COLOR &
APPEARANCE

CADNEWS®

SPRING 2024 NEWSLETTER

RETEC 2024
CALL FOR PAPERS

TECHNICAL ARTICLE
ADDITIVES FOR DURABLE, FLEXIBLE, AND ACCURATE LASER MARKINGS IN PLASTICS

KEVIN LUCERO, ULRICH QUITTMANN | EMD ELECTRONICS

MEMBER SPOTLIGHT

SPRING 2024 CHAIRMAN'S MESSAGE

Spring is in the air, and welcome to the 2024 Spring edition of CAD News!

The gray winter is behind us, and I am sure that everyone is looking forward to the beautiful colors of Spring. Spring is also election time for our CAD Board of Directors. Please make sure you visit our website and select the Elections Portal tab for voting instructions and candidate biographies. This year we will also be voting on the Councilor position for CAD. The Councilor provides the Division members a voice in the governance of SPE. Mercedes Landazuri's term expires on June 30, and I would like to thank her for all her contributions, insights, and dedication as the CAD representative to SPE. On the note of board members, we have two long-time members who will leave the Board. Mark Freshwater of Paramount Colors and Mike Willis of Sun Chemical. Mark and Mike have been invaluable to CAD over the years, and both have chaired various committees, as well as serving as Division Chair. Their contributions are innumerable, and they both will be missed.

After skipping the 2021 event, the NPE Plastics Show returns to the Orange County Convention Center in Orlando, Florida, May 6 – 10. We will have our CAD Spring Board Meeting later that week. If you are interested in attending, please feel free to contact any Board member for details.

Planning is in full swing for the 2024 CAD RETEC "Sailing Away With Color" in Tampa, Florida on September 23 – 25. This will be our 62nd event, and the Tampa Marriott Water Street Hotel will sure to please!

If you have an interest in presenting a paper, please contact **TJ Stubbs** (tstubbs@teknorapex.com), **Karen Carlson** (karen.carlson@emdgroup.com), or **Brian Coleman** (brian.coleman@celanese.com). Sponsorship is now open and we have Silver, Gold, and Platinum opportunities, contact **Cheryl Treat** (cheryl.treat@sunchemical.com), **Scott Aumann** (saumann@chromacolors.com), or **Christine Gehres** (christine.gehres@specialchem.com). Check your inbox in the coming months for registration dates.

I hope you find the information in the newsletter interesting. Thank you everyone and enjoy the wonderful colors of Spring!

ALEX PROSAPIO
Color and Appearance Division Chair
aprosapio@sudarshan.com

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COUNCILOR'S REPORT

FEBRUARY 1, 2024

JULIANA MONTOYA

SPE has hired Juliana Montoya as Content Director for Plastics Engineering Magazine. Juliana has a masters in materials engineering, and is the former editor-in-chief of El Empaque + Conversion, a packaging and conversion periodical in Latin America.

GAIL BRISTOL

Gail Bristol passed away in December. Gail was part of the SPE staff team for more than thirty years, including serving as the Society's Managing Director. During her tenure, the SPE Foundation was established. She received the "President's Cup" Award in 2008, and was named a Distinguished Member of SPE in 2014 for her career of service. Gail has also been a member of the Plastics Pioneer Association since 2006, serving as PPA President from 2015 – 2017, Managing Director from 2021-2023, and most recently as a member of the Board of Governors and the By-Laws Committee Chairperson.

GIRL SCOUT PATCH PROGRAM

April 6th, PlastiVan will hold another full day session with the Girl Scouts in Lemont, IL. If you are interested in attending, please enquire with Eve Vitale.

ANTEC 2024

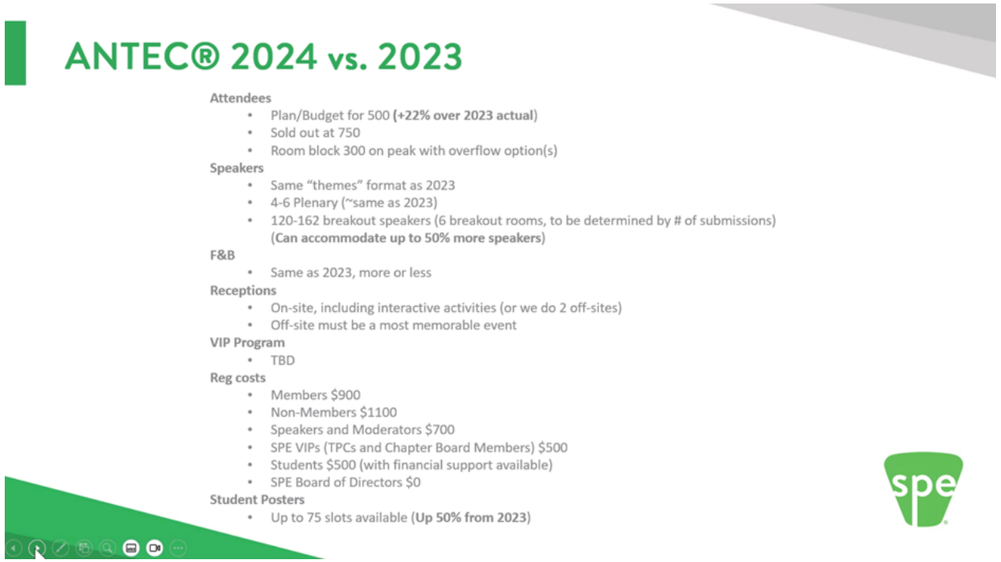
The next Chapter Leadership session will be held at ANTEC in St. Louis, March 4th, 10am-3pm

