COLORING THE WORLD OF PLASTICS

SPE®
COLOR & APPEARANCE

SPRING 2016

CAD NEWS®

Published by The Color and Appearance Division of the Society of Plastics Engineers

Chairman's Message

Welcome everyone, to the 2016 Spring edition of CADNEWS®. The winter months are behind us and many are looking forward to the warmer times and activities. We hope you are finding time to spend with family and friends at this time of year.

First, I want to take time to remember George Rangos, who passed away on April 20. George was a valued member of the Color and Appearance Division, having served on its board since 1992 after joining SPE in 1979. His many contributions to our group include Division Chair, Technical Program Committee Chair, Councilor, and Endowment Committee Chair. While we miss George's presence, input, and experience, his support and contributions will continue to benefit us.

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Our next division event will be 2016 SPE ANTEC® at the JW Marriott Indianapolis (IN), May 22-25. The Color and Appearance Division sessions will take place on Monday, May 23. Co-chaired by Tom Chirayil and Brian West, the CAD portion of the ANTEC® technical program will offer nine papers on a variety of topics regarding the coloring of plastics. Keynote topics will be presented by Doreen Becker, *"Color Trends for 2016"* and Diane Langer *"Innovations and Trends in Coloration"*. Without the research and innovation given by these presenters and companies, these shows would not have as much success.

Our Spring Color and Appearance Division meeting is scheduled for Tuesday, May 24, at 8:00AM. This meeting is open to all CAD members; please contact a board member in advance for details. Also, the CAD Annual Business Meeting will be held after the final CAD afternoon paper at 4:00PM (Monday, May 23) in the same session room. All SPE members are invited to attend.

CAD RETEC® will return September 11-13, 2016, at the Sawgrass Marriott Resort in Ponte Vedra Beach, FL. The 54th CAD RETEC®

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Color and Appearance Division

Chairman's Message (continued)

event promises an excellent venue for technical, marketing, and business papers, networking, exhibits, and the Coloring of Plastics tutorial. We are seeking technical papers for this show - contact Betty Puckerin or Michael Willis for details. For all other show inquiries concerning exhibits, attendances, or conference details, contact the event chair, Scott Aumann.

The BOD continues to change its shape and grow. We will welcome new BOD members following the elections for the 2016-2019 term. The Color and Appearance Division of SPE strives to educate, train, inform and to provide professional interaction opportunities to the global community involved in visual performance and aesthetics of plastics. Specifically, the BOD organizes the efforts, events, and activities to meet these goals. Anyone interested in joining should contact a BOD member for details.

We'd also like to thank outgoing directors Tracy Phillips and Tom Rachal. Tracy joined the board in 1999 and served on several committees, chaired the 2003 SPE CAD RETEC®, and as 2008-2009 CAD Chair. Tracy's efforts with orchestrating the website functions and social media are notable during her time as Communications Committee Chair. Tom joined the BOD in 2008, serving on several committees, Awards Committee Chair, and Chair of 2013 SPE CAD RETEC® in Baltimore.

As this will be my last newsletter as this Division Chair, I thank you for taking the time to read our updates. I also offer many thanks to the CAD BOD for their support during the past year. Their professionalism, creativity, and enthusiasm are very apparent during our meetings and events. I ask everyone to give their support to the incoming CAD Chair, Brenda Mullins.

On behalf of the Color and Appearance Division, we hope to see you through 2016!

2015-2016 SPE CAD Chair

In Memoriam

George Rangos involvement within the SPE and the plastics industry was a gift of personality, technical expertise, and friendship to all who met him. Georges' background in the pigments industry was extensive and broad and he shared that knowledge with anyone who needed his skills. His ability to build strong relationships was a reflection of his willingness to be open and generous with his time and talents to all who crossed his path. George was well liked and a respected professional by both colleagues and customers alike.

George enjoyed trying to mentor new members and get them involved in the industry via the SPE CAD and supported that thru his efforts on the scholarship committee. George will be missed greatly by all his Ferro Corp colleagues, customers, and industry associates who cherished his friendship, humor, feisty Greek spirit, and his wonderful attitude towards life. While George was a private person, his faith and love for his charming wife Beth was one thing that was evident and admired by all who know how great a guy he was.

Our thoughts and prayers go out to Georges family for their loss and hope they know how much of a gift we all got to share knowing and dealing with George in our professional lives. Thank you George.

SPE Color & Appearance Division Mission Statement

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

Editor's Note

Hello and welcome to the spring edition if the SPE Color and Appearance Division Newsletter. Hope everyone has survived the winter and are in full swing for spring and summer. ANTEC® is less than a week away and there is a well-structured and informative program put together by the Color and Appearance Division for the morning and afternoon of Monday the 23rd for attendees of the show so make sure if you are at ANTEC® that you show your CAD support and attend these presentations. Program schedule is included in this edition.

It is with a heavy heart to announce that the Color and Appearance Division has lost an outstanding person that brought so much to the Division and the entire coloring of plastics industry. George Rangos, whose tribute is included in this edition, passed away in his sleep on April 20th. He was a great asset to the Board of Directors of the Division and will be hugely missed by all he interacted with.

Our Divisions annual elections to the CAD Board or Directors were held through April this year and congratulations are in order to those who were elected to serve the 2016 to 2019 term. There were 7 incumbents re-elected and we welcome two newcomers on to the BOD. It should be noted that we are also saying so long to two long time BOD members who have decided to step down from the BOD to pursue other interests. Tracy Phillips and Tom Rachal have been tremendous assets in the functionality of the BOD and their presences on the Board will be dearly missed. Election results are included in this edition so if you happen to see one of these elected members and outgoing members say hello and thank them for their service.

Hope you enjoy this edition of the CAD Newsletter and look for more information coming this summer as we get closer to RETEC® 2016 in Ponte Vedra Beach Florida.

Mark Tyler

Election Results

Elected for 2016 to 2019 term
to the Color and Appearance Board of Directors
are the following persons.
Newly elected members to the BOD are indicated in Italics.

Ann Smeltzer	Brian West
Chuck DePew	Doreen Becker
Jim Figaniak	*Mark Ryan*
Nathan Karszes	Scott Aumann
Scott Heitzman	

COLOR & APPEARANCE SESSION I
ROOM 302/303

Moderator: Ann Smeltzer

8:00 am - 9:00 am	Keynote: Color Trends for 2016 *Doreen Becker, ASI*
9:00 am - 9:30 am	Fundamental Factors for Opacity and Tint Generated with Titanium Dioxide *Philipp Niedenzu, Chemours*
9:30 am - 10:00 am	Impact of Pigments on the Dimensional Stability of Plastics *James Rediske, BASF*
10:00 am - 10:30 am	Color Development for Non-Warping Thin Wall Injection Molding *Brian West, Techmer PM*
10:30 am - 11:00 am	Continued Studies of the Effects of Metallic Pigment Dispersions on the Physical Properties of Thermoplastics *Jeffrey Drusda, Silberline*

COLOR & APPEARANCE SESSION II
ROOM 302/303

Moderator: Mark Freshwater

1:30 pm - 2:30 pm	Keynote: Innovations and Trends in Coloration *Diane Langer, BASF*
2:30 pm - 3:00 pm	Accelerated Weathering Test Standards for Plastics: Why Don't They Work? *Sean Fowler, Q-Lab Corporation*
3:00 pm - 3:30 pm	High Gloss "Piano Black" Acetal Copolymer *Bruce Mulholland, Celanese*
3:00 pm - 4:30 pm	High Performance Inorganic Pigments *Mark Ryan, Shepherd Color*

September 11th – 13th

This year's CAD RETEC® will be held at Sawgrass Marriott Golf Resort and Spa located at 1000 PGA Tour Blvd , Ponte Vedra Beach, FL 32082.

Hotel Registration— Click here to reserve your room or call (800) 457-4653. Block deadline will expire August 12th.

