Winter 2018

# CAD NEWS

*A publication of the Color and Appearance Division of the Society of Plastics Engineers*

Greetings to you all.

Spring is just around the corner; The Cold and Gloomy winter season is coming to an end. It is the time of year when everything in nature is changing with new life. After the long cold, dark winter months, spring is a breath of fresh air. It will soon be time to step outside and view the display of flowers bursting into colorful life.

It's also the time of year where our division board of directors has elections to fill open seats. As this newsletter goes to press our members are voting for Board of Directors and SPE Councilor for the term of 2018 thru 2021. The Board of Directors is the governing body of the Color and Appearance (CAD) Division of SPE. The Division Board of Directors is composed of 27 elected Directors, the Council Representative (Councilor), and the 5 Division officers, for a total of 33 positions on the board. All are Volunteers, but are chosen by this election. Fourteen people are candidates, six incumbent members and eight new canidates. For Councilor, we have two candidates, both have many years of experience with SPE and CAD.

Today our current membership of CAD is 725 members, we have a large division with members covering 24 countries. Many who will soon be attending our first Conference of the year - ANTEC® is well known to be the largest plastics related technical conference where cutting edge academic and industry research is presented. The dates for ANTEC® 2018 will be May 7th thru 10th at the Orange County Convention Center in Orlando Florida Held in conjunction with NPE. Doreen Becker and Ann Smeltzer are putting together a great program. Check out the CAD sessions at ANTEC® on Monday afternoon, May 7th.

SPE COLOR & APPEARANCE

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It may be a little earlier to discuss RETEC® (Charleston SC. Sept 23-25) But, it is never too early to discuss the value and benefits of Sponsorship. Events such as ANTEC® and RETEC® attracts many attendees and can be a great opportunity to highlight your organization by being a sponsor. The are several sponsorship opportunities; however, due not delay as the slots have been known to fill quickly.

Sponsorships can connect a company to either potential clients or potential partners. Sponsors are also recognized in publications such as this newsletter. Acting as an event sponsor emphasizes the reach your name has in the industry, depicting your company as one that supports the education of plastics coloration. Our web page www.specad.org can be a great resource for information, or contact any SPE CAD Board member.

On behalf of the Color and Appearance Division, we look forward to seeing you in Orlando for ANTEC®/NPE in May! .

*Cheryl Treat*

Chairman

"Color is my day-long obsession, joy and torment." ~Claude Monet

## 2017 Fall Newsletter Editor's Note

Hello everyone and I hope everyone has had good start to 2018. As Winter hopefully releases its grip and relinquishes to Spring soon in your area there are several items to look forward to. 2018 will bring us ANTEC® / NPE Co-Conference in Orlando, Florida. This co-conference occurs once every three years so it is packed full of technical presentations and keynote speakers on the ANTEC® side and all aspects of plastics on the NPE side. If you have never experienced this event and are on the fence about attending, jump off and see for yourself what it is all about. It will not be disappointing. But hurry, Conference sponsored rooms are going fast and choices are becoming limited. There is the Munsell 2018 Conference, June 11-15, 2018 in Boston, Mass. Act quick as early registration ends March 1st, 2018.

2018 also brings RETEC® in Charleston, SC in September. This conference strength is by delivering a strong technical program every year and this year will be no different. Please help keep this the best technical conference by doing your part and present a paper on subject matter that is crucial to you and your business. Information can be found in this Newsletter on how to let us know you are interested.

As of this publishing, the deadline to vote for Board of Directors and Color and Appearance Councilor is a couple days away, March 2nd 2018. Please look at the candidates and vote. It does make a difference and is very important to the running of our Division so do the part and vote now.

In this issue, you will find the Councilor's report that will let you know what is happening within the SPE. You will find information about the Color and Appearance Division Scholarship program as well as where to find 2017 conference proceedings and Board of Directors meetings minutes. You can find out who is on the Board of Directors and their contact information on the last page of this Newsletter.