GLENN BEALL SYMPOSIUM AT ANTEC

On Wednesday, March 6th, the ANTEC® 2024 program will feature a Symposium Honoring the Career Achievements of Mr. Glenn Beall. Glenn's indelible legacy has significantly contributed to the growth of plastics and SPE. The symposium will feature Glenn giving a keynote presentation, and sessions will include speakers focusing on various areas of his expertise, such as rotational molding, injection molding, product design & development, additive manufacturing, thermoforming, and more. Some speakers will include John Bozzelli, Mike Sepe, Mark Wolverton, Al McGovern, Len Czuba, Eric Foltz, David Tucker, Mark MacLean-Blevins and Jon Ratzlaff.

COUNCILOR'S REPORT

FEBRUARY 1, 2024

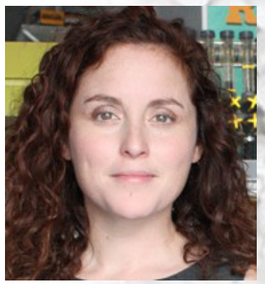


SPE MEMBERSHIP REPORT FROM PAT FARREY

For 2023, through the month ended 10/31/2023:

- 30 SPE Chapters have gained members
  - Average gain: +41 members
  - Average % gain: 20.7%
  - Top gainers by #:
    - Quebec Section + 181
    - Applied Rheology Division + 174
    - Ontario Section +161
    - Automotive Division +140
  - Top gainers by %:
    - East Africa Section +100% (new Chapter)
    - Quebec Section +71%
    - Ontario Section +56%
    - Lower Rio Grande Valley Chapter +33%
- 1 SPE Chapter remained even for the year-to-date
- 45 Chapters have lost members
  - Average loss: 13 members
  - Average % loss: 11%
- Total # of Chapter memberships are up 2.5% YTD
- Total student membership is down 1.23%
- Total SPE membership is up 2.9% YTD
- SPE has ~ 22,500 members. That number fluctuates monthly, but that's it on average.
- We also reach 37,500 additional stakeholders. These are people who are not members, rather they're customers (users of SPE products or services) or those who somehow engage with SPE.
- More people are opting to not become members, or "join," but still participate in the SPE community.

Pat will continue to report these same metrics twice yearly, 6/30 and 12/31, so Chapters can begin to benchmark performance.



Respectfully Submitted by Mercedes Landazuri, Color and Appearance Councilor

CALL FOR PAPERS

TAMPA MARRIOTT WATER STREET
TAMPA, FLORIDA | SEPTEMBER 23 – 25, 2024

DEADLINE FOR ABSTRACTS
MARCH 29TH 2024 (FLEXIBLE)

PAPER DEADLINE
JUNE 3RD, 2024

Chairperson: Alex Prosapio, Sudarshan
aprosapio@sudarshan.com

Vice-Chairperson: Mark Tyler, Silberline
tylerm@silberline.com

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Karen Carlson, EMD Electronics
Karen.carlson@emdgroup.com

Society of Plastics Engineers Color & Appearance Division Endowment Scholarship Program for the 2024 – 2025 School Year

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

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

Scholarship Eligibility
1. Applicants for these scholarships must be full-time undergraduate students in either a four-year college or a two-year technical program or enrolled in a graduate program.
2. All applicants must be graduates of public or private high schools.

Scholarship Criteria
1. Applicants must have a demonstrated or expressed interest in the coloring of plastics industry.
2. Applicants must be majoring in or taking courses that would be beneficial to a career in the coloring of plastics industry.
3. An applicant must be in good academic standing with his or her school.
4. Preference is given to student members of SPE and also to students who have a parent(s) as a member of the Color & Appearance Division of the SPE.
4. Financial need of an applicant will be considered for most scholarships.

Application Procedure
To be considered for a scholarship from the Color & Appearance Division Endowment Scholarship Program, applicants must complete an application and return it to the address specified on the application by June 7, 2024. All applications submitted must include:
1. A completed application form.
2. Three recommendation letters: two from a teacher or school official and one from an employer or non-relative.
3. A high school and/or college transcript for the last two years.
4. An essay by the student (500 words or less) telling why the applicant is applying for the scholarship, the applicant's qualifications, and the applicant's educational and career goals in the coloring of plastics industry.

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

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

Society of Plastics Engineers Color and Appearance Division

Call for Board of Directors / SPE Council Representative Candidates

2024 to 2027 Term

The Color & Appearance Division of the SPE will be conducting its annual Board of Directors elections April 2024.

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

SPE Council Representative (CAD)
The Color & Appearance Division of the SPE is also electing a Council Representative for the 2024 to 2027 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).

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

George Iannuzzi
PH: 914-261-8189
george@koelcolours.com

All candidates must be identified and have all their information to SPE CAD BOD by March 31st, 2024

Visit SPECAD Website for more information

SPE Color & Appearance Division Mission Statement:

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

MEMBER SPOTLIGHT

josh jacobs

WE WANT TO INTRODUCE OUR BOARD MEMBERS TO THE CAD MEMBERSHIP

tell us about yourself.