For Exhibitor information, please contact:
Brian West or +1 865-457-6700

For new Sponsors or new Sponsorship opportunity information, please contact:
Cheryl Treat or +1 419-217-0862

For more information about the conference, please contact the Conference Co-Chairs:
Scott Aumann or +1 912.210.0175
Mark Tyler or +1 859.372.3221

SOCIETY OF PLASTICS ENGINEERS 2016 CAD RETEC® GOLF OUTING

SPE COLOR & APPEARANCE

Course Location:1 King and Bear Drive, Saint Augustine, FL 32092 (904) 940-6088

The King & Bear is the only golf course in the world that has been co-designed by Arnold Palmer and Jack Nicklaus. This course offers a mixture of two different design styles. The front nine is an open, links-style layout that gives a nod to the heritage of the historic city of St. Augustine, Florida. The back nine is more traditional Florida golf fringed with loblolly pines, 200-year-old oak trees, indigenous coquina rock, and numerous water features.

After golf we will have the pleasure of visiting the World Golf Hall of Fame and see the legends of the game all in one place. Both the Stadium and Valley course will closed during our visit to Sawgrass.

Price: $125.00 per golfer

Includes:
- Warm ups on the Range
- Green Fees
- Awards (hole prizes)
- Cart Fee
- Scramble format
- Admission to World Golf Hall of Fame after Golf.

Caddies and Forecaddies are available upon request
Callaway Rental clubs are available upon request

Schedule (EST)
Sunday, September 11th
Registration: 8:00am to 8:45
9:00 am Shotgun Start

Questions Contact: Mark Tyler (859) 372.3221 or Mark Freshwater (201) 665.0091

2016 CAD RETEC®

September 11 – September 13, 2016 Ponte Vedra Beach, FL
Sponsored by the Color & Appearance Division of SPE
MAIL-IN/FAX REGISTRATION FORM
Attn: Bruce Mulholland

CONFERENCE INFORMATION

Advanced registration deadline: August 12, 2016

(SELECT ONLY ONE TYPE OF REGISTRATION)

SPE Member

Advance (by 08/12/16)	$340
Late / Onsite	$440

SPE Non-Member:

Advance (includes SPE membership)	$490
Advance (decline SPE membership)	$550
Late/Onsite (includes SPE membership)	$590
Late/Onsite (decline SPE membership)	$650

OTHER REGISTRATION TYPES:

Speaker/Moderator	$170
Student (w/ Valid Student ID):	$ 50
Emeritus:	$100
Tabletop registration (by 8/12/16)	$950
Tabletop after 8/12/16	$1,175

Each registration includes one access pass to all papers per registrant. Tabletops include two full conference registrations.

EXTRA CONFERENCE LITERATURE:

Extra RETEC® 2015 $115 x ___ = $_____
Archive DVD (1961-2007) $175 x ___ = $_____
(available on site)

Membership Renewal
SPE membership dues renewal $109

OTHER EVENTS REGISTRATION/RSVP
(MARK RESPONSE/INDICATE QUANTITY)

Opening Reception (Sunday) RSVP: Yes No FREE
Awards Lunch (Tuesday) RSVP: Yes No FREE

Golf Outing (Sunday): $ 125 x _____ = $ _____
5K Fun Walk (Tuesday): $ 20 x _____ = $ _____
"Coloring of Plastics" Tutorial (Sunday): $490

Total due from all items checked above: $ _____

* Full refunds available thru April 12, 2016
* Refunds less a $30 fee April 13 to August 26, 2016
* No refunds after August 26, 2016
* SPE Memberships are processed after CAD RETEC®

Circle answers below:

Is this your first CAD RETEC®? Yes No

If no, have you attended a CAD RETEC® in the last five years? Yes No

REGISTRANT INFORMATION (Please Print):

SPE Membership #: _____

Name: _____

Title: _____

Company: _____
Address: _____
_____

Country of Citizenship: _____

Email:_____

Daytime Phone: _____

For checks, make in US dollars only payable to:"SPE CAD" and mail this form with check payable to the SPE CAD to:

Bruce Mulholland, Celanese
8040 Dixie Highway,
Florence, KY 41042

If paying by credit card, fax to: 859-372-6382, or
e-mail to: bruce.mulholland@celanese.com

For Credit Card Payments Only:

Circle One: AMEX VISA MasterCard

Card No: _____

Expiration Date: _____
Name on card (if different from above):

_____

Signature:_____

Date: _____

2016 CAD RETEC®

September 11 – September 13, 2016 Ponte Vedra Beach, FL
Sponsored by the Color & Appearance Division of SPE
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Advanced registration deadline: August 12, 2016

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__"Coloring of Plastics" Tutorial $ 490 x ____ = $ ____

Total due from all items checked above: $ _____

PAYMENT METHODS
For checks, make in US dollars only payable to:"SPE CAD" and mail this form with check payable to the SPE CAD to:

Bruce Mulholland, Celanese
8040 Dixie Highway,
Florence, KY 41042

Below is for Credit Card Payments only

If paying by credit card, fax to: 859-372-6382, or
e-mail to: bruce.mulholland@celanese.com

For Credit Card Payments Only:

Circle One: AMEX VISA MasterCard

Card No: _____

Expiration Date: _____
Name on card (if different from above):

_____

Signature:_____

Date: _____

1st REGISTRANT INFORMATION (Please Print):

SPE Membership #: _____

Name: _____

Title: _____

Company: _____
Address: _____

Citizenship: _____

Email: _____

Daytime Phone: _____

2nd REGISTRANT INFORMATION (Please Print):

SPE Membership #: _____

Name: _____

Title: _____

Company: _____
Address: _____

Citizenship: _____

Email: _____

_____

Circle answers below:

Is this your first CAD RETEC®? Yes No

If no, have you attended a CAD RETEC® in the last five years? Yes No

Society of Plastics Engineers
Endowment Scholarship Program
For the 2016 – 2017 School Year

The Endowment Scholarship Program offered by the Color & Appearance Division of the Society of Plastics Engineers awards 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 $4,000 annually. Scholarships are awarded for one year only, but applicants may re-apply 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.
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 at SPECAD.org/scholarship or direct through Ann Smeltzer and return it to the address specified on the application by June 3rd, 2016. 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 at 412-298-4373 with any questions.

Councilor's Report

The Winter Council Meeting was held via teleconference on February 5, 2016 with 64 Councilor's participating. This was an abbreviated Council meeting with four main topics: (1) financial update; (2) Governance Task Force update; (3) Bylaws and Policies review; and, (4) electronic election process review. Financial update included preliminary results for year-end 2015 of break-even performance even though SPE had losses in investments and $350K less income for ANTEC® due to it being an NPEF year with no income from exhibits. SPE appeared to do a good job of controlling expenses 2nd half 2015 to achieve this performance.

President-elect Scott Owens presented key aspects of the new governance model being worked on. The new structure will be similar to the existing Executive Committee structure with seven vice-president positions. The differences in the new model include: all seven VP positions will be elected and none appointed; VP positions are functional with specific job responsibilities; and, two of the VP positions will be elected by membership and not just by Council. VPs will be elected to two year terms, with a maximum lifetime of 8 years unless elected to the position of President-elect. The new governing body will be closely linked to Sections, Divisions and key standing committees. VP positions will either chair these committees, or at least serve as a committee member. More details will be presented at the ANTEC® Council meeting with a vote to accept this change at the Fall Council meeting scheduled for late August.

The Bylaws and Policies committee presented changes to Article 4.5.2 and Policies 011, 013 and 014. All were minor changes and approved. Policies 013 and 014 deal with Section and Division establishment and both had the requirement of the new entity establishing a bank account in the name of the new entity. As SPE becomes more global, it has been determined that there are some regions that prohibit this. We added language saying that the bank account shall be established unless restricted by federal, state or local laws.

CEO de Vos presented the schedule for the electronic elections of Society officers. This will be the first time an electronic process has been used. Monday, April 4, 2016 will begin the electronic process for President-elect, April 11th for Senior Vice President, and April 18th for Vice Presidents. Nominations "from the floor" are still possible and need to be submitted to the Nominating Committee prior to March 20, 2016.

