeff who developed it and made the transition happen. If any of you have seen the new website and remember the old, you can attest it is so much more modern and fits todays needs. Still much work to be done but it was Jeff who got us this far.

Thank you, Jeff, for your continued efforts on the CAD BOD and especially the new CAD Website.

2021 RETEC® BEST PAPER AWARD

Andy Francis, Q-Lab

"UVC Durability Testing of Plastics"

ANTEC® 2023 SAVE THE DATE

SPE is hosting **ANTEC® 2023** at the Hilton Denver City Center

DENVER, CO | MARCH 27–30

2023 ANTEC® showcases the latest advances in industrial, national laboratory and academic work. Papers will share findings in polymer research and/or new and improved products and technologies.

IN MEMORY OF

FRANK LEWIS FASANO, SR.
March 23, 1931 – August 26, 2022

Frank spent his career as a chemist, specializing in pigments and dyes. He received an award from the Society of Engineers in 1963. He was a plastics expert and was a member of the Society of Plastics Engineers for 60 years, and a member of the American Chemical Society for 64 years. He became a Senior Member of the Society of Plastics Engineers in 1994. He also received The Honored Service Member award from the Color and Appearance Division in 1998. He retired from Hoechst-Celanese in Coventry, RI in 1994. He then started his own business selling pigments and dyes to Jaysynth Dyestuff (India) for 5 years before finally retiring. Frank will be missed by those he touched and those he influenced.

spe COLOR & APPEARANCE

SPE Color and Appearance Division Mission Statement

The Color and Appearance Division of SPE strives to educate, train, inform and provide professional interaction opportunities to the global community involved in visual performance and aesthetics of plastics.

INVITATION TO ATTEND CAD BOARD MEETING

The Color and Appearance Division (CAD) holds 4 Board of Directors (BOD) meetings each year, either in person or virtually. Any CAD members in good standing with in SPE and has Color and Appearance as their selected division are welcomed to attend these meetings. If interested in attending these meetings, please contact the current CAD Chairperson or any BOD for more information.

CADNEWS® Technical Content – Scott Heitzman

The Technical Content portion of our winter addition of CADNEWS® includes an excellent paper from 2017 that was presented at ANTEC! The paper A Stepwise Approach for Color Matching Material that Contains Effect Pigments by Dr. Breeze Briggs. The paper defines color, options in measuring color and some fundamental matching methods to help you with your effect color matches. A quick read and implementation will improve your color match acceptance rate and dramatically cut your time to match.

CADNEWS® Color Notes – Scott Heitzman

Welcome CADNEWS® Color Notes. The idea is to create discussion and provide comments regarding questions you may have related to color and appearance, color measurements, and colorants in general. Do not miss your opportunity to anonymously ask our team of experts a question. Use the link below to submit your questions. Our SPECAD Color Notes committee will provide a response to one or more of the submissions in the upcoming CADNEWS® letter.

http://specad.org/color-questions-for-cad/

A Step-wise Approach for Color Matching Material that Contains Effect Pigments

Dr. Breeze Briggs, BASF Colors & Effects USA LLC, ANTEC 2017

Abstract

A red color can be described as cherry red but that description can mean many different things. How can a color be matched with a description like “cherry red”? A method to describe the correlation between the physical color and the perceived color is necessary. Several models are used today to define the link between the common vocabulary used to describe color and a quantitative measurement of that color. This translation of color is very important to a colorist as these parameters allow for meaningful communication. The color space models and instrumentation to quantify the colors are tools used for many different applications, color matching being one of the most important for a colorist or color scientist. The development and standardization of instrumentation has allowed for further insight into the communication of color. In this paper, the method used to perform a color match is investigated through a stepwise approach to using different analytical tools. This approach is applied to some of the most difficult pigments to match; those that exhibit color shift.

Introduction

Defining Color

In 1976 the International Commission of Illumination (CIE) adopted two color models that were designed to represent the differences in color by mapping it over space. Color is represented with three different components: brightness, a green to red spectrum and a blue to yellow spectrum. The CIELAB model (Figure 1) contains these three components and are used to quantify color beyond a qualitative description. The three components are shown graphed along the three axis the L*- lightness/darkness (along the x axis), a*- red/green (along the y axis) and b* - blue/yellow (along the z axis)[1].