I am a Market Development Engineer for Uniform Color. The company is headquartered in Holland, MI, although I work remote from Mooresville, NC. I began my career in the plastics industry as a Material Handler at a recycled PET facility in Ohio. Shortly after beginning that job I signed up for classes at Terra State Community College, where I obtained an Associate's degree in Color Matching of Plastics. Later down the road I also earned my Bachelor's degree in Learning Design & Technology and an MBA from Bowling Green State University.

when did you join the board?

This is my first term on the board. I officially joined the board in July of 2023.

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

I joined the board of directors in 2021, which is when I began attending the meeting. Although, I went to my first SPE RETEC in 2006 with my classmates from Terra State Community College.

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

My favorite part of being on the board is working to get new people involved in the plastics industry. Getting into the industry significantly changed my life's trajectory and has been very rewarding in many ways. I want to share that with the next generation of professionals.

any fun facts about you?

I live with my wife, Ashley, and two children, Charlie and Katelynn. We have 2 dogs, Evvie (Golden Retriever) and Baker (Golden Doodle). In my free time I enjoy playing Ultimate Frisbee, playing guitar, traveling, and reading. I am a big fan of Cleveland sports and alternative country music.

spe
COLOR & APPEARANCE

SPE Color and Appearance Division Mission Statement

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

INVITATION TO ATTEND CAD BOARD MEETING

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

CADNEWS® Technical Content – Scott Heitzman

The Technical Content portion of our Spring 2024 edition of CADNEWS® includes a paper presented during the recent RETEC. The paper by Kevin Lucero & Ulrich Quittmann of EMD Electronics, highlights the use of additives in plastics to increase sensitivity for laser marking. The paper, Additives for Durable, Flexible, and Accurate Laser Markings in Plastics will help make sure you " check the boxes"- selection of laser, laser enhancing additives, polymer type and colorants to ensure the best performance for your application. Take a moment to read and as always if questions you can ask any questions using the Color Notes Link below.

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/

ADDITIVES FOR DURABLE, FLEXIBLE, AND ACCURATE LASER MARKINGS IN PLASTICS

Kevin Lucero, Ulrich Quittmann
EMD Electronics - Surface Solutions, an affiliate of Merck KGaA, Darmstadt, Germany

Abstract

Laser marking offers an accurate, flexible, and durable alternative to eliminate solvents, inks, or hot stamping used in traditional printing or identification methods. Infrared lasers, such as fiber and DPSS (Diode Pump Solid State), are well established in industrial practice for marking processes for metals. However, plastics present a unique challenge because they do not show absorption in the range of the typical wavelength of 1064 nm. This paper will primarily highlight the use of additives in plastics to increase the sensitivity of plastics to 1064nm wavelength lasers, as well as highlight ancillary benefits of laser marking including but not limited to circular economy improvements, track and trace, and serialization.

Introduction: Laser Marking Market Potential, Current Examples of Laser Marking Additives in Market Applications

Laser marking offers an accurate, flexible, and durable alternative to eliminate solvents, inks, or hot stamping used in traditional printing or identification methods [1]. Laser marking is utilized by a wide range of plastics industrial applications, including but not limited to, rigid packaging, flexible packaging, films, wire and cable, bottle caps and closures, security seals, consumer goods, automotive switches, trims, handles, and many other applications. In addition to industrial applications, laser marked plastics also find uses in food packaging, livestock animal tags, kitchen appliances, and laboratory equipment such as catheters, tissue sample containers, and disposable syringes, among others. Laser markings are scratch resistant, stable in subsequent sterilization processes, and can be applied in a sterile environment [2]. Many of these applications require long-term durability. For example, animal livestock tags must remain on an animal for years and endure environmental weathering from rain, snow, mud, and other harsh conditions.

Meanwhile, the labeling requirements for manufactured goods may include information such as expiration dates, serial numbers, lot-number information, graphic logos, QR codes, barcodes, and other data. Such detailed information allows for tracking and tracing of individual products. For example, scanned barcodes or QR codes, allow for the recall of automotive parts produced within a specific window of manufacturing dates. Lasers also offer product designers and engineers increased labeling options for non-planar surfaces as lasers can mark curved surfaces or areas normally inaccessible with inkjet printing or hot stamping. Compared to traditional labeling methods, laser marking is contact-free, solvent-free, and agile [1][2]. Contact-free markings allow for hygienically pure labeling in laboratory applications such as petri dishes or retain containers. Solvent-free markings eliminate costly surface pre-treatment preparations such as for pad printing in silicone applications. The agility of laser marking allows for revisions to be implemented via software inputs rather than via costly hardware or tooling adjustments. An example of this is the serialization of lot numbers or expiration dates. [1][2].

Fig 1. Clockwise from top left: livestock ear tags, bottle caps/closures, wires and cables, barcode for container

Laser types

Infrared lasers, such as fiber and solid state (DPSS), are well-established in industrial practice for marking processes on metals. The most common wavelength used for industrial laser marking is 1064nm wavelength [2]. Laser types used include fiber lasers and pulsed lasers, such as Nd:YAG (neodymium-doped yttrium aluminum garnet) lasers or Nd:YVO_4 (neodymium-doped yttrium orthovanadate) lasers. Early laser marking efforts utilized CO_2 lasers. However, CO_2 lasers are continuous-wave lasers which do not have high peak energy. A high peak power is required to sufficiently excite the material and produce localized heat [1][2].