During the meeting I stated some concern about delays in e-mail blasts being sent out. Russell Broome promised to address this.

The next Council meeting will be May 21 – 22, 2016 in Indianapolis, IN at ANTEC® 2016.

Respectfully submitted,
Bruce Muholland

Connect With SPE CAD Via Social Media

LinkedIn

Join SPECAD's Group On Linked In
www.linkedin.com/groups?gid=152108
Group Name: SPE Color & Appearance Division **Group ID** 152108

Board Minutes

Dear Members:

Just a reminder that you can view past and current BOARD MINUTES on the SPECAD website.

We do not typically publish the minutes in the electronic versions of our newsletter, but they are always available for our members to view from our website.

Also, our Treasurer's Report is listed in the minutes as an attachment. All available on the link below.

To access the link see below.
http://www.specad.org/index.php?navid=28

BEST PAPER – RETEC®2015

THE INFLUENCE OF ULTRAVIOLET LIGHT ABSORBERS ON THE COLOR OF PLASTICS

Tad Finnegan and Edward Malits
BASF Corporation, Tarrytown, NY

ABSTRACT

Plastics used outdoors are exposed to the damaging effects of UV-A (315 to 400 nm) and UV-B (280 to 315 nm) ultraviolet light, potentially limiting the lifespan of these materials. To mitigate this damage, UV absorbers are used to capture the ultraviolet light before it degrades the chemical bonds in the polymer. UV absorbers used commonly in plastics (*e.g.,* benzophenones, benzotriazoles, hydroxyphenyltriazines, and cyanoacrylates) absorb in both the UV-A and UV-B spectrums but with differing sensitivities. Strong absorption in the UV-A spectrum can impinge on the visible spectrum, absorbing blue light and introducing a yellow appearance to the plastic. The contribution of UV absorbers to the color of plastics and their role in color matching are investigated.

INTRODUCTION

Plastics that are used outdoors degrade due to the absorption of solar radiation through a variety of mechanisms [1]. The impact of this degradation is observed as a loss of mechanical properties and deterioration of the appearance of the material, ultimately limiting the performance of the plastic in its intended role. In particular, ultraviolet (UV) light is responsible for initiating the photochemistry that leads to the degradation of the plastic.

Ultraviolet light is part of the electromagnetic spectrum, spanning wavelengths from 100 nm to 400 nm. The UV spectrum can be divided into three spectral ranges: UV-A (315 to 400 nm), UV-B (280 to 315 nm) and UV-C (100 to 280 nm). Most short-wavelength UV light (100 nm to 290 nm) is blocked by atmospheric oxygen and ozone, so only the UV-A and a portion of the UV-B spectrum reach the surface of the Earth [2]. Of the UV radiation reaching the Earth's surface, approximately 95% is UV-A and 5% is UV-B.

To understand how UV light drives the degradation of plastic materials, consider the energy of UV light. The energy of a photon is inversely proportional to its wavelength; as wavelength decreases, energy increases. The energy of a photon is given by the equation

$$E = \frac{hc}{\lambda}$$

where

h is Planck's constant
c is the speed of light in a vacuum
λ is the wavelength of the photon

If we consider the UV-A and UV-B spectrum, we find the energy of these photons ranges from 300 kJ/mol to 425 kJ/mol. These energies are similar to the bond dissociation energies of the chemical bonds found in organic molecules. Thus, UV light is sufficiently energetic to break down organic molecules, including polymers. Table 1 provides the typical bond dissociation energy of chemical bonds frequently found in polymers [3].

Table 1. Bond dissociation energies of common organic bonds.

Bond	Energy, kJ/mol
C-H (methyl)	439
C-H (tertiary)	404
C-H (benzyl)	377

Bond	Energy, kJ/mol
C-C (alkane)	347-356
C-O	335
C-Cl	338

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One mechanism to prevent the photodegradation of polymers is to employ UV absorbers. These compounds absorb UV light and dissipate the absorbed energy without breaking down or initiating photodegradation. The mechanisms of absorption and energy dissipation for several classes of UV absorber have been studied extensively [4]. Several chemical families of absorbers offer efficient absorption of UV light, high light stability, high heat stability, and thermodynamic compatibility to make them practical for use in plastics.

The absorbance of light by UV absorbers is described by Beer-Lambert Law,

$$A = -log_{10}\left(\frac{I}{I_0}\right) = \varepsilon l c$$

where

A is the absorbance
I is the intensity of transmitted light
I_0 is the intensity of incident light
ε is the molar absorptivity (a measure of the attenuation of a particular wavelength of light)
l is the pathlength
c is the concentration

Absorbance is linearly proportional to both the concentration of absorber used and the pathlength the light traverses through the absorbing medium. For thin parts, this means a higher concentration of UV absorber will be required to stabilize the plastic. Additionally, at high pathlengths or high concentrations, it is expected that absorbance will be higher.

The molar absorptivity of a UV absorber can be shifted through the use of functional groups attached to the absorber's chromophore. For example, substituting a chlorine onto the benzotriazole group (2-hydroxyphenyl-5-chlorobenzotriazole) results in an absorption spectrum that is shifted to longer wavelengths. Figure 1 illustrates this shift.

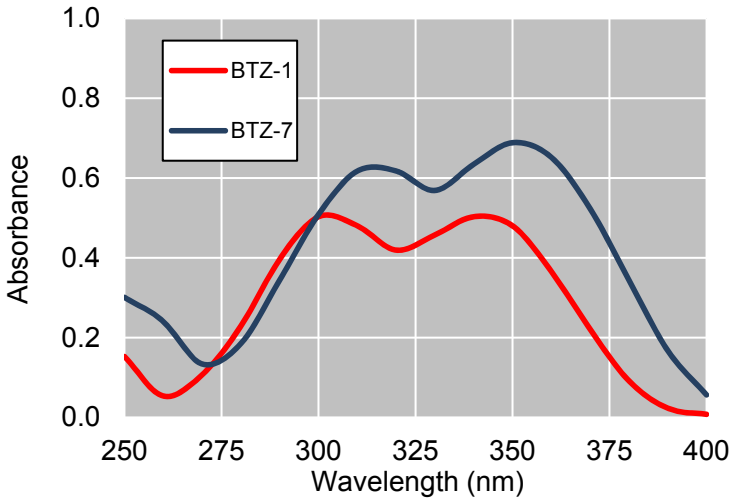

Figure 1. Wavelength shift between benzotriazole BTZ-1 and 5-chlorobenzotriazole BTZ-7 (at equal molar concentrations)

Shifting the absorption spectrum to longer wavelengths may provide benefits to a plastic's durability by blocking more of the UV-A spectrum, but it can also have unwanted effects in terms of appearance: the UV absorber begins to absorb short wavelength visible light (*i.e.,* blue light), which we perceive as yellow

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color. While the sensitivity of most people is low at these short wavelengths, the color matching functions used by software to measure and describe color can measure the impingement of UV absorption in the visible spectrum, particularly between 380 to 400 nm. Figure 2 shows the CIE 1964 10º Standard Observer color matching functions, and Figure 3 highlights the same functions between 380 and 420 nm.