A similar color model CIELCh is also used to model color space. It also uses three components to describe color, brightness (L*), chroma (C) which is the saturation of color and hue (h°) which is the color and is represented as an angle around a sphere starting at 0° (red), 90° (yellow) 180° (green) and 270° (blue) and continuing around to 360° (red). (Figure 2)

Figure 1: CIELAB color space model

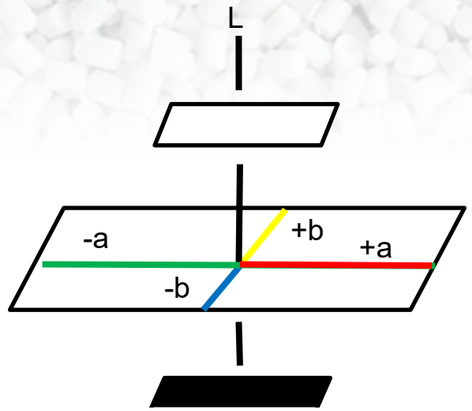
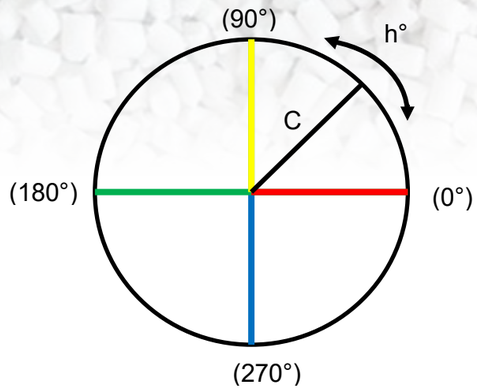


Figure 2: CIELCh model for color space



The CIELAB and CIELCh models are used as a common quantitative vocabulary for color. Another important factor particularly with color matching, is the ability to measure the difference between two colors. By using values from the CIELAB model, the L*, a* and b* values are used to quantify a color difference outlined in Equation 1. A calculated color difference using this equation is referred to as ΔE_{ab}. The ΔE_{ab} was developed with a simple Euclidean distance measurement that gives a broad understanding of the difference between two colors but it is not a good representative of how the colors are perceived. Although for a high level understanding Equation 1 is a good first approximation, it falls short in representing some color spaces. It is quite possible to obtain color values mathematically but cannot be perceived by the human eye with ΔE_{ab}.

Further development of this model with the CIE94 and CIEDE2000 that incorporate parameters that more closely resembles color differences that can be perceived. The CIEDE2000 incorporates values from the CIELCH model and quantifies color differences with weighted values in order to compensate for color that is actually perceived by the human eye.

Equation 1: $$\Delta Eab = \sqrt{(L_2^* - L_1^*) + (a_2^* - a_1^*) + (b_2^* - b_1^*)}$$

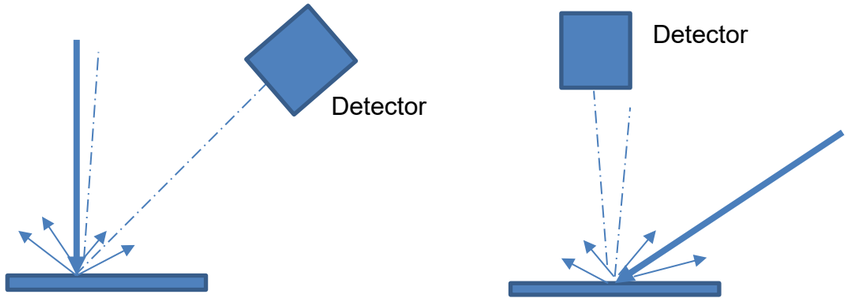
Measuring Color

Single Angle Spectrophotometer

Depending upon the setup of the spectrophotometer, there is a range of illuminating and observation angles, the most basic being the 0/45 or 45/0. The samples are either illuminated with a beam with an axis at 45° or is observed at 45°. (Figure 3) As the illuminating and observation angles of these systems are fixed reflecting light in measured at only one angle. Therefore, the amount of information that can be gleaned from this type of measurement is limited to one illuminating angle and one observation angle.[2] In samples where the angle of observation yields little difference in the color