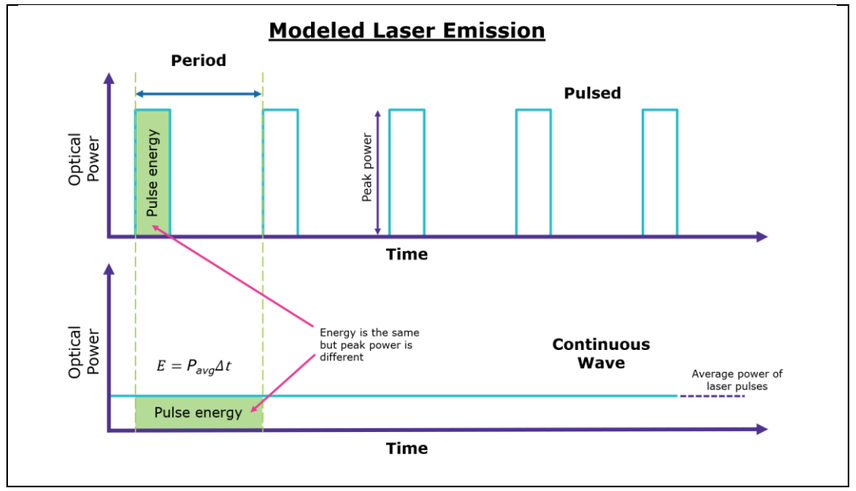

Fig 2. Pulsed vs Continuous Wave lasers

Pulsed lasers include a Q-switch which allows for the controlled emission of the laser beam in pulses which have higher peak power than continuous wave lasers, as seen in Fig 2. Pulsed laser beams are more effective in producing visible markings of good line resolution and contrast compared to continuous wave lasers.

The energy densities of the lasers used are in the range of 1 J / cm^2 to 2,000 J / cm^2, preferably 10 J / cm^2 to 2,000 J / cm^2. When using pulsed lasers, the pulse frequency is in the range of 1 to 100 kHz [1]. Another alternative to continuous wave or pulsed lasers are excimer lasers. Such lasers include F2 excimer lasers (157 nm), ArF excimer lasers (193 nm), KrCl excimer lasers

(222 nm), KrF excimer lasers (248 nm), XeCl excimer lasers (308 nm), XeF excimer lasers (351 nm), frequency-multiplied Nd: YAG lasers with wavelengths of 355 nm (frequency tripled) or 265nm (frequency quadrupled) [1]. Appropriate laser selection will depend on the application performance requirements. Many lasers are small enough to be used as desktop units such as shown in Fig 3.

Fig 3. Left: example of a vanadate (Nd:YVO_4) desktop laser unit

Right: TPU sample containing laser additives being laser marked

Increasing the laser sensitivity of plastics

Laser additives are functional materials which increase laser sensitivity [2]. The method for industrial laser marking is to expose a material to the beam path of a laser to create a visible mark. Metals, glasses, and ceramics may often be etched without laser additives. [3] However, plastics present a unique challenge because they do not exhibit strong absorption of 1064 nm wavelength light [2]. Therefore, laser marking additives are required to increase the laser sensitivity which allows for improved contrast, sharper line resolution, and a wider range of

operating conditions for the laser [2][3]. Operating conditions of the laser may include settings such as power, pulse frequency, scan speed, line spacing, raster pattern distribution, and vector file optimization, among others. Of particular importance for commercial applications is scan speed. Faster scan speeds reduce the cycle time of each part in the manufacturing process. Increasing laser sensitivity of any material allows for faster production of parts therefore creating an economic benefit for many companies. Without laser additives, the produced markings may not offer sufficient contrast to be legible. In this case, laser additives may offer a scan speed on the order of 10x faster than without additives. Fig 4. shows such an example. In the polypropylene control on the left, we see that a laser setting combination of 500 mm/s and 20 kHz yields a very faint marking. In comparison, the polypropylene containing laser additive shows that 5000 mm/s scan speed yields a more legible marking at a much faster speed.

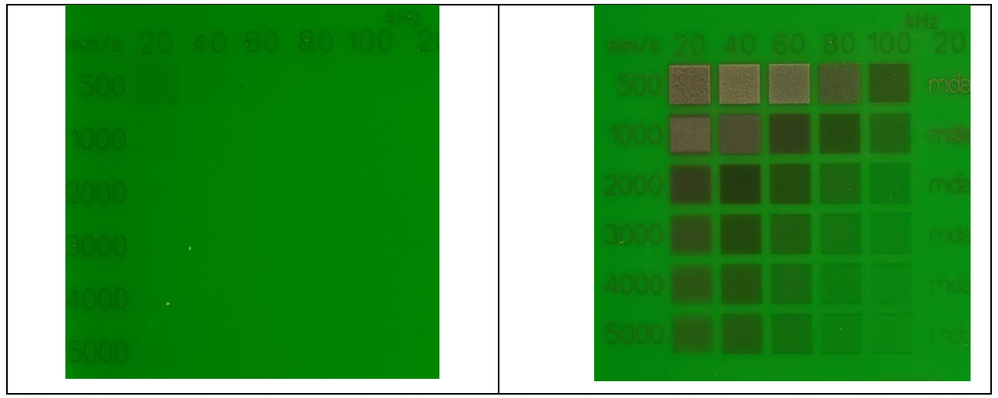

Fig 4. Left: green polypropylene control vs right: green polypropylene containing laser marking additives. Both samples have been laser marked with a test matrix grid showing laser pulse frequency (x-axis) vs scan speed (y-axis)