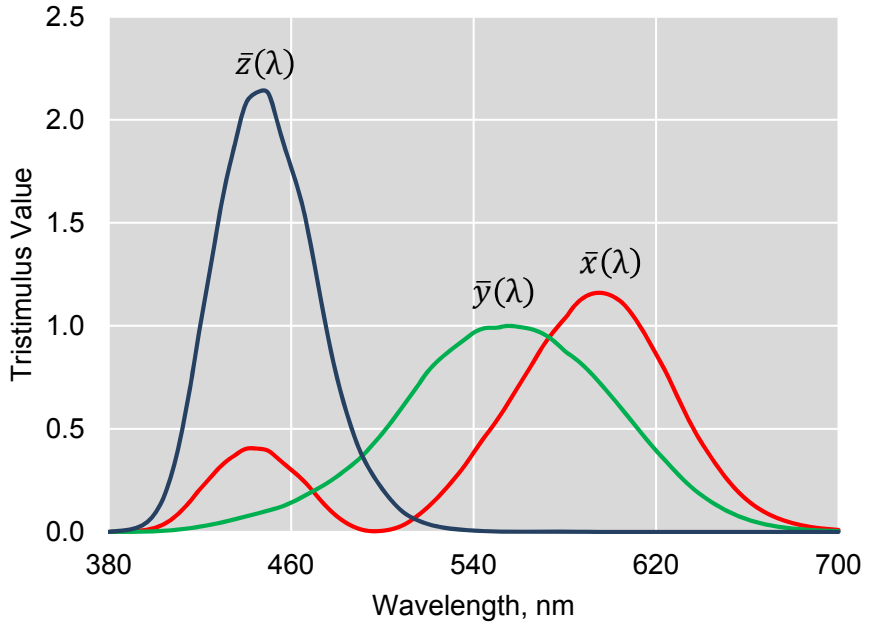

Figure 2. Color matching functions for CIE 1964 10º Standard Observer

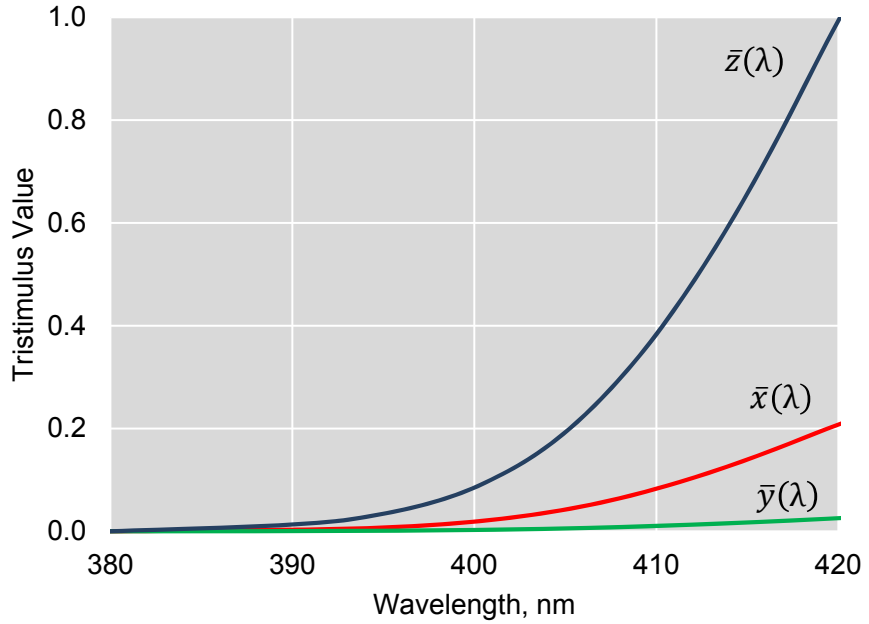

Figure 3. Color matching functions for CIE 1964 10º Standard Observer, (380 to 420 nm)

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The purpose of this paper is to investigate the influence of different UV absorbers on the color of polycarbonate and polypropylene. The focus of our investigation will be on the following four families of absorbers:

- 2-hydroxybenzophenones ("benzophenones," abbreviated BPO)
- 2-hydroxyphenylbenzotriazoles ("benzotriazoles," abbreviated BTZ)
- 2-(2'-hydroxyphenyl)-1,3,5-triazine ("hydroxyphenyltriazines," abbreviated HPT)
- cyanoacrylates (abbreviated CYA)

The molecular structures of the UV absorbers used in this study can be found in Appendix A.

EXPERIMENTAL

Injection-Molded Polycarbonate
Five UV absorbers (BTZ-5, BTZ-6, CYA-1, HPT-1 and HPT-2) and an antioxidant blend (0.3% Irganox® 1076 / 0.6% Irgafos® 168) were compounded into Lexan™ 141-111 (Sabic) using a Leistritz 27mm co-rotating twin screw extruder. Two concentrations of UV absorber were compounded for each sample, 1.0% and 3.0%. Prior to compounding, the polycarbonate was dried in a vacuum oven overnight at 100ºC. Samples were molded into 50mm long x 50mm wide x 3.2mm thick plaques using a Boy 50T injection molding machine.

Injection-Molded Polypropylene
For the unpigmented polypropylene experiments, five UV absorbers (BTZ-1, BTZ-2, BPO-1, HPT-1 and HPT-2) and an antioxidant blend (0.2% Irganox® B 215) were compounded into Profax™ PP 6301 polypropylene homopolymer (LyondellBasell) using a Leistritz 27mm co-rotating twin screw extruder. Two concentrations of UV absorber were compounded for each sample, 0.2% and 0.5%. Samples were molded into 50mm long x 25mm wide x 1mm thick plaques using a Boy 50T injection molding machine.

For the pigmented polypropylene experiments, 0.25% UV absorber (BTZ-1 or BTZ-2), 1.0% colorant masterbatch, and an antioxidant blend (0.2% Irganox® B 215) were compounded into Profax™ PP 6323 polypropylene homopolymer (LyondellBasell) using a Leistritz 27mm co-rotating twin screw extruder. The color masterbatch contained 10% pigment (Pigment Red 254 or Pigment Blue 15:1) in a polypropylene carrier. Samples were molded into 50mm long x 38mm wide x 1.5mm thick plaques using a Boy 50T injection molding machine.

Reflectance Measurements
Reflectance measurements were made on the polycarbonate samples using a Perkin-Elmer Lambda 800 UV-Vis Spectrophotometer with a 150mm integrating sphere. Samples were backed with a white reference standard and the specular component was included in the measurement.

Color Measurements
Color measurements were made using a benchtop Konica-Minolta CM 3600d integrating sphere spectrophotometer with the 10º standard observer, D65 illuminant and specular component included. Samples were measured over a white reference backing with either a large area view (polycarbonate samples) or medium area view (polypropylene samples). CIELAB color and ASTM E313-84 yellowness index were calculated using Colibri™ 3.4.8 color matching software.

DATA / RESULTS

Injection-Molded Polycarbonate
The reflectance curves from 380 to 420 nm for the polycarbonate samples containing BTZ-5, BTZ-6, and CYA-1 are shown in Figure 4. BTZ-5 shows the lowest absorption in the visible region, but at 400 nm, still shows only 26% reflection, compared to 70% reflection for the sample containing no UV absorber. BTZ-6 shows the highest absorption at 400 nm for all concentrations. For both BTZ-5 and BTZ-6, increasing the

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concentration from 1% to 3% shifted the reflectance curve to longer wavelengths, increasing the absorption in the visible spectrum significantly.

