



COLOR &
APPEARANCE

CAD NEWS[®]
SUMMER 2024 NEWSLETTER

RETEC 2024
PRELIMINARY SCHEDULE

TECHNICAL ARTICLE

**RELATIONSHIP OF OPACITY WITH TITANIUM
DIOXIDE CONTENT & FILM THICKNESS**

JAMIE GINN, SCOTT GRANGER, P. M. NIEDENZU,
E. I. DU PONT DE NEMOURS & CO., WILMINGTON, DELAWARE, USA.

MEMBER SPOTLIGHT



SUMMER 2024 CHAIRMAN'S MESSAGE

Happy early Summer! Welcome to the 2024 Summer edition of CAD News! As we all look forward to the season's warm days, BBQs, and vacation time, our RETEC Committee is busy putting final touches on this year's event – Sailing Away with Color, located at the Tampa Marriott Water Street, September 23-25, in Tampa, FL. We are really excited about this year's location and all that Tampa has to offer. Our Technical Program Committee is putting together an excellent program with two full days of papers and a panel discussion focusing on FDA Regulations. I am the RETEC Chair for this event and I look forward to what is going to be a spectacular conference. Registration is open so please visit our website for more information and the registration process. There are still sponsorship opportunities as well as booth space available, so please reach out to any board member for details.

We are very pleased to announce that the 2024 elections for SPE CAD Board are complete. Re-elected directors: Bruce Mulholland, Earl Balthazar, Jack Ladson, Josh Jacobs, Cheryl Treat, Brian Coleman, and Mercedes Landazurri, and newly elected: Onur Ege Onar. I would also like to congratulate Doreen Becker as she has been elected as our new SPE CAD Councilor. The CAD Board also wants to thank Brian West who has stepped down as a director. Brian has served many years on the CAD Board, serving two terms as Chair, RETEC Exhibitor Chair, to name a few. His contributions to CAD over the years are innumerable, and he also holds a SPE Honored Service Award. This award recognizes special members for their contributions to the Society. Only 292 members have been elected to this prestigious status since it was established in 1992.

As my term as CAD Board Chair concludes, I would like to give special thanks to the entire Board of Directors team and their companies who sponsor them for their hard work and support this year. It was a rewarding experience and I wish George Ianuzzi a successful term as Chair for 2024-2025.

Please enjoy the newsletter and look forward to seeing you in Tampa!

ALEX PROSAPIO

Color and Appearance Division Chair
aprosapio@sudarshan.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 colorants 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

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Milliken



CAD RETEC®

Tampa, Florida • September 23-25, 2024
Presented by SPE Color and Appearance Division



Pre-registration online Go to [CAD RETEC 2024 Homepage](https://www.cadretect.com)

Onsite Registration Tampa Marriott Water Street

- Monday, September 18 1:00 PM – 7:00 PM
- Tuesday, September 19 7:30 AM – 5:00 PM
- Wednesday, September 20 7:30 AM – 3:00 PM



Preconference Tutorial [Coloring of Plastics](#)

Presented by Bruce Mulholland, SPE Fellow

Monday, September 23, 2024 8:00 AM – 4:30 PM

Fee: \$550 (Must Pre-register for event. Extra fee not included with CAD RETEC® 2024 registration)

CAD RETEC® 2024 Golf Outing



Monday September 23th, 2024
Innisbrook Resort Island Course
Registration and lunch 7:30am–9:00am

Split Tee Times starting at 8:21 to 9:03 on 1 and 10
Price: \$ 115.00 per golfer

Includes: the range, green fees, cart fee, lunch, Awards (hole prizes), scramble format
For more details, visit

Welcome Reception



Monday, September 23, 2024
8:00 pm – 11:00pm
Sponsored by Milliken

Breakfast



Tuesday, September 24, 2024
7:30 am – 9:00 am
Sponsored by The Shepherd Color Company

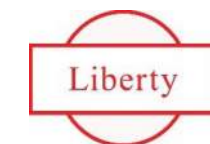
PLASTIVAN®

Changing The Perception Of Plastics One Classroom At A Time

Tuesday, September 24, 2024

For more information visit [SPE Plastivan](https://www.speplastivan.com)

