What’s Old is New

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- In-Situ Crystallization of PEKK
- 2019 Thermoformer of the Year
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Cover photo courtesy of Illig Maschinenbau GmbH & Co. KG
Welcome to the Conference Edition of Thermoforming Quarterly. Tradition holds that this issue features two major items: the official “Thermoformer of the Year” announcement and our Division scholarship winners. I’m a big fan of both – we celebrate an outstanding individual from our professional ranks, and we congratulate our students who are seeking futures in plastics. In just a few short weeks, we will all have the opportunity to recognize these folks at our conference in Milwaukee. This year’s event is jam-packed with high-quality technical content, industry plant tours, hands-on sessions, and even a visit to the Harley Davidson museum where we will host our opening reception.

2019 is also a “K” year where over 250,000 people will visit the Messe on the banks of the River Rhine in Dusseldorf, Germany. Even though the plastics industry faces a different set of market conditions than three years ago, the K Fair offers an opportunity for attendees to get a sense of how global our business is. On p. 24, we offer a brief overview of thermoforming OEM companies including machinery manufacturers and toolmakers. Attendees can also note that SPE will have a booth in Hall 12, Stand E04.

This issue features some new research from Germany where a group of 3 companies collaborated to develop recycled cPET for thermoforming. By taking mixed APET flakes and additives, material scientists were able to manipulate the extrusion and thermoforming process to develop thermally stable material for food trays (see pp. 16-22). In another interesting development for high-heat applications, France-based specialty chemicals and advanced materials Arkema has created a unique, tunable, amorphous PEKK material that can be crystallized in-situ (see pp. 30-32). Potential applications include areas where extreme temperature resistance is required, such as aerospace or chemical processing.

We are all more than aware of the ongoing discussion about plastics and the environment. Our editor reports from Grand Rapids where the Plastics Industry Association (PLASTICS) hosted their 4th annual Re|Focus conference (see pp. 34-37). Topics included novel uses for polyethylene in asphalt, design-led thinking for end-of-life materials management, and updates from several long-term studies on recycling plastics in the current infrastructure. As a DC-based organization, PLASTICS provided insight into legislation at both the state and federal levels. As was to be expected, there were no easy answers to a very difficult problem. SPE continues to provide a forum for key technical and scientific discussions on this important topic. As a community-based group, however, it is critical to the organization’s vitality and success that individuals get more involved. Start a discussion online, host a seminar at your company or at your local school, or engage with your employees about the need to promote responsible management of plastic materials.

This issue also contains obituaries for two of our former colleagues, Walk Walker and Jim Armor, both of whom contributed many volunteer hours to our Division. Let’s raise a glass to them in Milwaukee.

As summer comes to a close and we look forward to the business end of the year, I encourage everyone to visit Milwaukee in September. When our industry convenes to celebrate our future and our present, we can do great things together. See you soon.
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Tooling Tech Group Buys Assembly Equipment Maker Alpha Integration

May 30, 2019 — Major mold maker Tooling Tech Group has purchased Alpha Integration Inc., a company in Murfreesboro, Tenn., that provides custom automated assembly and inspection equipment.

Tooling Tech announced the acquisition May 30. Terms were not disclosed.

Alpha Integration employs about 45 people. The company will continue to operate out of its Murfreesboro location while its business practices will be integrated into the overall Tooling Tech Group operations.

Alpha Integration develops and manufactures assembly, material handling, dispensing, sorting, testing, welding and fastening systems for the automotive, cosmetic, electrical, construction and life sciences industries.

This is the fourth acquisition since 2018 for Tooling Tech, which is owned by New York private equity firm GenNx360 Capital Partners. Founded in 1982, Tooling Tech makes compression molds, blow molds, rotational molds, thermoforming tooling and die-cast tooling and metal stamping dies.

Based in Macomb, Mich., Tooling Tech employs about 600 people in 12 U.S. locations. The company is the second-largest mold and tool maker in North America, according to Plastics News ranking, with $185 million in sales.

A year ago, Tooling Tech acquired automotive mold makers Century Tool Group, which included two Michigan operations: Century Tool & Gage Co. and CTG Bel-Kur Automation.

Tooling Tech serves a range of industries including automotive, appliance, lawn and garden, agricultural, aerospace, marine and off-road vehicles.