I hope you enjoy reading through the Winter Newsletter and as always, if there is something missing or you would like to see in the Newsletter, do not hesitate to let us know and we will see what we can do.

*Mark Tyler*

Color and Appearance Newsletter Editor
mark.tyler@xxxcelanese.com

## Society of Plastics Engineers
## Board of Directors / SPE Council Representative
## Elections for Color & Appearance Division

VOTING WILL BE CLOSING MARCH 2nd 2018

**SO VOTE NOW!**


**BOARD OF DIRECTORS**

The Color & Appearance Division of the SPE is conducting its annual Board of Directors elections for the term 2018 to 2021. The election is open to current SPE members with CAD as their primary division. 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.

**SPE COUNCIL REPRESENTATIVE (CAD)**

The Color & Appearance Division of the SPE is also electing a Council Representative for the 2018 to 2021 term. The CAD Councilor provides the CAD members a voice in the government of SPE by representing the SPE Color & Appearance Division at SPE Council meetings (3-4 meetings per year – 2 meetings at ANTEC®, 1 face-to-face meeting in the Fall and potentially one conference call).

**Visit the Color & Appearance Division Elections Portal to vote for your choices.**

VOTE BY MARCH 2, 2018

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# Call For Papers

Color and Appearance Division

## SPE CAD RETEC® 2018

**Embassy Suites**
**Charleston, South Carolina**

SPE® COLOR & APPEARANCE

**DEADLINE FOR ABSTRACTS:**
**MARCH 31, 2018**


## September 23–25, 2018

Events will be located both at the hotel and the convention center

**CHAIRPERSON:**
Brenda Mullins, BASF
Brenda.mullins@basf.com (313) 920-7113

**TECHNICAL PROGRAM:**
Jeff Drusda, Silberline
Drusdaj@silberline.com (507) 952-4629

Alex Prosapio, Sudarshan
Aprosapio@sudarshan.com (845) 641-0506

# ISCC/AIC BOSTON MUNSELL2018

## Bridging the Science, Art, and Industry of Color

## June 11-15, 2018

For more information go to Munsell2018.org

**The Year of Munsell**

This year marks the 100th anniversary of the incorporation of the Munsell Color Company as well as 100 years since the passing of Albert H. Munsell. It is also the 75th anniversary of the Munsell Renotations.

To commemorate these milestones, the Inter-Society Color Council (ISCC) and the International Color Association (AIC) are hosting a very special event in June of 2018 to honor the pioneering contributions of Munsell to the world of color

**Munsell Centennial Symposium** will take place from June 11th to the 15th at the Massachusetts College of Art and Design formerly known as the **Massachusetts Normal Art School** where Munsell taught for over thirty years.

The focus of the event is "*Bridging the Science, Art and Industry of Color*" with the theme of **Celebrating the Past | Envisioning the Future.**

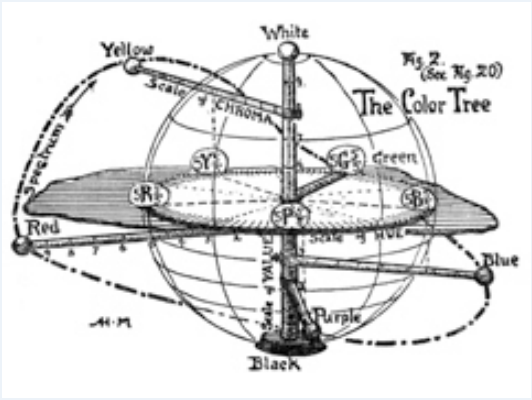
**Interdisciplinary Program**

The five-day interdisciplinary program features invited presenters from around the world who are experts in the fields of color science, art and design, and industrial color. Program Schedule

Breakout sessions on Tuesday and Friday include tutorials, hands-on workshops, field trips and AIC Study Group meetings.