In the case that laser marking may occur without additives, laser additives may still be used to further increase the sensitivity of the polymer to laser excitation. Such speed enhancements may sometimes be in the order of 2-4x faster. Fig 5 shows a 2x improvement in speed from the 500 mm/s of the control vs 1000 mm/s of the PA containing laser additive.

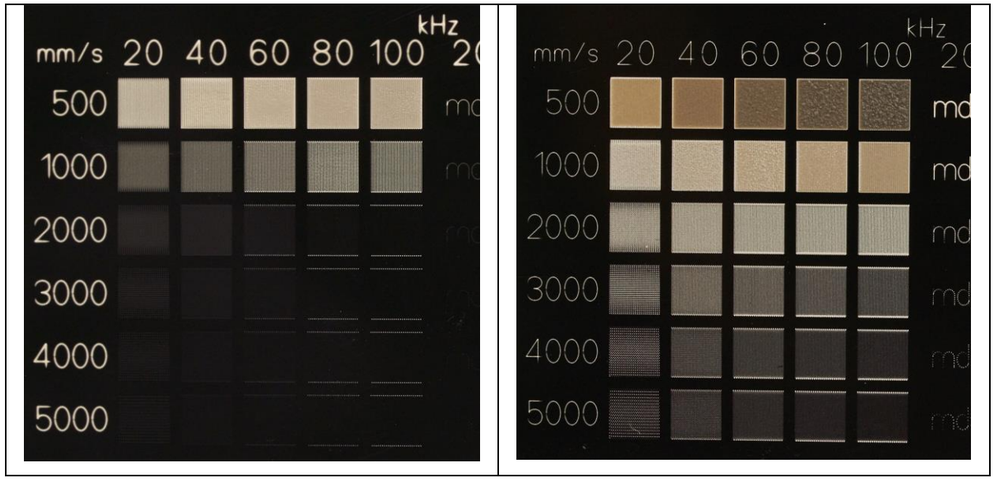

Fig 5. Left: black polyamide control vs right: black polyamide containing laser marking additives. Both samples have been laser marked with a test matrix grid showing laser pulse frequency (x-axis) vs scan speed (y-axis)

Laser Marking categorizations and polymer influence

Visible markings created by lasers may be categorized as engraving, ablation, foaming, or carbonization [1]. Engraving occurs when the laser beam causes material removal, thus inscribing an etched path following the laser beam. Ablation is similar to etching, except it refers to material removal of a surface layer, usually a coating or polymer film, to reveal a second layer beneath. Foaming occurs when the laser beam breaks the chains of the polymer into monomer units, causing foaming due to the localized heating. Carbonization occurs due to the liberation of functional groups in the polymer, thus leaving a carbonized appearance in the path of the laser beam. In the case of polymers, aliphatic polymers have an inherent tendency to foam whereas aromatic polymers have an inherent tendency to carbonize [2].

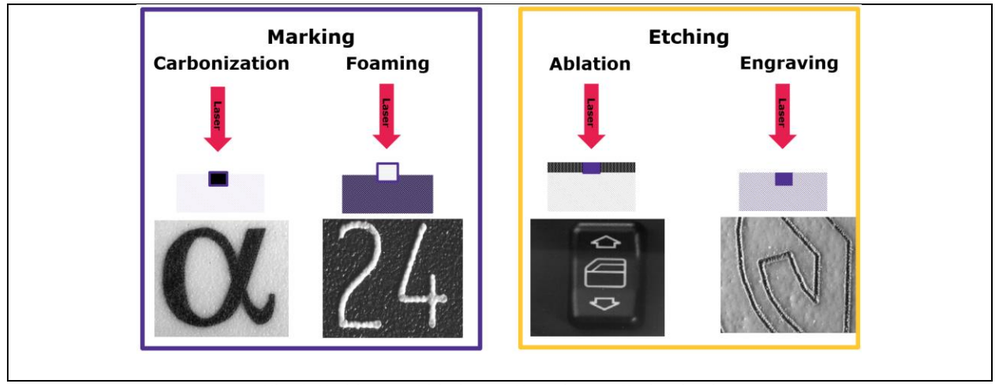

Fig 6. Etching vs Ablation vs Foaming vs Carbonization

However, a combination of laser settings and laser additive choice can, in some cases, be used to overcome the inherent tendency of a polymer chemistry to create foaming or carbonization.

Upon inscription with a laser, aliphatic polymers (such as polyoxymethylene, polymethyl methacrylate, polyamide, and others) will generally exhibit a tendency to foam whereas aromatic polymers (such as polycarbonate, polyethylene terephthalate, polybutylene terephthalate, acrylonitrile butadiene styrene, polyether sulfones, and others) will exhibit a tendency to carbonize [4].