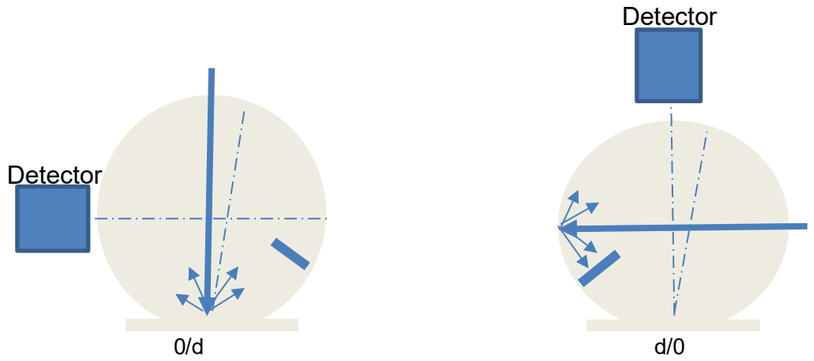
measurements, a simple single angle spectrophotometer is sufficient to do the job. However, samples that exhibit color shift depending upon angle of observation and samples that are glossy require instrumentation with a higher degree of complexity in order to properly characterize the sample.

Figure 3: 0/45 and 45/0 single angle spectrophotometer setup



A second type of single angle spectrophotometer uses an integrating sphere to either illuminate the sample diffusely or collect radiant power from the integrating sphere (Figure 4). With this arrangement the measurement of the specular component excluded (spex) or specular component included (spin) can be accomplished with a gloss trap which will adjust for samples that have gloss.[1,3] This spectrophotometer can then account for samples that have texture, gloss and haze. However, the illumination and observation angles are still fixed so the measurement of a sample that contains color shift based upon the angle of observation is not sufficiently mapped using this single angle spectrophotometer.

Figure 4: 0/d and d/0 single angle spectrophotometers

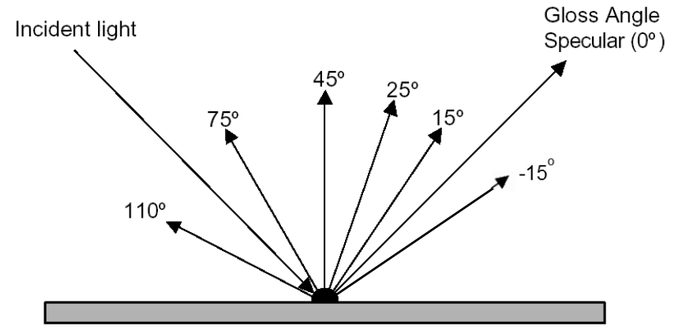


Multi-angle Spectrophotometer

The second type of spectrophotometer is one that measures the light reflected at several different angles. A multi-angle spectrophotometer is particularly useful in measuring color that does not remain the same at all angles of observation, such as pigments that are described as having color shift. An incident light is first directed toward the surface that is being measured, the light reflected at 90° is called the gloss angle or specular angle. From the specular angle, detectors are set up at varying

distance from the specular. This set up measures at -15°, 15°, 25°, 45°, 75°, and 110° from the specular angle (Figure 5). These angles are referred to as the aspecular angles which is the same thing as an observation angle, effect angle, cis-trans position or degree from gloss.[2]

Figure 5: Specular and aspecular angle set up for a multi-angle spectrophotometer.



Effect pigments

Color matching of material containing effects can be particularly difficult because of a shift in the color appearance of the effect pigment as the observation angle changes. This phenomenon can be described in several different ways; flip and flop, color shift, color travel, etc. but according to ASTM E259 these color changes are referred to as a change in the near and far aspecular color. The color change as the observation angle changes is due in part to the platelet-like nature of the effect pigments and the interaction of light with the surface. Effect pigments can be made from several different types of material, mica being one of the most common types. Mica consist of many flat layers of a silicate material that is milled to a certain particle size and TiO_2 or Fe_2O_3 is deposited on the surface. As the angle of observation moves from near to far aspecular, the light that is detected by a multi-angle spectrophotometer shifts from the light reflecting off the flat part of the effect platelet to the edge of the platelet. The mica and deposited material may exhibit a different refractive index due to a difference in material thickness on different parts of the effect platelet. The nature of the reflecting light can change depending upon several factors but ultimately the resulting color shift is due to how the light is interaction with the surface of the material. [2,4] The nature of the structure of the effect pigment whether it be mica, glass flake or a metallic lends itself to large color shifts depending upon the angle that it is observed at. It becomes difficult to color match with these pigments when this change in the near and far aspecular color is not properly characterized

Experimental

Reference Sample

A display sample was prepared as a reference to perform a series of test to investigate the limitations and possibilities of the current methods and instrumentation for color matching.