**Opportunity to Make Connections**

The 2018 Munsell Centennial Color Symposium will bring together color professionals from all fields to network and make connections. It is a not-to-be-missed opportunity to meet fellow experts and enthusiasts from around the world who share your passion for color.




| Early Registration Prices | ISCC Member | Non-Member |
|---|---|---|
| All-Inclusive Package | $550 | $650 |
| General Sessions Only Package | $400 | $500 |
| Student | $200 | $200 |

| Treehouse Dorm (Price is for a 7 night stay.) | |
|---|---|
| Single Room | $360 private room |
| Shared Room | $300/person |
| Double Room | $520 |

Early registration is open until March 1st.
Registration Details.

*We invite you to help us publicize this special event by sharing the information from our website on social media and with your contacts. ISCC Organizing Committee-Munsell Centennial Symposium.*

Munsell2018.org iscc.org aic-color.org

# Councilor's Report– Summary of Fall Council Meeting
## August 25 – 26, 2017

**SPE Financial Update**

CEO Pat Farrey provided details on SPE's current financial position and offered his perspective from the world of association management. SPE members and leaders should not underappreciate our successes: Farrey pointed out that many associations would love to have our ANTEC® numbers of 1400 attendees and $200k in revenue.

SPE has a strong cash position, the strongest for many years. Operational expenses are tracking on-budget. Corporate sales and membership dues are down leading to revenues that will be below budget by $377k, excluding the 1-time payment from Wiley for the journal publishing contract. Expenses are greater than revenues by $123k. Investment income of $220k helps to offset revenue losses though it cannot be relied upon for guaranteed future income.

Preliminary results show that ANTEC® was profitable again in 2017. Costs were higher than budget and proportionally higher than historical numbers but in-line with expectations.

Membership dues have fallen to $70k/mo for the past two months, though overall membership totals are up, primarily driven by e-members. It will be difficult to achieve corporate sales goals in 2017. Corporate sales are up 30% over 2016.

**CEO Report**

CEO Farrey offered that his observations at 60 days revealed no major surprises. His single strategic objective is to improve profitability. Short term priorities include the following:

In-depth review of IT infrastructure and systems (ref. section 4.4 of 3YOP)

More staff support for membership / affiliate group services through the hire of a new Member Services Manager

Need to replace Business Development position. Need better focus on increasing non-dues revenue including advertising, corporate sponsorships and exhibit sales. (This position was filled as of September 2017).

Farrey also covered some additional topics:

Operational changes: re-integration of Managing Director role into CEO role

Expense control: CEO review of all items including travel and capex

Longer term priorities: NGAB, young professionals, marcomms, awards

**Recognition & Awards**

The structure of the Pinnacle Awards and related criteria have been reviewed by a sub-committee of the executive board. Vice-President of Education & Technology, Brian Landes, presented his group's findings to Council. Complete details of the changes are available for members to access via The Chain where all presentations are posted. After discussion, Council decided to postpone implementation of the changes until after ANTEC® 2018.

The Awards Committee called for reflection on nominees for the prestigious International Award. Other awards include the Research Award (contributions to polymer science), the Engineering Technology Award, the Business Award and the Education Award. All forms can be found online at www.4spe.org and the deadline is September 18.

President Al-Zubi recognized SPE Managing Director Russell Broome's service to SPE and presented him with a plaque (plastic, not metal). Broome thanked everyone and encourage all members to focus on the needs of industry for SPE to remain vibrant and relevant.

President-Elect Brian Grady announced a new opening on the Nominating Committee. Councilor Scott Steele encourage everyone to find new candidates in order to have competitive elections.

**ANTEC®**

The subject of commercial papers at ANTEC® has been discussed for several years. Changes will now allow for technical marketing presentations. Templates have been created by Mark Spalding of Dow Chemical. Guidelines have been published and are available to membership. The goal is to allow more commercial information. While no official paper is required, a PowerPoint presentation will be reviewed by the ANTEC Program Committee. The presentations will subsequently be published alongside papers in the proceedings. Company logos are permitted but cannot consume more than 5% of the space on a slide.