Network Reception



Tuesday, September 24, 2024
5:45pm – 7:00pm
Sponsored by Liberty Specialty Chemicals

CAD RETEC® 2023 Fun Run/Walk



Wednesday, September 25, 2024
Sponsored by Chroma Specialty Chem
\$25 Registration fee
SPE CAD will match every \$25 donation

Awards Lunch

Wednesday, September 25, 2024
12:00pm – 1:30pm
Sponsor TBD



Preliminary Technical Program
Tuesday September 24th, 2024

Time	Category	Speaker/Company	Title/Sponsor
7:30-9:00 AM	Breakfast		Sponsored by The Shepherd Color Company
8:45 AM	Opening Remarks	Alex Prosapio- Sudarshan	Welcome to CAD RETEC® 2021 in Atlanta, GA
9:00 AM	Keynote	Scott Farmer- Techmer PM Board	<i>Keynote: Plastics Industry Overview</i>
9:30 AM	Keynote	Mike McHenry- Techmer PM CEO	<i>Keynote: Plastics Industry Overview</i>
10:00 AM	Break	Exhibits open Exhibit Area	Sponsored TBD
10:30 AM	Presentation	Dave Wawer	<i>Presentation: The Intersection of Customer Sustainability Pressures with Plastics Laws & Regulations: Educating Brand Owners About The Value of Color for Plastics and Packaging</i>
11:00 AM	Presentation	Mercedes Landazuri	<i>Color Trends</i>
11:30 AM	Presentation	Chris Ahmer	<i>Evaluation of a new white pigment in LDPE masterbatches and compounds</i>
12:00-1:30 PM	Lunch	On your Own	
1:30 PM		Breeze Briggs	<i>Improving Sustainability</i>
2:00 PM	Paper	Jack Ladson	<i>Enhancing Precision and Improving Colorimetric Representation in Reflectance Spectroscopy: A Comparative Analysis of Aperture Diameters Minimizing Variance on the Way to the Mean.</i>
2:30 AM	Paper	Arno Boehm	<i>Advances in Solar Energy & Heat Management for Automotive & Architectural'</i>
3:00 PM	Break	Exhibit Area	Sponsored by Trust Chem
3:30 PM	Paper	Arno Boehm	<i>High Speed Laser Marking for Cable & Wire</i>
4:00 PM	Paper	Tempo Chemical Solutions	TBD
4:45 PM	NTF	Moderator	New Technology Forum



Network Reception

Tuesday, September 24, 2024
Exhibitor Area, Regency Ballroom 5:45 pm – 7 pm
Sponsored by **Liberty Specialty Chemicals**



Preliminary Technical Program
Wednesday, September 25, 2024

Time	Category	Speaker/Company	Title/Sponsor
7:00 AM	Activity	Fun Run/Walk (Hotel lobby)	Sponsored by Chroma Specialty Chemicals
8:50 AM	Opening Remarks	Alex Prosapio- Sudarshan	Welcome Day 2
9:00 AM	Paper	Bonnie Piro	<i>Pigment Selection Process: Balancing the "MUSTs, WANTs and the NICE TO HAVEs"</i>
9:30 AM	Paper	Andy Francis	TBD
10:00 AM	Break	Exhibit Area	Sponsored by Vivify
10:30 AM	Paper	Doug Koener	TBD
11:00 AM	Paper	Salvatore Monte	<i>Nano-Organometallic Chemical Functionalization of the Carbon Interface</i>
11:30 AM	Presentation	FDA Speaker	TBD
12:00 PM – 1:30 PM	Luncheon	Awards Luncheon	Sponsored by TBD
1:30 PM	Presentation	Rachel Bond	<i>U.S. state laws and other emerging issues affecting food-contact materials</i>
2:00 PM	Presentation	Eric Andrews	<i>EU Regulations</i>
2:30 PM	Break	Exhibit Area	Sponsored by EMD Electronics
3:00 PM	Panel	Moderator: TBD	<i>Panel Discussion: Future of Regulations</i> Rachel Bond Eric Andrews FDA Speaker
4:00 PM	Closing Remarks	Alex Prosapio- Sudarshan	Closing Remarks & Raffle (must be present to win)
5:00 PM			Conference Ends