This formulation included the following in a polypropylene resin:

0.5% Pigment Violet 19 (blue shade)

1.0% White transparent effect pigment (5-25 µm)

1.0% Semi-transparent copper effect pigment (10-130 µm)

This formulation was first extruded on a single screw extruder with melt temperature 430°F, followed by injection molding to form a flat chip with the dimensions of 2 inch X 2 inch.

Color Matching Method 1 - Single Angle Spectrophotometer

The first color match was performed using a single angle spectrophotometer resulting in L*a*b* values that were used to perform a color match using a propriety color match program which contained a pigment library of organic and inorganic pigments measured on a single angle spectrophotometer. The color matching program parameters were set to match according to the spectral curve of the reference sample. It was also instructed to minimize the amount of components to one resin, one white, one black and three other pigments.

The resulting color match formulation was then extruded on the same single screw extruder except two passes through the extruder were preformed to get better dispersion of the inorganic pigment. This first round sample was then injection molded into the same 2 inch x 2 inch flat chip as the reference sample.

Color Matching Method 2 - Multi-angle Spectrophotometer

The second round color match was performed on a multi-angle spectrophotometer resulting in not one set of L*a*b* values but in five sets of values, one at each of the aspecular angles of -15°, 15°, 45°, 75°, and 110°. Using all of those values, a best fit formulation was generated by first minimizing the ΔE and then refining with the best spectral curve fit. The propriety color matching program that was used to perform the color match included a library that contained organic, inorganic and effect pigments with data at each of the aspecular angles making it possible to match the change in color and lightness as the angle of observation was changed.

Color Matching Method 3 - Microscopy

One final confirmation test was performed testing the reference sample for the closest color match. A visual representation of the effect pigment components in the reference sample was investigated by an optical microscope with a digital camera. The flat reference chips were set on the slide scope with outside light sources lighting the chip from below. The surface of the chip was investigated at several different optical magnifications. Snap shots of the surface along with dimensional measurements of the effect pigments that were present were obtained while view with bright field.

Results and Discussion

Color Match Method 1 - Single Angle Spectrophotometer

Using the single angle spectrophotometer, a best fit formulation was found to be the following in a polypropylene resin:

2% Pigment Yellow 53

1% Pigment Violet 19 (blue shade)

The single angle spectrophotometer was unable to detect the change of color with the change in observation angle as it only took information at one angle. Although it was able to appropriately pick out the base pigment of the Pigment Violet 19, it was not able to interpret the high sparkle nature of the copper effect pigments. The best fit option tried to compensate for the influence of the copper color with a Pigment Yellow 53. The influence of the small particle size white pearl effect was not incorporated into this match as the influence of the white pearl is more evident at the flop angle which

was not measured with the single angle spectrophotometer. The resulting color difference from the reference sample to this color match using a single angle spectrophotometer is very large at 28.86 with a D65 illuminant (Table 1).

Table 1: CIELAB and CIELCh values for the reference samples (Ref.) and the first color match (CM #1) using a single angle spectrophotometer.

	L*	**a***	**b***	**C**	**h**	**ΔE**	**spex(0.00)**
Ref.	35.71	28.32	-6.88	29.14	346.34		
CM #1	25.64	39.19	11.27	40.78	16.04	27.34	

Color Match Method 2 - Multi-angle Spectrophotometer

The second color match using the multi-angle spectrophotometer resulted in a much closer color match than with the single angle spectrophotometer. As the color of the sample was measured at five different angles, the shift in color at different observation angles were measured effectively capturing the dynamic nature of the sample and incorporating that into the best fit formulation.

The following formulation was the best fit formulation using a multi-angle spectrophotometer:

1.5% Green transparent effect pigment (8-48 µm)

1% White transparent effect pigment (8-48 µm)

0.5% Pigment Violet 19 (red shade)

0.4% Semi-transparent copper effect pigment (6-48 µm)

The Pigment Violet 19 was again selected as the base pigment however a red shade PV 19 was identified as the best fit. As an adjustment for the greater a* value attributed to the PV 19 compared to the reference, a green interference effect pigment was also added. In addition, a white transparent and a semi-transparent copper effects were also identified in the best fit formulation. The particle sizes of the white and copper effects and the addition of a green effect will directly affect the appearance of the sample. Those differences are pronounced in the color match versus reference in the a* values particular at the angles near specular. This is not surprising as a green interference pigment was added to compensate for the red shade PV 19 but was not in the reference sample. The ΔE was decreased from the first color match to a range of 5-17 with the second color match. The color difference compared to the reference is still too large to be acceptable for most applications.