Assigning of copyright to SPE for ANTEC® papers will no longer be required. Instead the author will be required to grant SPE permission to publish, without surrendering copyright.

The ANTEC® Task Force continues its important work on what changes are required to keep our flagship conference relevant and dynamic. VP Jaime Gomez cautioned that councilors should not extrapolate too much from early findings. Another update will be provided by December 2017.

*Continued on page 9*

**Sections & Divisions News**
The VP of Divisions, Creig Bowland, resigned his position due to work and family commitments. Since then, Jason Lyons of Arkema, has been appointed.
The Sections Committee has recently published a letter outlining their strategic projects to improve communication and member benefits. Members are encouraged to use The Chain for the latest news and information about affiliate groups and general SPE business.

**NGAB & PlastiVan**
Eve Vitale, Director of SPE Foundation, presented an overview of both the Foundation Board and PlastiVan (PV) programs. Currently, there are 4 educators and a program coordinator who are part of the PV team. Vitale reviewed scholarship programs and encouraged everyone to consider more ways to support plastics education via the PV program. All councilors had the opportunity make slime as Vitale led a demonstration of actual PV classroom education.

The Next Generation Advisory Board continues to grow. The current NGAB membership stands at 67. VP Gomez pointed out that 89% of student members do not renew their membership when they graduate and NGAB can act as a bridge to transition members from student status to young professional status. The Executive Board continues to commit essential resources for NGAB success. Councilor Jon Ratzlaff challenged councilors to bring this NGAB news to their respective boards and encouraged them to engage NGAB.

*Bruce Mulholland*

Councilor, Color and Appearance Division
bruce.mulholland@xxxcelanese.com

## Connect With SPE CAD Via Social Media

Join SPECAD's Group On LinkedIn to network with industry peers, participate in group discussions of industry and technical topics, find job opportunities, and get the latest division and conference announcements.

Group Name: SPE Color & Appearance Division
Group ID 152108
www.linkedin.com/groups?gid=152108



SPE COLOR & APPEARANCE

## Invitation to Attend Our Board Meetings

The Color and Appearance Division regularly holds Board of Director (BOD) meetings at the ANTEC® and the CAD RETEC®. In addition, a Summer BOD meeting is typically held about 6 weeks prior to the next CAD RETEC® .

The Summer meeting is scheduled in various locations. A Winter BOD meeting is held in January. The Winter meeting is typically held at a site of a future CAD RETEC®.

Any SPE CAD members who wish to attend are welcome at these meetings. If interested in attending the next Board meeting, please contact the Division Chairperson for more information.

# Society of Plastics Engineers Endowment Scholarship Program
# For the 2018 – 2019 School Year

## Applications must be received by June 4th, 2018.

The Society of Plastics Engineers Color and Appearance Division have scholarships available for qualified individuals.

Each year, scholarships are awarded in honor of some of those who have influenced our industry through education of up to $4,000 each. Additional full or partial scholarships may be awarded based on available funding and on the number of qualified applicants.

| | |
|---|---|
| **Jack Graff Memorial Scholarship** | **up to $4000.00** |
| **Gary Beebe Memorial Scholarship** | **up to $4000.00** |
| **Bob Charvat Memorial Scholarship** | **up to $4000.00** |
| **Steve Goldstein Memorial Scholarship** | **up to $4000.00** |
| **George Rangos Memorial Scholarship** | **up to $4000.00** |

**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.
5. 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 available on our website and return it to the address specified on the application by June 4, 2018. All submitted applications 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.

Please feel free to contact Ann Smeltzer by email or by phone at 412-298-4373 with any questions.