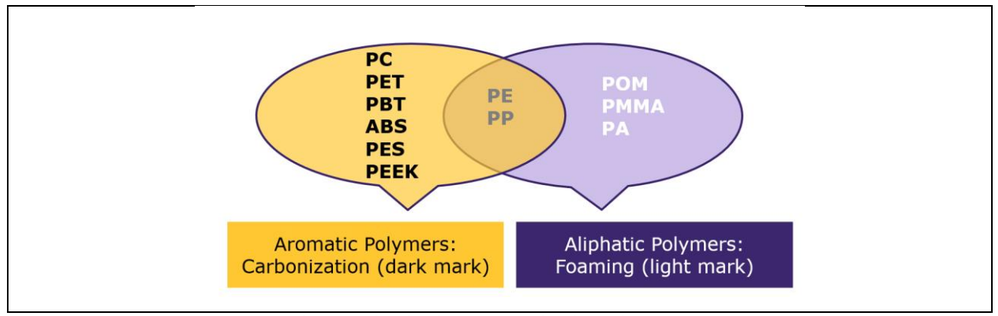

Fig 7. Carbonization vs Foaming by polymer type

Laser settings also influence the tendency of a polymer containing laser additives to carbonize or foam. Laser settings which create a high-peak energy exhibit a tendency to foam. Whereas laser settings which create a lower peak-energy tend to carbonize.

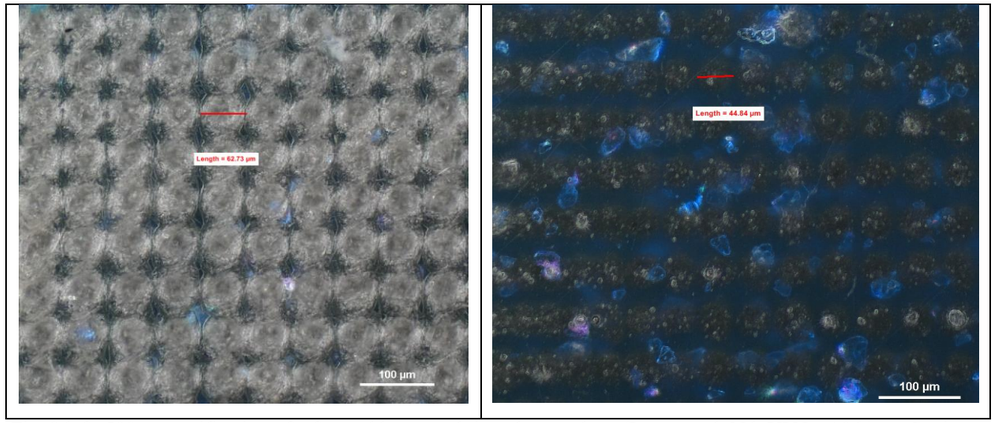

Fig. 8 left: 500x magnification of a foamed laser mark in polypropylene (Laser used: Nd: YVO_4, 1064nm. Settings: 15W, 40 kHz, 2400 mm/s)

right: 500x magnification of a carbonized laser mark in polypropylene (Laser used: Nd: YVO_4, 1064nm. Settings: 15W, 120 kHz, 7,200 mm/s)

Chemistry of additives and incorporation into polymers

Examples of laser marking additives include bismuth oxychloride, bismuth oxide, copper phosphates, and other metal oxides on mica or other substrates [2]. The concentration of laser marking additives is dependent on the polymer chemistry as well as the type of additive, but concentrations in the range of 0.1%-0.5% by weight are typical [1]. Haziness or discoloration due to the introduction of laser additives is dependent on the type of additive as well [1]. Some laser marking additives, such as antimony-doped titanium dioxide, have a greater influence on haziness or discoloration whereas other additives, such as mica surrounded by a layer of antimony-doped tin oxide, introduce significantly less haze and discoloration [1]. Proper selection of additives will depend on the clarity vs contrast requirements of the intended application. Suitable polymers for the addition of laser additives includes, but is not limited to, thermoplastic polymers, e.g. polyethylene, polypropylene, polyamides, polyesters, polyether esters, polyphenylene ethers, polyacetal, polybutylene terephthalate (PBT), polyethylene terephthalate (PET), polymethyl methacrylate (PMMA), polyvinyl acetal, polystyrene, acrylonitrile-butadiene-styrene, acrylonitrile-styrene-acrylic ester, styrene-acrylonitrile (SAN), polycarbonate, polyether sulfones, and polyether ketones and their copolymers, blends, and/or polymer blends such as PC/ABS [1][2]. Suitable thermoset polymers include polyurethane,

melamine resins, polyesters, and epoxy resins. Laser marking additives may be incorporated into a plastic using a masterbatch or concentrate, in a manner similar to color pigments, fillers, or other additives. For laboratory testing, laser additives may be incorporated by doping plastic pellets with the laser additive powder by mechanical mixing of the pellets together. The laboratory production of the doped plastic granules or powder is done by placing the granules in a suitable mixer and wetting with dispersing aids [2]. The laser additive and the required color pigments are then added to the mixture and mechanically mixed via tumbler or another device. In industrial practice, the coloring and additives may be added to the polymer using a color concentrate or masterbatch compound. To do this, color pigments and additives, under high shear in extruders, usually with co-rotating twin screw extruders, are dispersed in the molten plastic [2]. The plastic melt exits through a perforated plate on the extruder head and is replaced by suitable post-processing (e.g., underwater pelletizing) into granules. The granules thus obtained can be further processed directly in an extruder or an injection molding machine. The extrudate formed during processing exhibits a more homogeneous distribution of the laser additive. The extrudate, often referred to as a masterbatch or concentrate, may then be processed together with virgin resin using a variety of plastics processing methods such as injection molding, film extrusion, injection stretch blow molding, among others to create the plastic part. Subsequently, the laser marking of the plastic part occurs with a suitable laser [1]. Due to the comparatively low loading concentrations, processability of the polymer is generally unaffected by the addition of laser additives.