CAD RETEC® 2024
 09/23 - 09/25/24 | TAMPA
CONFERENCE
REGISTRATION

(SELECT ONLY ONE TYPE OF REGISTRATION)

SPE MEMBER 2024

Advance	\$480
Late / Onsite (After 8/16/24)	\$580

SPE NON-MEMBER:

Advance	\$740
Late/Onsite (After 8/16/24)	\$840

OTHER REGISTRATION TYPES:

RETEC Committee	\$225
CAD BOD member	\$335
Speakers/Moderator	\$225
Student (w/ Valid Student ID):	\$100
Emeritus:	\$200
Tabletop advanced registration	\$1,650
Tabletop late reg (After 8/16/24)	\$1,850

EXTRA CONFERENCE LITERATURE:

Extra RETEC 2024 papers	\$150 x _____ = \$ _____
Archive DVD (1961-2007) (available on site)	\$100 x _____ = \$ _____

EVENTS REGISTRATION / RSVP

Golf Outing (MONDAY)	\$115
5K Fun Walk (WEDNESDAY)	\$25
“Coloring of Plastics” Tutorial (MONDAY)	\$550

FULL REFUNDS AVAILABLE THRU AUGUST 23, 2024
 REFUNDS LESS A \$100 FEE AUGUST 24 TO SEPTEMBER 6, 2024
 NO REFUNDS AFTER SEPTEMBER 6, 2024



CAD RETEC®
 Tampa, Florida • September 23-25, 2024
 Presented by SPE Color and Appearance Division



SPE CAD RETEC® Coloring of Plastics Tutorial

The Color and Appearance Division of SPE has been presenting the “Coloring of Plastics” tutorial at the start of the CAD RETEC® conference for many years. Many SPE members and non-members have benefited from this program. The tutorial is a great starting point for those just beginning a career, or an excellent continuing improvement opportunity to those who wish to add to their base knowledge of coloring of plastics. The course is full of practical information which is embellished and enlightened by the active participation of all the attendees.

The tutorial runs a full day on Monday prior to CAD RETEC® and does require a separate registration and fee. The attendance is limited to 20 persons, so register soon. Attendees receive a full-color manual to use as a reference when they return home.

Who might benefit from attending the tutorial?

- Executives needing to better understand their company’s coloring issues
- Managers newly appointed and/or desiring to communicate more effectively with peers and subordinates
- Color formulators/matchers to better understand the theory behind their work
- Color specifiers/approvers to understand limitations in coloring of plastics
- Sales personnel hoping to gain more technical knowledge to better serve their customers
- Product designers wishing to better understand the technology behind the coloring of plastics, to make better and more informed decisions
- Color manufacturing personnel to understand the impact of compounding on color
- Color processors (injection molding, extrusion, etc) to better understand the technology ways they can impact the final color

Attendees will leave the course with a better understanding of color technology and should be more effective in their careers around color.

For more information about Color of Plastics Tutorial, please contact the Conference Chair and Tutorial Instructor Bruce Mulholland @ captcolour@aol.com or call 859-982-5256

To register for this opportunity please visit the [SPECAD Website](#)

**SOCIETY OF PLASTICS
ENGINEERS
2024 CAD RETEC®
GOLF
OUTING**

MONDAY 09.23.2024
INNISBROOK RESORT
ISLAND COURSE

COURSE LOCATION
1402 Innisbrook Dr,
Palm Harbor, FL 34683
PH: (740) 524-4653

SCHEDULE (EST)
Registration: 7:30am to 9:00
Split Tee Times starting at 8:21
to 9:03 on 1 and 10

PRICE
\$115.00 per golfer
Includes: Range, Green and Cart Fees

AWARDS (HOLE PRIZES)
Scramble Format – Teams will be drawn based on
handicaps again this year



Look forward to picturesque views and challenging play for golfers of all levels. Considered to be equally, if not more, demanding as Copperhead, the Island course features tight fairways, intimidating water hazards, abundant bunkers, and extraordinary elevation change rarely found in Florida. The finishing hole tests the greatest players and is one of the most photographed in Florida. The Island course has been ranked among the country's Top 50 Resort Courses by Golf Digest; and has hosted numerous U.S. Open Qualifiers, NCAA Championships, and the LPGA TOUR's Legends Championship.