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

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


### Abstract

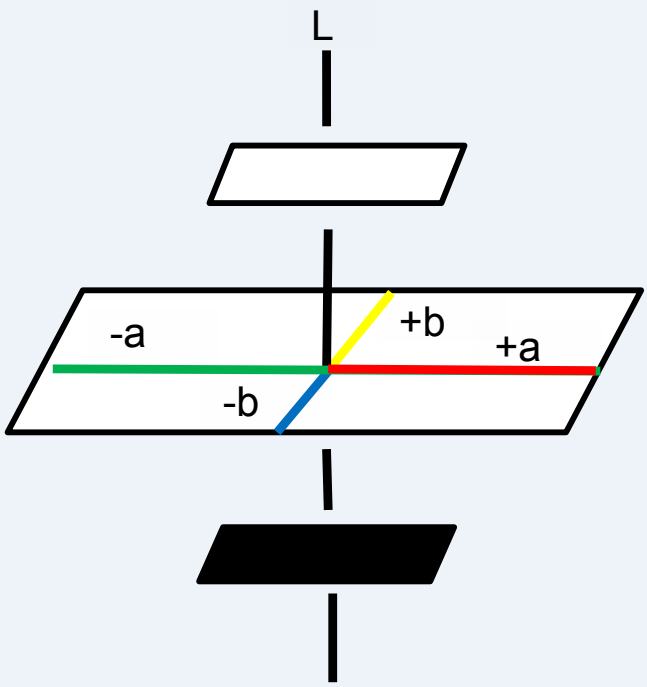
A red color can be described as cherry red but that description can mean many different things. How can a color be matched with a description like “cherry red”? A method to describe the correlation between the physical color and the perceived color is necessary. Several models are used today to define 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

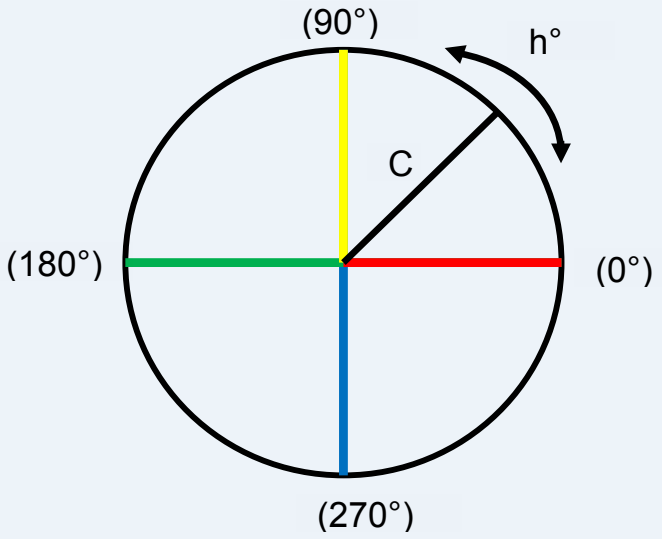
In 1976 the International Commission of Illumination (CIE) adopted two color models that were designed to represent the differences in color by mapping it over space. Color is represented with three different components: brightness, a green to red spectrum and a blue to yellow spectrum. The CIELAB model (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].

Figure 1: CIELAB color space model



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 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 $\Delta E_{ab}$. The $\Delta E_{ab}$ 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 $\Delta E_{ab}$.

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**:

$$\Delta Eab = \sqrt{(L_2^* - L_1^*)1/2 + (a_2^* - a_1^*)1/2 + (b_2^* - b_1^*)1/2}$$