Table 2 : CIELAB and CIELCh values for the reference sample (Ref.) and the second color match (CM #2) using a multi-angle spectrophotometer.

							spex (0.00)
	L*	**a***	**b***	**C**	**h**	**ΔE**	**-15°**
Ref.	74.04	20.88	-19.68	28.69	316.7		
CM #2	80.13	7.75	-11.78	14.1	303.33	16.5	
	L*	**a***	**b***	**C**	**h**	**ΔE**	**15°**
Ref.	66.98	22.55	-18.78	29.34	320.2		
CM #2	72.72	9.97	-9.11	13.51	317.57	16.9	
	L*	**a***	**b***	**C**	**h**	**ΔE**	**25°**
Ref.	44.44	28.46	-10.41	30.3	339.91		
CM #2	48.81	19.43	-5.06	20.08	345.39	11.4	
	L*	**a***	**b***	**C**	**h**	**ΔE**	**45°**
Ref.	25.57	34.18	0.3	34.18	0.49		
CM #2	28.1	29.35	-0.22	29.35	359.57	5.5	
	L*	**a***	**b***	**C**	**h**	**ΔE**	**75°**
Ref.	18.55	35.99	6.54	36.58	10.3		
CM #2	20.47	33.3	2.05	33.36	3.53	5.6	
	L*	**a***	**b***	**C**	**h**	**ΔE**	**110°**
Ref.	15.9	36.5	8.05	37.38	12.43		
CM #2	17.78	34.74	2.42	34.82	3.98	6.2	

Color Match Method 3 - Microscope

With the information from the two rounds of color matching plus additional information from the microscope a clearer idea of the actual effects and size ranges of those effect pigments can be defined. Using the components from CM#2 as a starting point, the microscope was able to define the effect components in two ways. First the particle size of the white and copper effect pigments could be measured. Secondly, it was identified that the formulation did not contain a green interference effect pigment. As a result of using multiple instrumentation tools, the following formulation resulted:

1% White transparent effect (5-25µm)

0.5% Semi-transparent copper effect (10-130 µm)

0.5% Pigment Violet 19 (blue shade)

With this additional information the ΔE for this system was decreased to 2. Although empirically this may still be too large of a ΔE for most applications, it does give the best results from each of the color matches.

Table 3: CIELAB and CIELCh values for the reference sample (Ref.) and the third color match (CM #3) using an optical microscope with a digital camera.

							spex (0.00)
	L*	**a***	**b***	**C**	**h**	**ΔE**	**-15°**
Ref.	74.04	20.88	-19.68	28.69	316.7		
CM #2	73.64	18.69	-19.26	26.83	314.14	2.3	
	L*	**a***	**b***	**C**	**h**	**ΔE**	**15°**
Ref.	66.98	22.55	-18.78	29.34	320.2		
CM #2	67.24	20.57	-18.38	27.59	318.22	2	
	L*	**a***	**b***	**C**	**h**	**ΔE**	**25°**
Ref.	44.44	28.46	-10.41	30.3	339.91		
CM #2	44.47	26.97	-11.93	29.49	336.14	2.1	
	L*	**a***	**b***	**C**	**h**	**ΔE**	**45°**
Ref.	25.57	34.18	0.3	34.18	0.49		
CM #2	25.2	33.67	-1.81	33.72	356.93	2.2	
	L*	**a***	**b***	**C**	**h**	**ΔE**	**75°**
Ref.	18.55	35.99	6.54	36.58	10.3		
CM #2	17.97	35.72	5.06	36.08	8.07	1.6	
	L*	**a***	**b***	**C**	**h**	**ΔE**	**110°**
Ref.	15.9	36.5	8.05	37.38	12.43		
CM #2	15.47	36.5	7.18	37.2	11.13	1	

The multi-angle spectrophotometer was able to define that a semi-transparent copper effect was present in the formulation but the particle size distribution was wrong. The digital picture from the microscope in Figure 6 at 20x magnification captures the particle size distribution which ranged from 18-104 µm. The closest commercially available product contained a distribution of 10-130 µm.