WHEN REGISTERING, INPUT YOUR HANDICAP TYPICAL 18 HOLE SCORE.
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QUESTIONS CONTACT: MARK TYLER (570) 952.5255 OR ALEX PROSAPIO 845-641-0596

SUSTAINABILITY UPDATE

BY DOREEN BECKER

There has been a lot of activity in the sustainability world in the past few months since our last newsletter. Probably the biggest one is the United Nations' Intergovernmental Negotiating Committee (INC-4) Meeting for the Global Plastics Treaty.

For those of you who are unfamiliar with this initiative, the United Nations has taken on the task of developing an international legally binding instrument on plastic pollution, including in the marine environment. This is based on a comprehensive approach that addresses the full life cycle of plastic, including its production, design, and disposal. The INC began its work during the second half of 2022, with the ambition to complete the negotiations by the end of 2024. The first session of the INC (INC-1) took place in Punta del Este, Uruguay from 28 November to 2 December 2022, followed by a second session (INC-2) from 29 May to 2 June 2023 in Paris, France. The third session (INC-3) marked the process' midway point from 13 to 19 November 2023 in Nairobi, Kenya, followed by the fourth session (INC-4) from 23 to 29 April 2024 in Ottawa, Canada which was the one I attended. The fifth session (INC-5) is scheduled for 25 November to 1 December 2024 in Busan, Republic of Korea.

The tenor and cadence of these negotiations continues to evolve with each meeting. The zero draft policy that was issued prior to INC-1 included draconian language that specified banning certain types of "problematic" plastics and additives, reducing plastic production and large Extended Producer Responsibility fines and taxation for many of our companies. It was also planned to have this legally-binding instrument finalized by the end of 2024.

Much of this has changed since the onset. Inger Andersen, Under-Secretary-General of the United Nations and Executive Director of the United Nations Environment Programme (UNEP) presented a more moderate view in her opening statement, acknowledging that the instrument should be crafted with both upstream and downstream measures in mind. This is a departure from Andersen's initial position at the start of the INC process which seemed to favor upstream measures as the primary solution to dealing with the problem of plastic pollution.

One of the major changes that has occurred in INC-4 is that most countries have split into two major factions; the High Ambition Coalition (HAC) and the Like-minded Developing Countries (LDC). Members of the High Ambition Coalition emphasized the need for upstream measures in the treaty and called for a reduction in plastic production. They are focused on contentious topics like production and primary plastic polymers.

The HAC is now made up of more than 60 countries. Like-Minded Developing Countries Coalition emphasized that the treaty should acknowledge the "disparate capacities" of developing countries so that they were not "unduly burdened", and that plastic remained an "indispensable" material for society, the economy and trade. They are focused on areas of convergence such as capability building and waste management. Despite the High Ambition Coalition's constant and consistent efforts to include sustainable consumption and production to be a key tenet of the intersessional work ahead of INC-5, they were unsuccessful. Conversely, the Like Minded Coalition's work in establishing consensus seems to have paid off, with reusability and recyclability being included in the text outlining the work of the ad-hoc, open-ended intersessional expert group. This can be considered a significant win for the Like Minded Coalition. Since the Like Minded Group and the High Ambition Coalition are furiously pursuing their individual agendas, the successful establishment of a legally binding instrument within the originally stipulated timeline seems increasingly unlikely to unite 193 participating countries.

Inger Andersen acknowledged that there remained other provisions that lacked consensus among Member States, citing the differing positions on chemicals and polymers of concern as an example. Andersen urged Member States to also start thinking "beyond INC-5" and the completion of the negotiating process. She stressed that UNEP advocated for a "start and strengthen approach". This seemed to be a tacit acknowledgement from UNEP that while a fully-fleshed out treaty may not be ready by the end of the INC -5 process, a robust framework was a good enough starting point for the diplomatic conference, once it is convened.