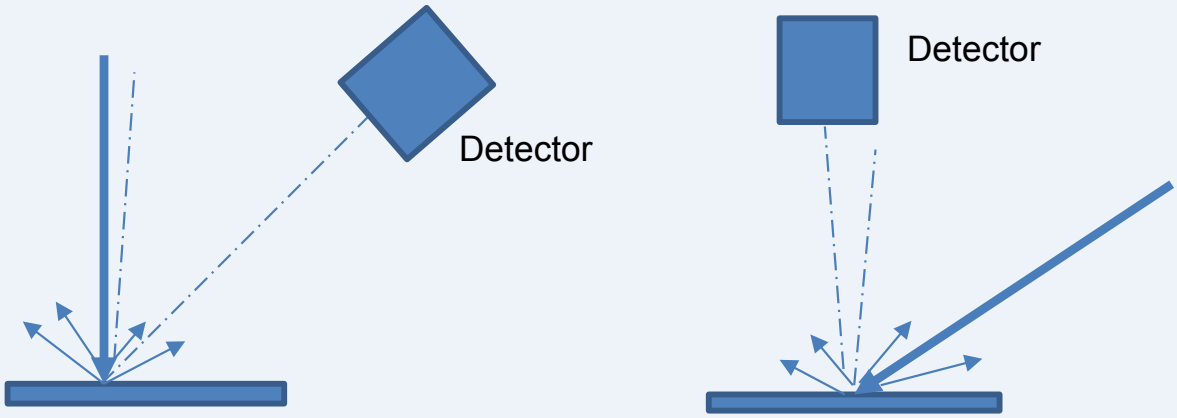
**Measuring Color**

**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.

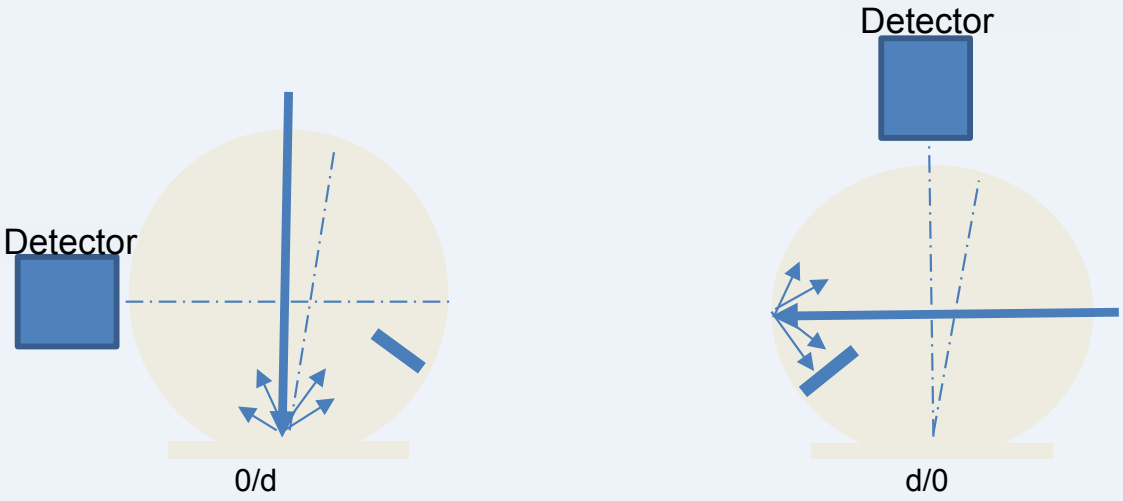
Figure 3: 0/45 and 45/0 single angle spectrophotometer setup