Circular Economy

In recent years, increased emphasis has been placed on the “circular economy” – an economic system based on the reuse and regeneration of materials and products, especially as a means of continuing production in a sustainable or environmentally friendly way [5]. Laser marking may offer several benefits to the circular economy of plastics packaging:

1. Identification of products can be made possible via track and trace features of QR codes, barcodes, and other serialization labels on plastics packaging. Information such as polymer resin type, material construction, and recycling directions may be encoded into such QR codes or barcodes. Scanning of such codes allow for retrieval of information in the form of a digital product passport which facilitates end-of-life recycling efforts [6].
2. Recycling of plastics requires sorting of plastics by resin type [5]. Film labels attached to bottles require the additional step of removing the film achieved by using solvent baths or mechanical removal. Laser marking allows for the creation of a label which replaces the traditional adhesive or film label in plastic packaging. By eliminating the adhesive or film label, this extra step is no longer required for recycling or streamlining the recycling process. Plastic packaging such as bottles or containers may then be constructed from mono-materials; materials which comprise a single polymer resin such as HDPE (high density polyethylene) or PP. Fig 9 shows an example of a shampoo bottle laser marked with such a label in mind. The bottle is made from post-consumer recycled high-density polyethylene.
3. Recycling of plastics imparts multiple heat-histories on resins. Laser marking additives retain their functional properties even after being recycled multiple times. The carbonization of previous markings shows negligible effect on discoloring the film after subsequent melt histories. Fig 10 shows such a comparison of the laser marking performance of a virgin film containing laser additives compared to a film made from resin which has been recycled three times. The laser marking performance of the additives are retained during the recycling process.

Fig 9. Laser-marked label of a shampoo bottle containing laser additives. Bottle is a mono-material made from post-consumer recycled high-density polyethylene.

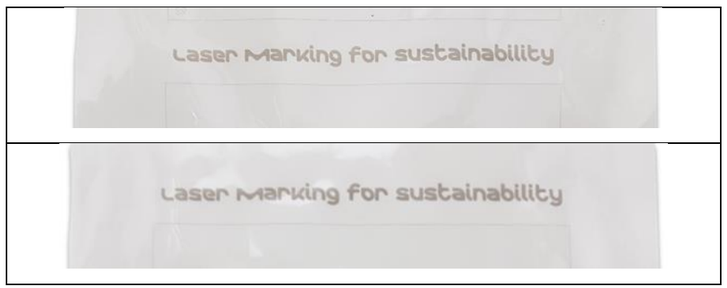

Fig 10. Top: virgin LDPE film containing laser additive. Bottom: 3x recycled LDPE film containing laser additive

Influence of other colorants or additives

Laser marking additives may be inhibited by some additives such as flame retardants, fillers, and colorants. Of particular importance is the influence of carbon black on laser marking. Carbon black has high absorption in the UV, visible, and infrared spectrum [7]. As such, the carbon black interferes with the function of a typical laser marking additive by absorbing an excess of 1064 nm laser energy. This excess energy causes the collapse of a foamed mark to create an engraving instead of foaming. Fig 11 shows the effect of increasing carbon black concentration in polyethylene and its effect on collapsing the foamed mark into an engraved mark.

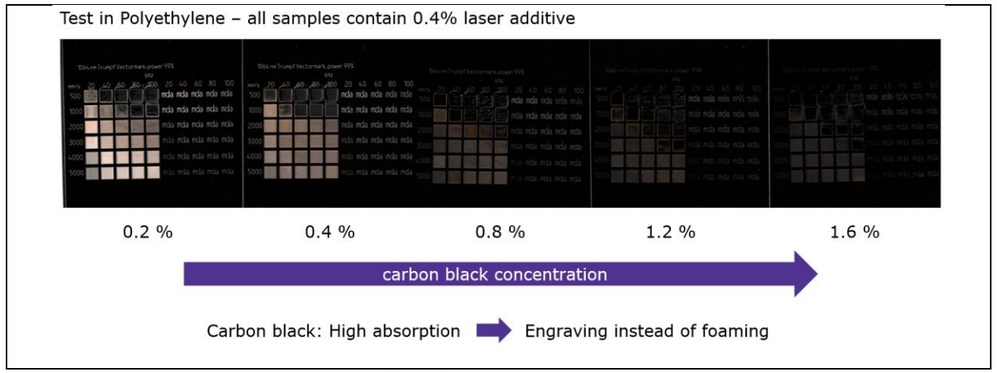

Fig 11. Polyethylene ladder study showing effect of carbon black concentration on laser marking contrast

On the opposite end of the contrast spectrum, light-scattering pigments such as zinc oxide, zinc sulfide, and titanium dioxide may also influence laser marking contrast. Titanium dioxide exhibits light scattering in the UV, visible, and infrared spectrum [8]. This light scattering competes with the absorption of laser additives causing a decrease in contrast. Fig 12 shows the

effect of increasing titanium dioxide concentration in polypropylene and its effect on decreasing contrast.