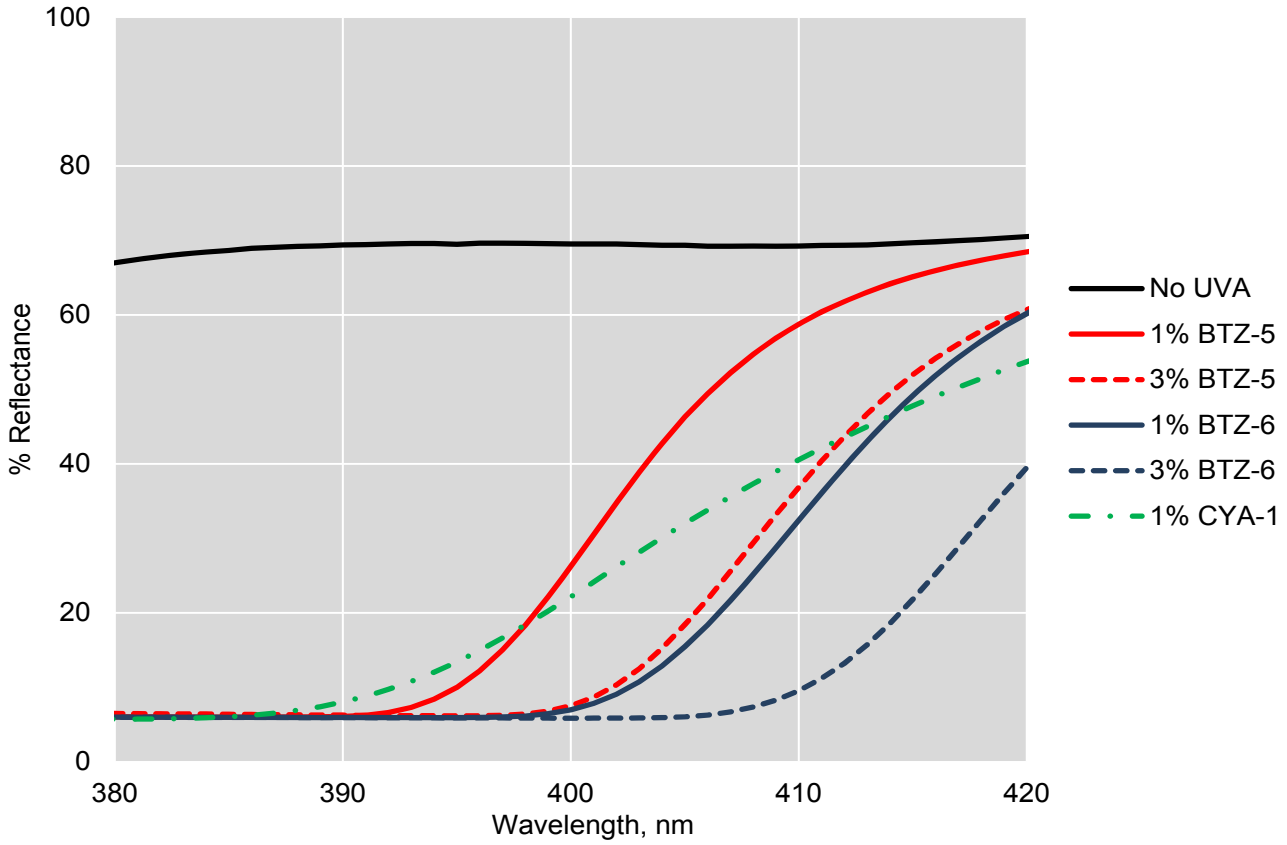

Figure 4. Reflectance curves for benzotriazoles and cyanoacrylates in polycarbonate

The reflectance curves for the polycarbonate samples containing HPT-1 and HPT-2 are show in Figure 5. Both HPT-1 and HPT-2 show lower reflectance and higher color than the benzotriazole UV absorbers as expected due to their higher molar absorptivity. HPT-1 showed higher reflectance and lower color than HPT-2. Increasing the concentration from 0.5% to 1.0% shifted the reflectance curve to longer wavelengths, increasing absorption in the visible spectrum significantly.

The yellowness index (YI) for samples containing BTZ-5 and BTZ-6 are shown in Figure 6. The YI value for polycarbonate without absorber was 3.4, and increased to 5.9 for BTZ-5 and 6.6 for BTZ-6 at concentrations of 1.0%. Increasing the concentration of the UV absorber to 3.0% increased the yellowness to 7.2 for BTZ-5, and 10.0 for BTZ-6.

The YI values for samples containing HPT-1 and HPT-2 are shown in Figure 7. At 0.5% concentration, the YI value increased from 3.4 to 10.3 for HPT-1, and to 12.9 for HPT-2. At 1.0% concentration, the YI value for the HPT-1 was 15.8, and for HPT-2 was 18.5. It is interesting to note that even at 1/6 the concentration of the benzotriazole, the hydroxyphenyltriazine introduces more color to the polycarbonate.

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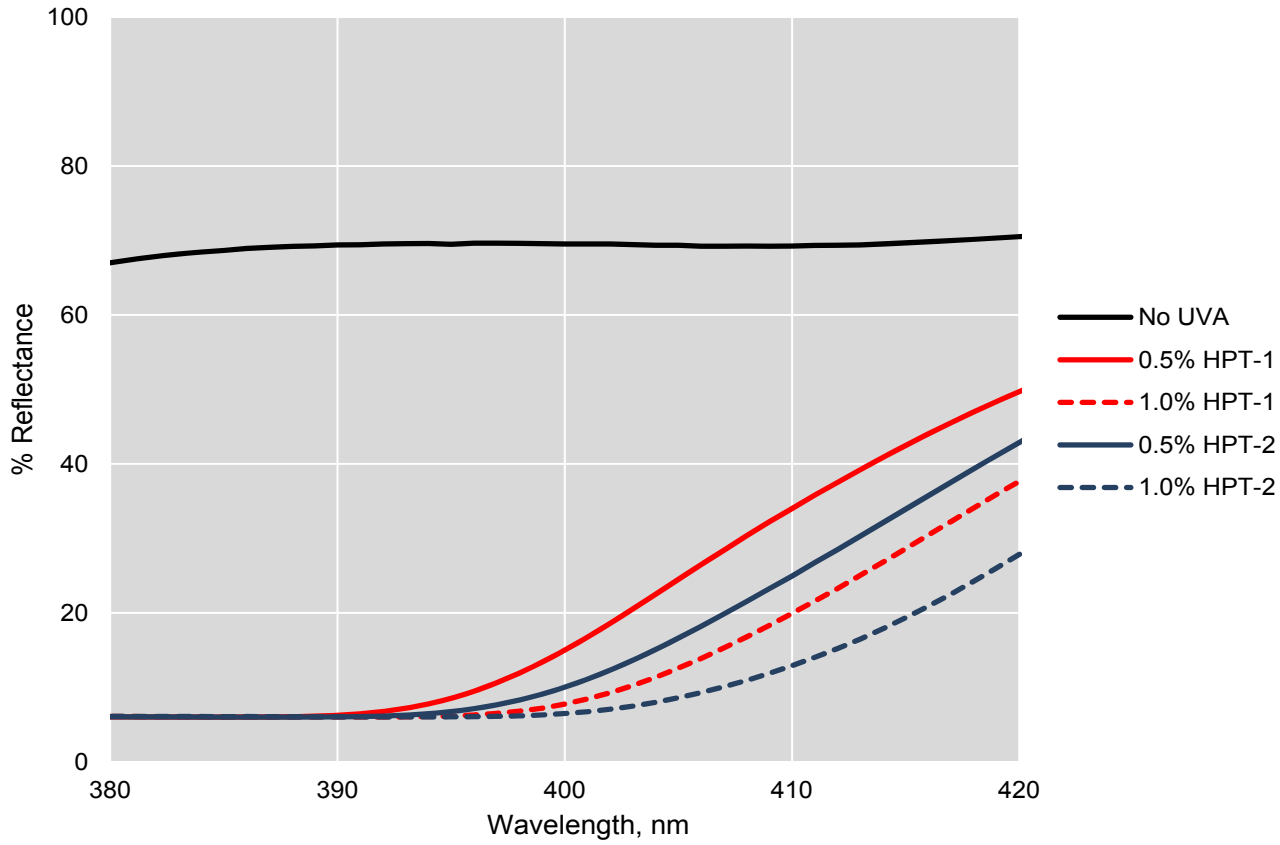