0/45 45/0

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



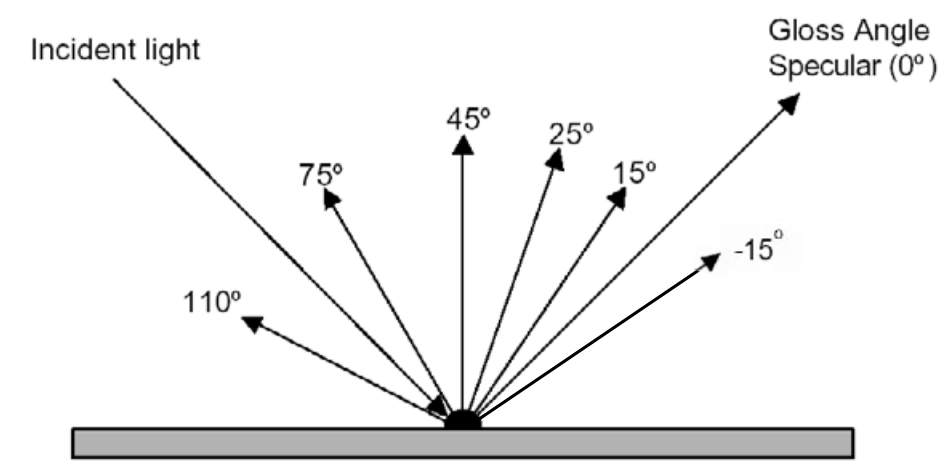

0/d d/0

**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.

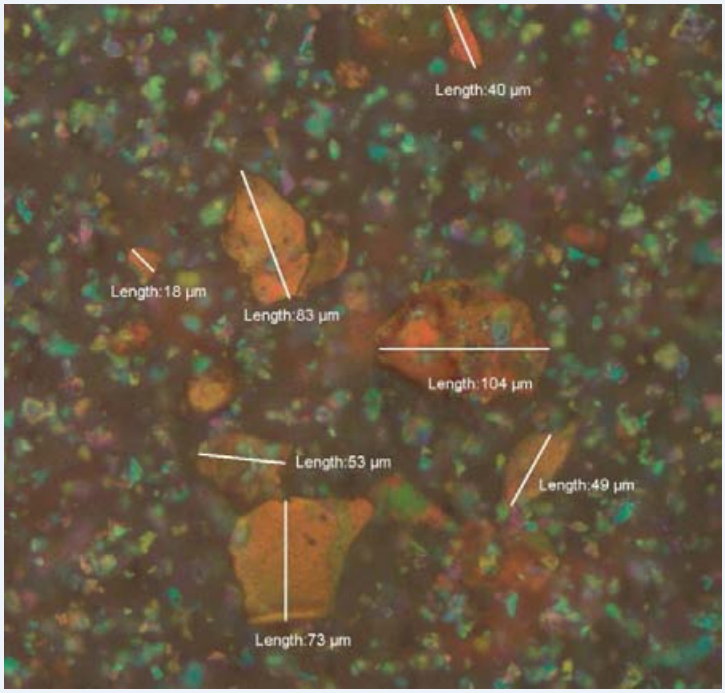



Figure 6**:** Microscopy of the reference sample under 20X magnification focused on the metallic copper component

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.

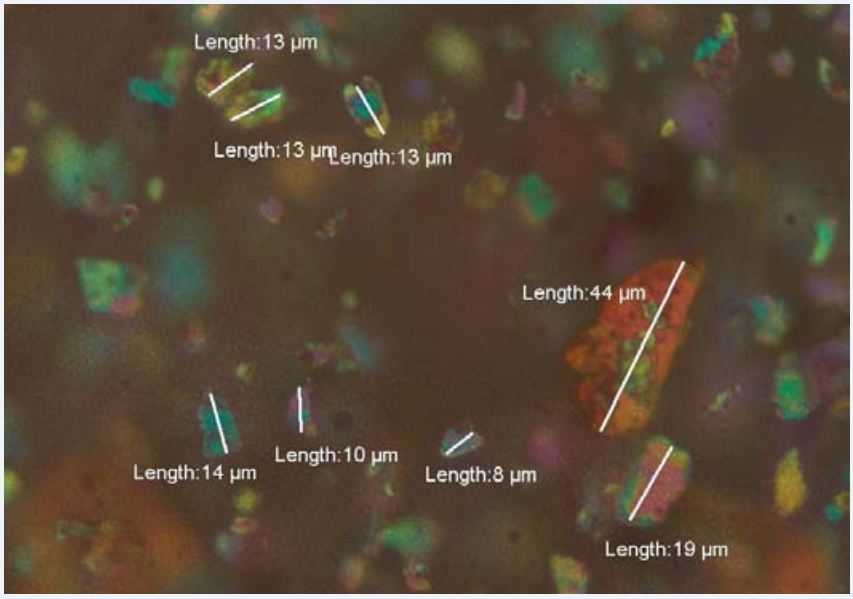



Figure 7: Microscopy of the reference sample under 40X magnification focused on the white pearl component

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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