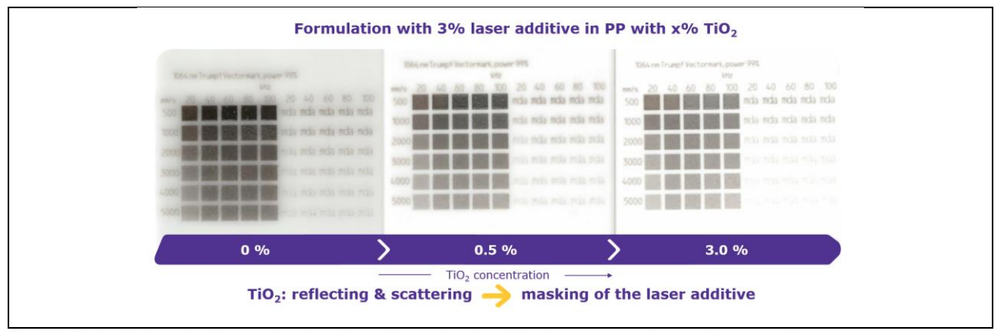

Fig 12. Polyethylene ladder study showing effect of carbon black concentration on laser marking contrast

Flame retardants may also negatively impact laser marking. Flame retardants, such as hydrated zinc borates liberate water molecules upon heating [9]. The liberation of these water molecules competes with the localized heating effect of laser marking additives, effectively canceling out their function. Care must be taken to select appropriate pigments, colorants, and functional additives to ensure compatibility with laser marking additives.

Conclusion

Laser marking of plastics offers a promising alternative to existing labeling technologies. Presently, widespread industrial applications use a range of laser additives for use in plastics applications. These applications will grow in demand as performance requirements for labeling become stricter and as circular economy requirements force manufacturers to evaluate more sustainable technologies for plastics. Particular care must be taken to ensure appropriate selection of laser, laser additive, and polymer resin, combined with other colorants and pigments to ensure the best performance for each application.

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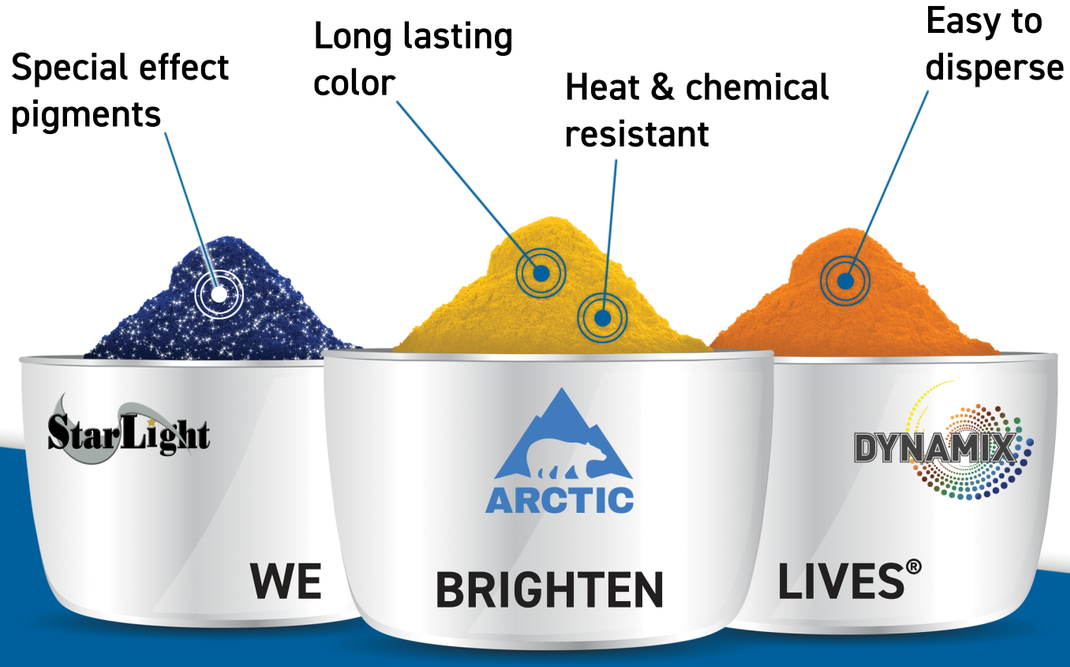

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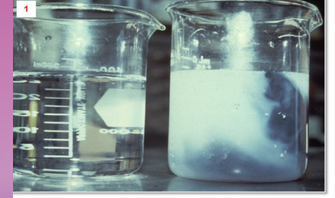

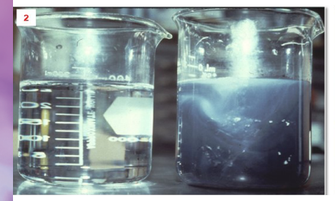

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