An artistic interpretation of the plastic waste crisis; a water tap with cascading plastic bottles displayed near the Shaw Centre venue of the INC-4 negotiations for the first-ever global plastics treaty, in Ottawa, Ontario, Canada April 23, 2024.

MEMBER SPOTLIGHT

mercedes landazuri

WE WANT TO INTRODUCE OUR BOARD MEMBERS TO THE CAD MEMBERSHIP

tell us about yourself.

I'm from San Francisco originally, but lived in Oregon, New York, Austria, Germany and Russia before settling down in Chicago. I'm Market Insight Manager at Ampacet and work from home but get to travel quite a bit for work. I went to Sarah Lawrence College for undergrad and Voronezh State University for grad school. I have two kids, 15 and 13. One is much smarter than me and the other is much kinder than me, so I'm learning a lot from them!

when did you join the board?

I was elected to the CAD board in 2017 and had the pleasure of meeting and learning from many board members who have since retired. I'm finishing up my second term as Councilor for CAD this year.

how long have you been attending cad meetings / been a member?

I joined SPE after being in the plastics industry for a month, so I've been a member of CAD for eight years now. I came into this industry knowing nothing about color science or plastics engineering, and my colleagues recommend that I get involved with SPE and attend conferences for the wealth of technical information. I dove in and devoured all the information I could at these events and it's helped me tremendously in my career. I've attended CAD RETEC every year since 2016 and it's still my favorite event of the year.

any fun facts about you?

I have a lot of hobbies. I co-host PlastChicks, an SPE sponsored podcast. I play guitar, percussion and sing professionally. I love ballroom, Latin & swing dancing – I used to teach but rarely find the time these days. I like to paint still life from the manufacturing world – usually injection molders. I speak a lot of languages and particularly love reading and translating poetry. My current obsession is skateboarding – I'm working to put together a Chicago chapter of GrISwirl, using the skateboard as a tool for unification and transcending barriers.

what do you like about the cad group and our meetings?

I've been impressed with how efficiently the CAD board operates. Education & succession planning are a key aspect of this. We have a mentorship structure where newly-elected directors are paired with seasoned members who can show them the ropes. Event and committee chairs always partner with a newer member, so that the newer member can learn the processes. Our executive committee go through a progression of serving one year as each of the roles on the committee. There's always someone to learn from, and always someone who can advise or help out in a pinch.

One thing I learned from an SPE Honored Service Member was that serving on these boards was a great place to make (and learn from your) mistakes. In your regular work, you may not get an opportunity to tackle tasks outside of your job description, or too much may be on the line to step outside of your comfort zone. In volunteer work, you can really stretch your own capabilities and learn a lot in the process.





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SUDARSHAN



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.

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mholland.com/our-markets/color-compounding

CADNEWS® Technical Content – Scott Heitzman

The Technical Content portion of our Summer 2024 edition of CADNEWS® includes a paper presented a decade ago at ANTEC®. The paper is, Relationship of Opacity with Titanium Dioxide Content and Film Thickness written by the respected group; Jamie Ginn, Scott Granger, P. M. Niedenzu, from E. I. du Pont de Nemours & Co., Wilmington, Delaware. The focus is not just titanium dioxide. I viewed it more broadly considering the general relationship of opacity to concentration and film thickness. If you have questions after the read drop, it to Color Notes and we will get back to you with answers from the committee.

CADNEWS® Color Notes – Scott Heitzman

Welcome to CADNEWS® Color Notes. Do you have a question regarding color and effects? Don't miss your opportunity to anonymously ask our team of experts. We can help create discussion as well as provide answers. Color, appearance, color measurements, and colorants in general are all in our scope. Use the link below to submit your questions. Our SPECAD Color Notes committee will provide a response in the upcoming CADNEWS®.