Figure 5. Reflectance curves for hydroxyphenyltriazines in polycarbonate

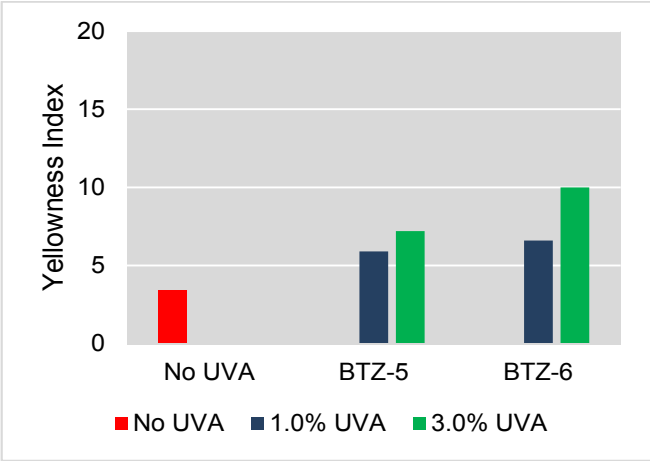

Figure 6. ASTM E313:84 Yellowness Index for Benzotriazoles

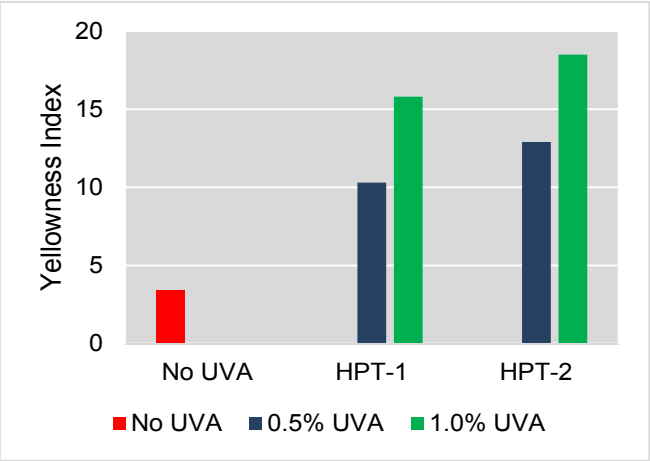

Figure 7. ASTM E313:84 Yellowness Index for Hydroxyphenyltriazines

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To visualize the change in color with increasing UV absorber concentration, the CIELAB a* and b* values were plotted for each sample, as shown in Figure 8. While there is some variation in the hue angle for each sample, the increase in chroma dominates the color development. At the maximum concentration for each sample, the lowest increase in chroma was for BTZ-5 (ΔC* = 3.0), and the highest increase was for HPT-2 (ΔC* = 11.5).

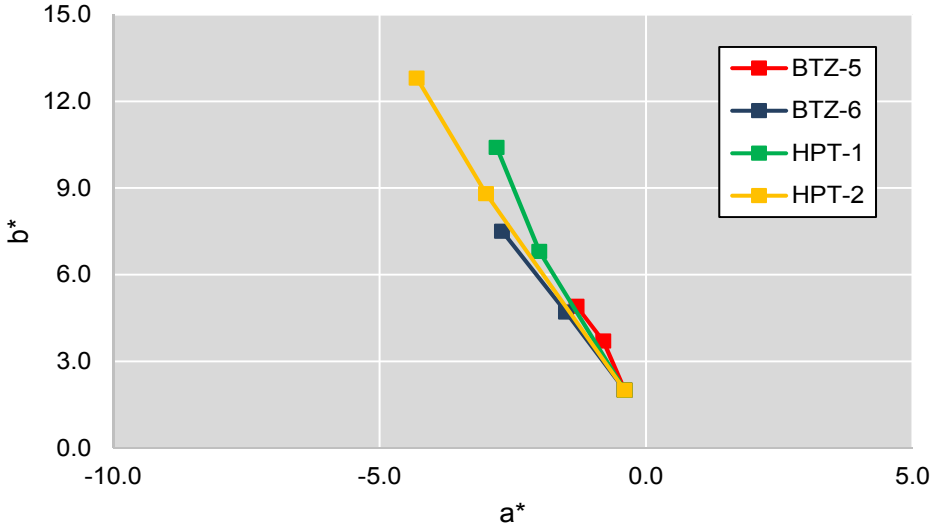

Figure 8. Color development in polycarbonate

Unpigmented, Injection-Molded Polypropylene

Table 2 shows the CIELAB color differences and yellowness index for unpigmented, injection-molded polypropylene with and without UV absorber. At low concentrations (0.2%), the ΔE* value is less than 1.0 for all UV absorbers. The change in YI values was less than 1.0 as well. As the UV absorber concentration increases, we see more color development and increases in both ΔE* and YI value as expected. BTZ-1 showed the lowest overall color development relative to the control, while HPT-2 shows the highest color development.

Table 2. Color differences and yellowness index for polycarbonate with various UV absorbers

Sample	Concentration, %	ΔL*	Δa*	Δb*	ΔC*	ΔH	ΔE*	YI Value
No UVA	---	---	---	---	---	---	---	6.0
BTZ-1	0.2	0.3	-0.3	0.3	0.3	0.3	0.5	6.0
BTZ-1	0.5	0.4	-0.3	0.3	0.3	0.3	0.6	6.1
BTZ-2	0.2	0.2	-0.5	0.7	0.8	0.4	0.9	6.5
BTZ-2	0.5	0.2	-1.1	1.6	1.7	0.9	1.9	7.3
BPO-1	0.5	0.3	-0.6	0.7	0.8	0.5	1.0	6.7
HPT-1	0.2	0.1	-0.3	0.5	0.5	0.3	0.6	6.5
HPT-1	0.5	0.1	-0.6	1.0	1.1	0.5	1.2	7.1
HPT-2	0.2	0.3	-0.4	0.7	0.7	0.4	0.8	6.7
HPT-2	0.5	0.3	-1.1	2.1	2.2	0.8	2.4	8.5

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Despite its high molar absorptivity, HPT-1 shows less color development than BTZ-2. This result runs counter to our observations in polycarbonate. Recalling Beer-Lambert Law, absorbance is linearly proportional to molar absorptivity, pathlength, and concentration

$$A = \varepsilon l c$$

In the polycarbonate, the high concentration of absorber (1% to 3%) and long pathlength (3.2 mm) provided us with extreme results. At these concentrations, nearly all of the UV light is extinguished within the first 0.05 to 0.10 mm. The remaining pathlength provided a higher probability for the UV absorber to extinguish visible light, introducing the strong color. In contrast, the polypropylene samples had both lower concentration (0.2% to 0.5%) and lower pathlength (1.0 mm). The UV light would not be extinguished until after 0.25 to 0.50mm, providing a lower probability for the absorber to extinguish visible wavelengths of light.

The CIELAB a* and b* values were plotted for each sample, as shown in Figure 9. As with the polycarbonate samples, there is some variation in the hue angle, but the increase in chroma dominates the color development.

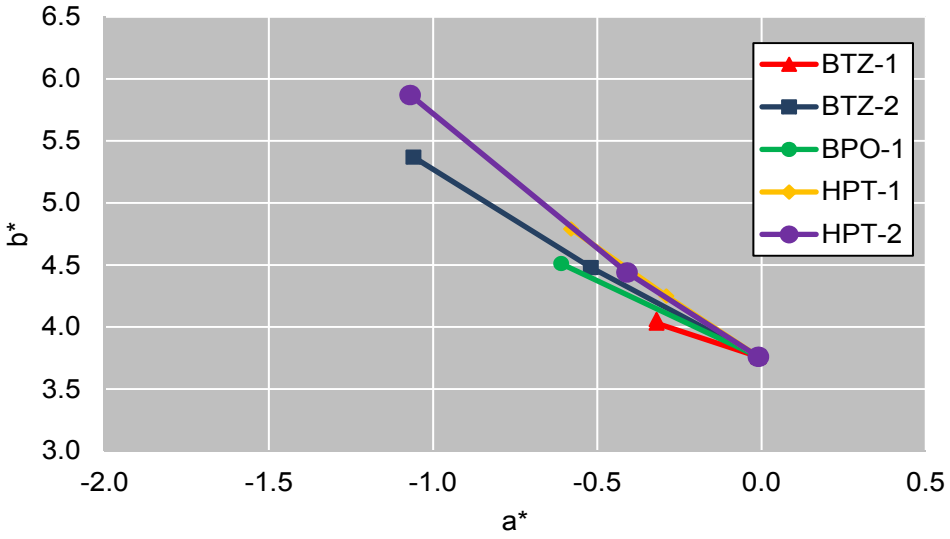

Figure 9. Color development in polypropylene

Pigmented, Injection-Molded Polypropylene
Table 3 shows the CIELAB color differences unpigmented and pigmented, injection-molded polypropylene with and without UV absorber. In all three cases, the addition of a UV absorber changes the color of the sample, with ΔE* ≥ 1.0 in all cases.