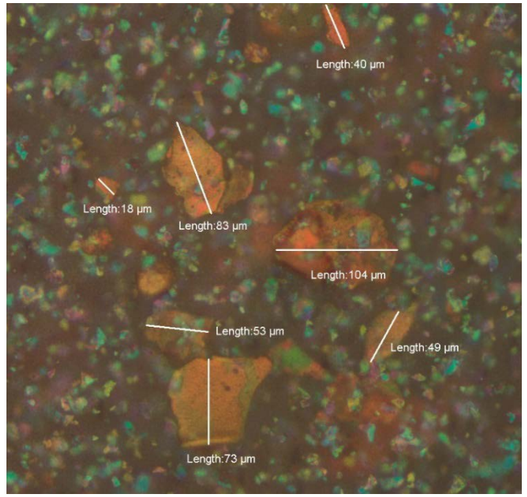


Figure 6**:** Microscopy of the reference sample under 20X magnification focused on the metallic copper component

The white interference effect could also be identified with the microscope at 40x magnification. The particle size distribution was measured to be from 8-19 µm. The closest commercially available product contained a particle size distribution of 5-25 µm. Figure 7 is also a good representation of the differences in appearances between the effect pigments. The white interference effect in both Figure 6 and 7 appear to have a multitude of colors. This is especially pronounced in Figure 7 where a single particle has several different colors. The reflection of all colors of light is what creates the white appearance of the effect. On the other hand the semi-transparent copper effect has a distinctive copper color to the particles. In addition, there is no indication that there is a green interference pigment present in the sample. These would be very distinctive from the copper effect in both color and size. The size would appear similar to the white interference but would take more of a green hue to the particles which is not present in these snap shots of the sample surface.

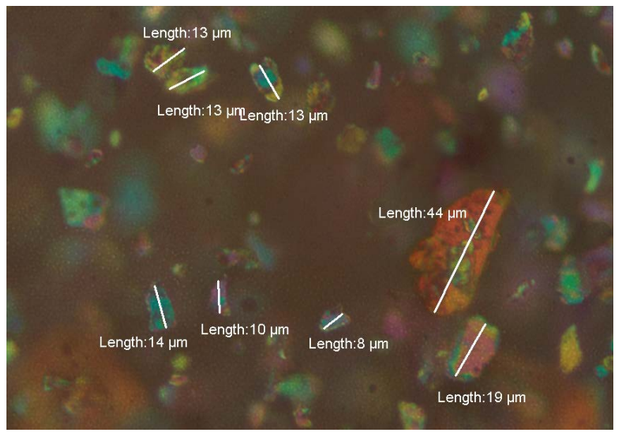


Figure 7: Microscopy of the reference sample under 40X magnification focused on the white pearl component

Adjustments can be made going forward by adjusting the L*, a* or b* values to minimize the ΔE further. The large shifts in CM# 2 in the a* value was eliminated by taking out the green effect pigment and the red shade PV 19 and replacing with a blue shade PV 19. The small shifts measured with CM# 3 in the a* and b* as the angle of observation is moved from -15° to 110° can be explained by the decreased concentration of the copper effect pigment where the aspecular angles -15° and 15° are shifted toward the green compared to the reference sample. An easier way to look at this is that the lower concentration of a copper will exhibit less red and by default more green. At aspecular angles 25°, 45° and 75° there is a shift blue because the influence of the white interference effect is predominate over the high sparkle of the copper effect particularly with CM# 3 where the white interference effect has twice the concentration of the copper interference effect.

Conclusion

The type and design of instrumentation used to perform a color match can dramatically change the quality of the match. In particular when color matching with effect pigments with multiple analytical tools (multi-angle spectrophotometer and microscope) ultimately lead to the best results. Results with the single angle spectrophotometer were by far the furthest from the reference sample with a ΔE of 27. The use of the multi-angle spectrophotometer resulted in a large decrease in the ΔE but, with a value of 5-16 depending upon the angle, it is still too large of a deviation from the reference. However, by taking this information from the multi-angle spectrophotometer and refining with information from the microscope, a clearly defined picture of the components can be extracted. This method resulted in a ΔE of 2 for most angles. By incorporation of more complete information from several analytical tools from the start can result in less time doing color matching by trial and error and also increases the likelihood of achieving a better match.

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