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

Abstract

One of the most popular pigments used for plastic film applications is titanium dioxide, TiO₂. Titania-based pigments are popular because of several desirable properties. For example, TiO₂ is preferred in plastics applications because it is non-toxic and a relatively inert material. In addition, TiO₂ does not migrate in a polymer matrix and generally does not require large shear forces to disperse it into a polymer melt when properly treated. TiO₂ morphology can be adjusted so as to attenuate different wavelengths of light for plastic end uses. This attenuation is often referred to as “opacity” within the TiO₂ industry. This paper describes the relationship of opacity as a function of titanium dioxide concentration, the thickness of the plastic matrix and the opacity performance.

Introduction

The interaction of particles with light occurs via three different pathways. The first pathway is the reflectance of the light, wherein the light wave does not penetrate through a particle. The second pathway is the scattering of light as the light penetrates the particle and is diffracted in different directions. The third pathway is the absorption of light by the particle. The three pathways to describe light interaction with particles rarely occur in isolation. Light interacts with particles via all three pathways simultaneously; the degree of interaction by each pathway is determined by the particle chemical composition and morphology. This paper describes the relationship of the three pathways of light interaction with particles whose design in morphology and chemical composition demonstrates a higher degree of scattering than absorption. The description of the relationship between the particle morphology and scattering are presented based on the wavelength of visible light. The relationship of scattering of select wavelengths and path length are also highlighted to demonstrate the performance of plastic articles which contain particles that interact with visible light.

Experimental:

All blown film samples were made by using a let down of a 70% masterbatch containing commercial grades of titanium dioxide. All samples were analyzed with a Technidyne Brightimeter™ Micro S-5. TAPPI Opacity values are represented as the average of three readings from various locations on the film sample to monitor opacity variance in the film. Table 1 highlights the data which were collected

from various films. Three distinctly different types of titanium dioxide materials were chosen based on morphology. All pigments contained an organic treatment with no inorganic modifications.

Results and Discussion:

The principles established by the Beer-Lambert law^{1,2} are useful in describing the role of path length for light scattering. Typically, the Beer-Lambert law is applied for the absorption of light; but the law has parallels in scattering phenomena in plastics. The refractive index difference can represent the molar absorptivity. Path length is the plastic thickness and concentration represents the amount of pigment within the matrix. The law states that there is a logarithmic dependence between the transmission, *T*, of light through a substance and the product of the absorption coefficient of the substance, *α*, and the distance the light travels through the material (i.e. the path length), *ℓ*. As the light moves through the medium, the Beer-Lambert law describes an exponential decay of the light as it is absorbed.

In the plastic case, the exponential decay is also noted due to the fact the light is scattered rather than absorbed. The parallels of transmitted light and reflected light can be noted. In the films reviewed, the refractive index of the titanium dioxide is not altered. Refractive index could be the analogy of absorbance in the Beer-Lambert law. In this study, the refractive index of the titanium dioxide was not altered. Hence, the role of refractive index is not under consideration in this review.

The second factor, path length, can be noted in Figure 1. The path length for the plastic film samples is represented by the film thickness. Increasing the path length will permit more opportunities for scattering to occur; hence, the TAPPI opacity is highest when film thickness is greatest.

The third factor is the concentration of material within the film which interacts with the light. Again, Figure 1 highlights the phenomenon of increasing concentration. As the amount of titanium dioxide is increased within a given thickness, the opacity climbs rapidly with the initial addition. However, the rate of opacity increase with titanium dioxide concentration starts to decay as the system becomes less efficient at scattering light.

The role of pigment morphology can be slightly noted in the TAPPI opacity measurements (see Figures 2 and 3). Pigment A and C demonstrate the ability to achieve a slightly higher opacity than Pigment B. However, all three pigments demonstrate the behavior expected based on the BeerLambert law.

Summary and Conclusions:

All three titanium dioxide materials exhibited an opacity pattern that is fundamentally described by the Beer-Lambert law. The law describes the relationship of path length, absorptivity and concentration. For the examples presented, the refractive index of all titanium dioxides was similar to remove the influence of extinction coefficient. The only adjustments to control opacity were thickness of plastic article and the amount of titanium dioxide. The law describes the role of path length and concentration which was demonstrated for all three pigments. The law serves as a useful guideline to describe the expected opacity performance of plastics containing titanium dioxide.