For the unpigmented and red samples, we see the same trend as before: BTZ-2 introduces more color to the sample than BTZ-1, and the increase in chroma governs the color change. Figure 9 shows the development of chroma with the addition of UV absorber to the unpigmented system, and Figure {X} shows the development of chroma for the red system.

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Table 3. Color differences for pigmented polypropylene with UV absorber

Sample		L* / ΔL*	a* / Δa*	b* / Δb*	C* / ΔC*	h / ΔH	ΔE*
Unpigmented	No UVA	86.8	-1.4	7.0	7.1	101.0	---
	0.25% BTZ-1	0.5	-0.7	1.6	1.7	0.3	1.8
	0.25% BTZ-2	-0.4	-0.7	2.4	2.5	0.2	2.6
Red Sample (0.1% PR 254)	No UVA	47.3	59.9	37.9	70.9	32.4	---
	0.25% BTZ-1	0.5	1.1	0.9	1.4	0.2	1.5
	0.25% BTZ-2	0.3	0.7	0.7	0.9	0.2	1.0
Blue Sample (0.1% PB 15:1)	No UVA	37.8	2.1	-44.9	45.0	272.6	---
	0.25% BTZ-1	-1.5	1.7	1.8	-1.7	1.8	2.9
	0.25% BTZ-2	0.6	-1.9	0.8	-0.8	-1.9	2.1

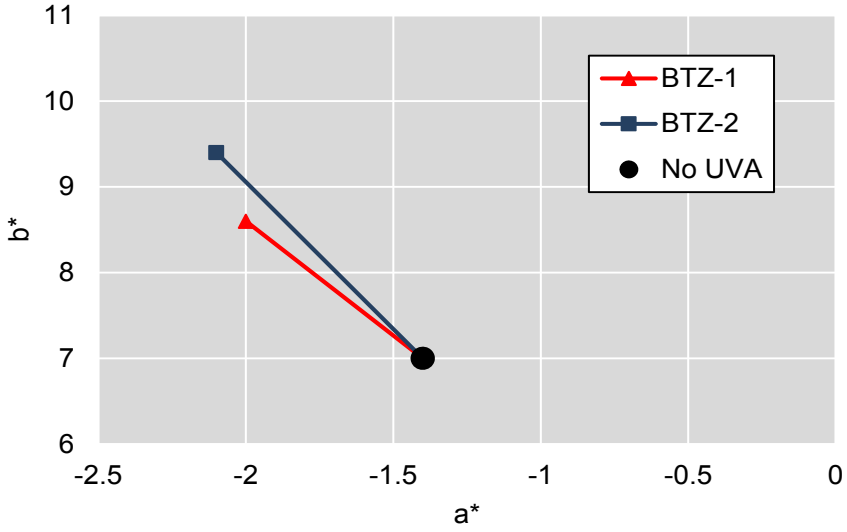

Figure 9. Color development in unpigmented polypropylene

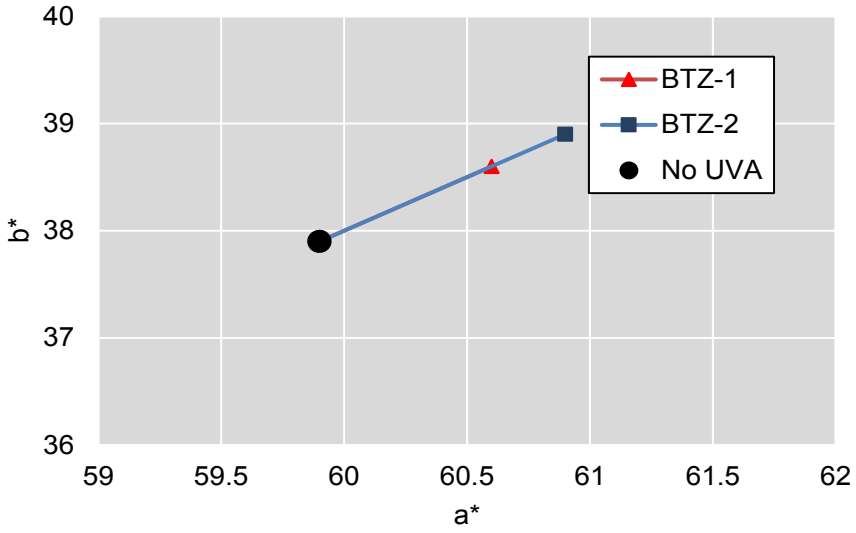

Figure 10. Color development in red polypropylene
0.1% Pigment Red 254

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For the blue pigmented samples, shown in Figure 11, we see for the first time that chroma development no longer dominates the color change. While chroma change in significant, the change in hue angle is equally important in its impact on ΔE*.

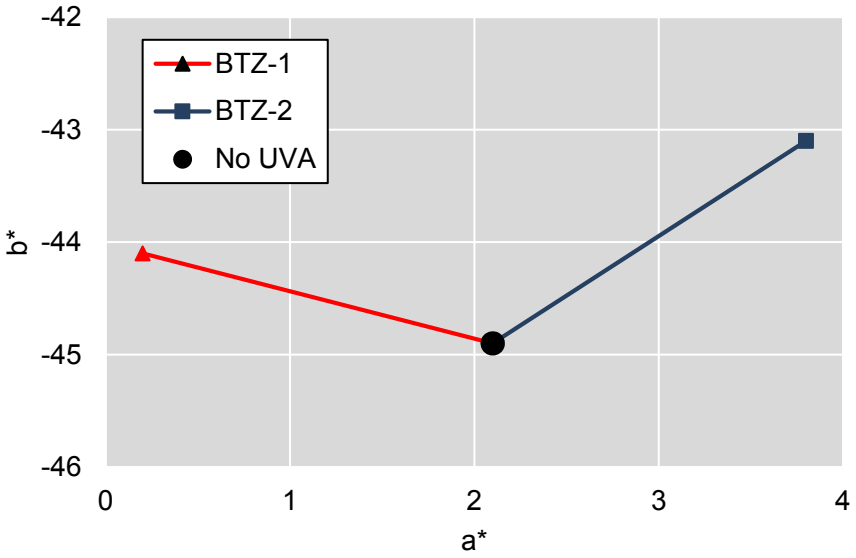

Figure 11. Color development in blue polypropylene
0.1% Pigment Blue 15:1

CONCLUSIONS

We observed that the combination of high molar absorptivity, long pathlength, and high concentration of absorber led to significant absorption in the visible spectrum at short wavelengths, as expected from Beer-Lambert Law. But it is also clear that at even modest concentrations, UV absorbers can have a significant impact on the measured color of both pigmented and unpigmented plastics. This poses a specific challenge to masterbatchers and compounders, who may develop a color solution without considering the potential impact of a UV absorber. To help mitigate potential problems, if an application requires UV absorber as part of the stabilization package, we recommend including the absorber in the color development cycle. It may even be useful to include the UV absorber as a "colorant" in color matching software, where it's concentration and presence can be fixed as part of the formula.

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4. Zweifel, Hans; Maier, Ralph; and Schiller, Michael. Plastics Additives Handbook, 6th Edition. Hanser. 2008

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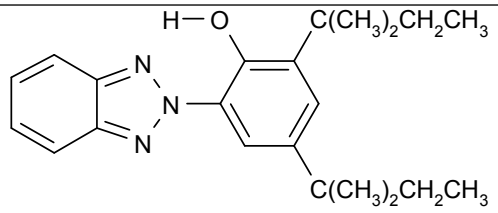
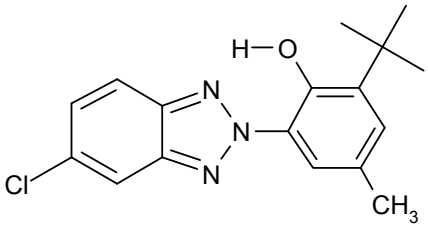
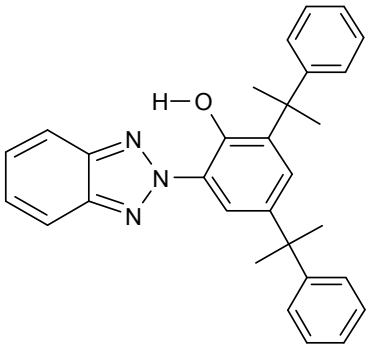
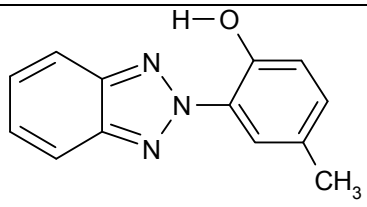
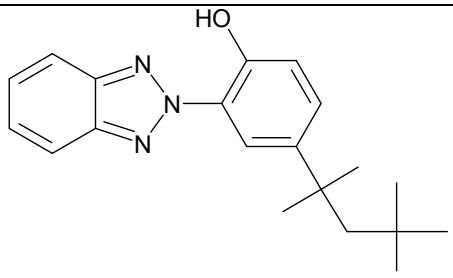
Indentity	Chemical Structure
BTZ-1	
BTZ-2	
BTZ-3	
BTZ-4	
BTZ-5	

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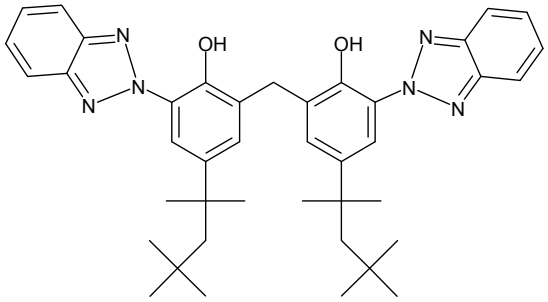
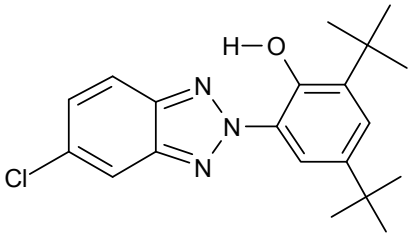
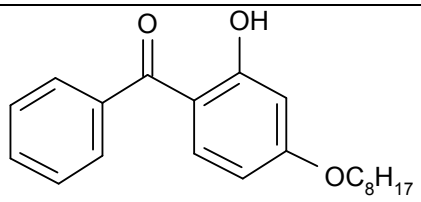
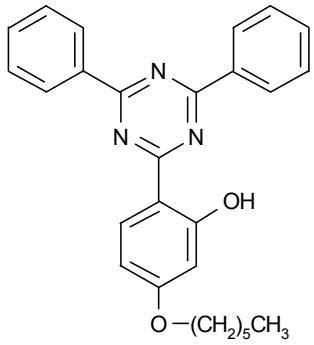
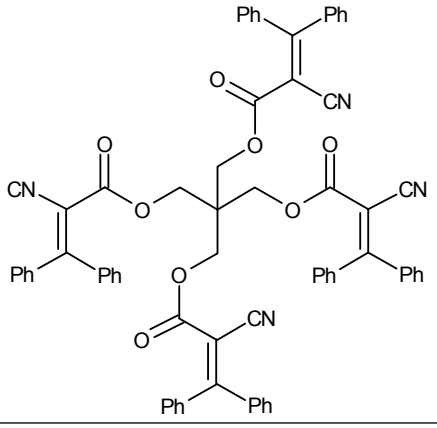
BTZ-6	
BTZ-7	
BPO-1	
HPT-1	
HPT-2	Proprietary
CYA-1	

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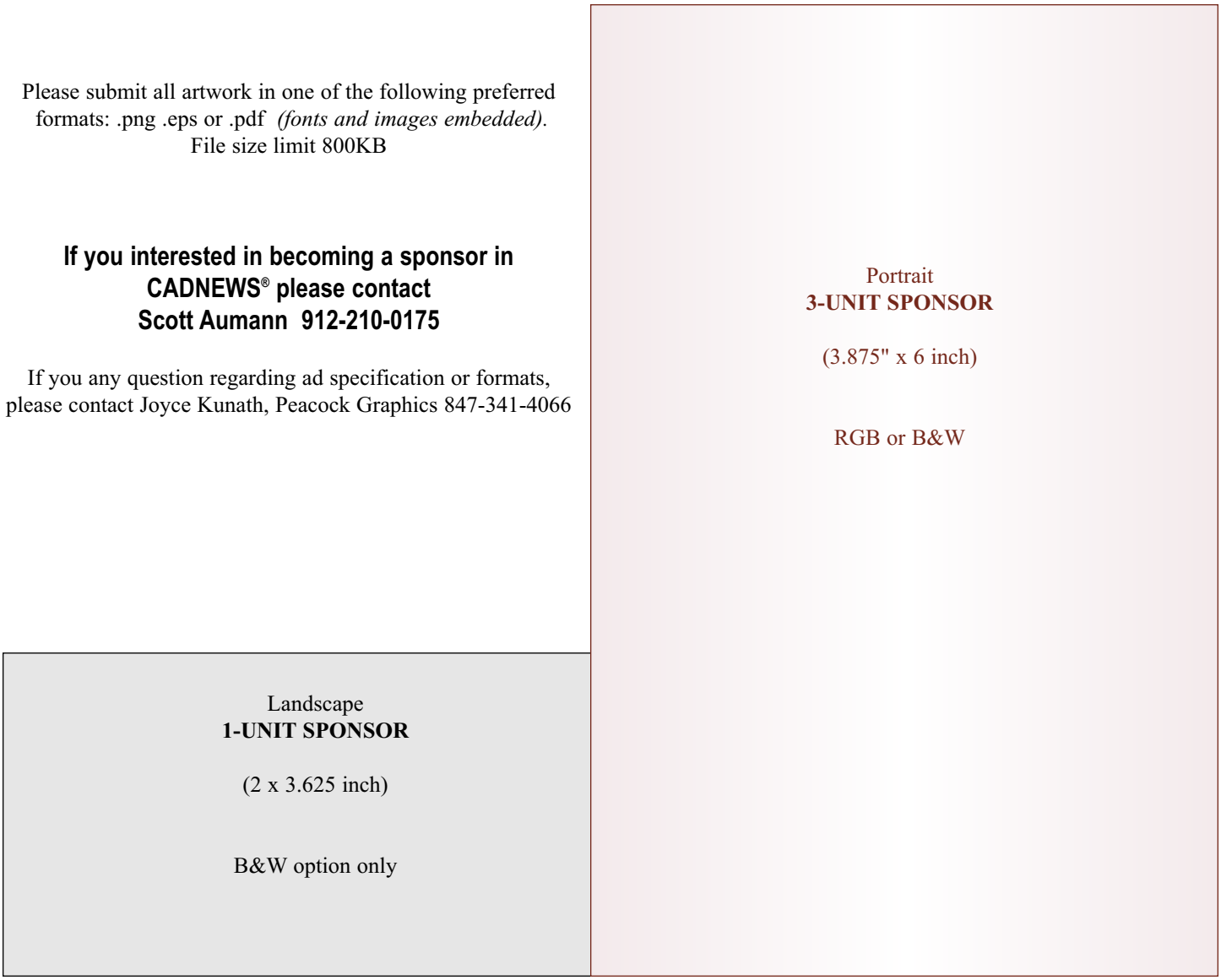

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