Reference:

1. J.H. Lambert, [Photometria sive de mensura et gradibus luminis, colorum et umbrae](#) [Photometry, or, On the measure and gradations of light, colors, and shade] (Augsburg ("Augusta Vindelicorum"), Germany: Eberhardt Klett, (1760).

2. Beer : [Bestimmung der Absorption des rothen Lichts in farbigen Flüssigkeiten](#), *Annalen der Physik und Chemie*, vol. 86, pp. 78–88 (1852)

Table 1:

TiO ₂ type	wt. %TiO ₂ in film	avg. TAPPI opacity	microns
A	0.5	27.8	50
A	0.5	35.4	75
A	0.5	41.2	100
A	1	40.2	50
A	1	47.8	75
A	1	52.7	100
A	2	52.8	50
A	2	61.0	75
A	2	65.3	100
A	4	66.4	50
A	4	74.5	75
A	4	793.1	100
A	8	79.8	50
A	8	86.0	75
A	8	89.8	100
B	0.5	22.1	50
B	0.5	28.0	75
B	0.5	32.9	100
B	1	32.2	50
B	1	39.7	75
B	1	45.0	100
B	2	44.9	50
B	2	52.0	75
B	2	57.9	100
B	4	57.9	50
B	4	65.5	75
B	4	70.4	100
B	8	69.6	50
B	8	77.7	75
B	8	82.3	100
C	0.5	50	26.16
C	1	50	38.34
C	2	50	51.04
C	4	50	63.78
C	8	50	77.83
C	0.5	75	33.91
C	1	75	45.73
C	2	75	59.27
C	4	75	72.39
C	8	75	84.6

C	0.5	100	38.57
C	1	100	50.62
C	2	100	63.98
C	4	100	77.61
C	8	100	88.64

Figure 1:

TAPPI Opacity relationships for Pigment A

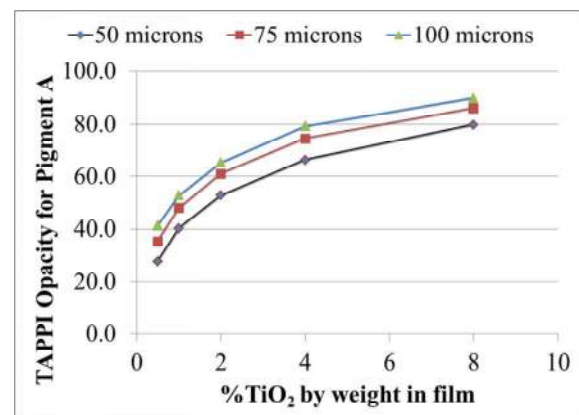
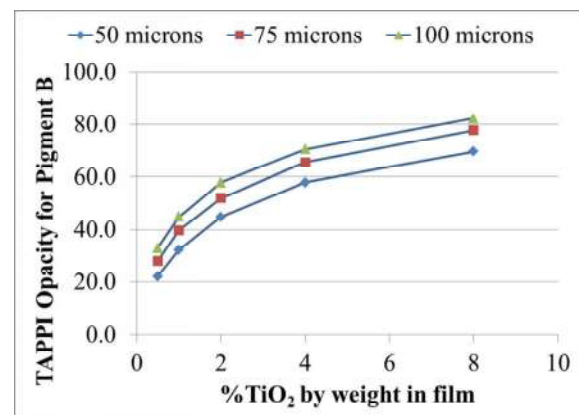


Figure 2:

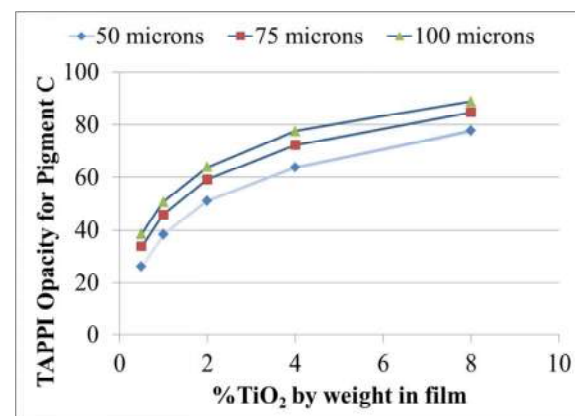
TAPPI Opacity relationships with Pigment B



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Figure 3:

TAPPI opacity relationships with Pigment C



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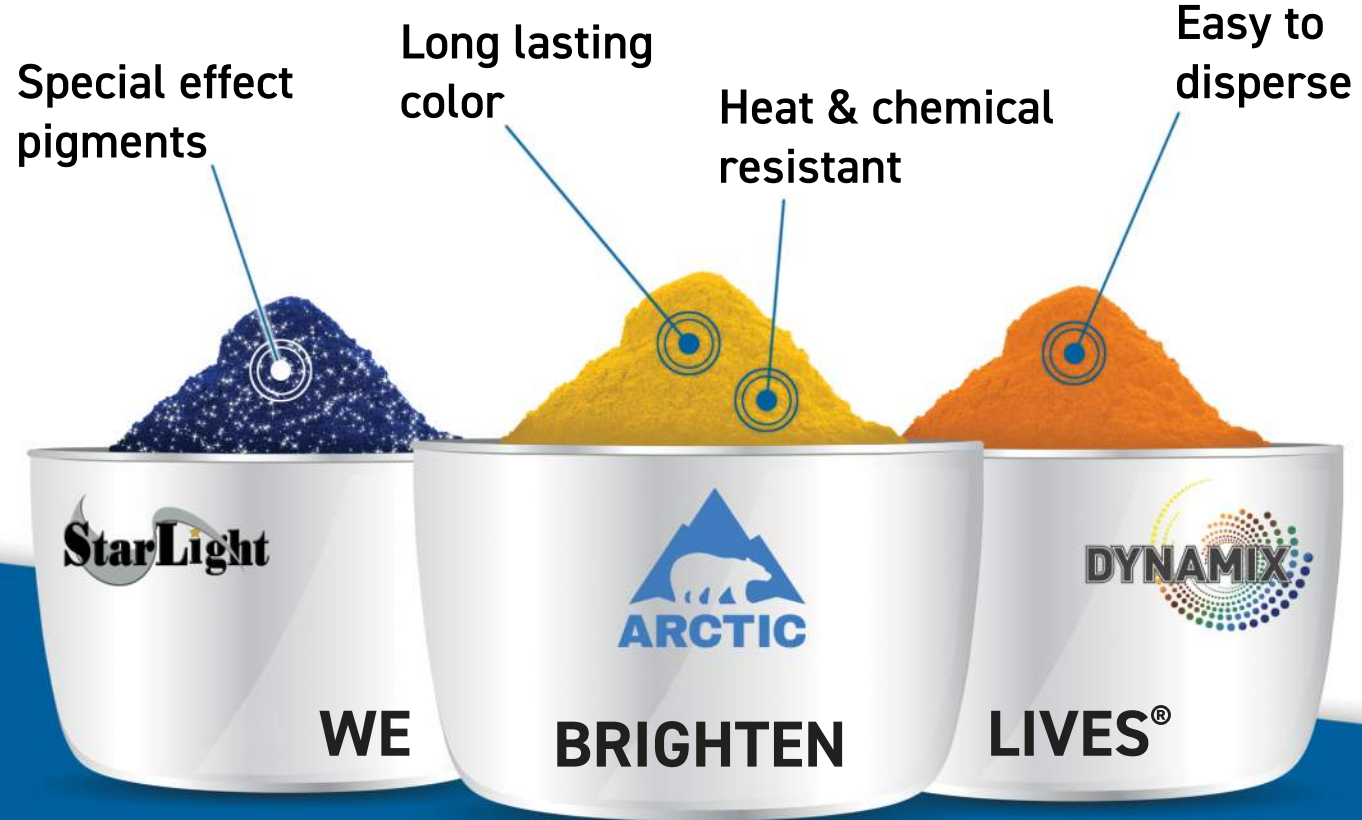
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