“Alpha’s expertise in integrating a variety of processes into automated assembly and test solutions complements our existing capabilities and enhances our ability to serve our existing customers while enabling us to reach new markets such as the medical and cosmetics sectors,” said Lee Childers, CEO of Tooling Tech Group. “This is a very exciting time of growth for our company.”

Alpha President Matthew Phillips said he looks forward to working with the Tooling Tech Group leadership team to support existing customers and gain new ones. “Partnering with TTG provides us more flexibility with increased resources and capacity, as well as a wealth of industry knowledge,” Phillips said.

Investment Firm Buys a Stake in Thermoformer Anchor Packaging

By Jim Johnson, Plastics News

June 26, 2019 — One of the nation’s largest thermoformers is taking on a private equity partner in a move the company said will help accelerate growth.

Anchor Packaging LLC, based in St. Louis, said June 26 that The Jordan Co. is taking an unspecified stake in the family-owned firm.

The Hermann family, which has owned the company for 56 years, will retain an ownership stake, the company said.

Anchor is ranked No. 9 on the latest Plastics News list of largest thermoformers in North America, with sales of $350 million in 2017. That’s up from $315 million the year before.

Anchor said the company has been able to triple sales during the past 15 years through organic growth. The influx of capital from the investment firm will help fuel additional growth.

“No we are talking about transformative growth — broadening our geographic reach through additional manufacturing facilities, new and complementary product lines to better serve our customers and new materials to offer our customers,” Anchor CEO Jeffrey Wolff said in a statement.

The company’s operations currently are concentrated in Arkansas with an additional location in Argentina, according to Anchor’s website.
Anchor uses polypropylene, polystyrene, polyethylene and PET to make packaging for food, consumer, household care, and agricultural products. The company also makes cups and lids.

“Anchor has been, and continues to be, a family business” Chairman Robert Hermann Jr. said in a statement. “We are excited to partner with The Jordan Co. to help fuel Anchor’s continued growth and increase our trajectory. The Jordan Co. possesses many of the same values, ethics, and long-term orientation that has been a hallmark of Anchor.”

Terms of the deal, expected to close in July, where not released.

“We plan to invest further in the business to support organic growth and continued new product development”, said Mike Denvir, a partner at Jordan, in a statement.

Jordan lists 30 current investments on its website, including American Freight, a discount furniture retailer and Bojangles’ restaurant chain.

**AMB Acquires UK food Packaging Business**

June 27, 2019 — Italian packaging producer AMB Spa has acquired TDX (Europe) Ltd, a UK-based manufacturer of PET, rPET and laminated rigid films for the food and packaging industry, to create a pan-European leader in the rigid and flexible plastics film and packaging market.

The combination of Udine-based AMB and TDX creates a one-stop-shop offering of products and services, from tooling and concept design, product specification, print design and application, allowing the group to deliver new products and services.

Together, AMB and TDX will have four sites across Europe plus a network of international distribution warehouses with 430 employees. The combined businesses will turnover in excess of €150 million ($168m).

Giles Peacock, chief operating officer of AMB, which celebrates its 50th anniversary this year, said: “This is a highly complementary acquisition that will help AMB widen our European footprint to be more local to our clients in Northern Europe. We have always had a clear vision, and part of the vision is to create a group that can offer a complete end-to-end process for food packaging customers.”

Mark Prinn, managing director of TDX, added: “We are excited to join forces with AMB and believe this partnership will significantly accelerate geographic expansion. The two companies working together in partnership will truly deliver a one-stop-shop that will create strong opportunities worldwide and we look forward to working together.”

**Sustainability** and food safety will continue to be core to the activities of the new partnership.

The acquisition of TDX (Europe) includes its product design, prototype and tooling business. While continuing to serve its existing local and global customer base, the design and tooling business will offer added value services to existing AMB customers by enhancing AMB’s capability to offer complete packaging solutions.

Bruno Marin, the chief executive of AMB, said: “We see this as our first major step in our new growth plans. 50 years of AMB has brought us to this point through innovation, talented people and unwavering focus on our defined vision.”

AMB installed its first multilayer coextrusion line for the production of food packaging in 1988 and since then has ramped up capacity with PET co-extrusion lines and 7- and 9-layer blown film lines. It was also the first company in Europe to start water-based production instead of solvent in 2014.

The company opened its second production plant in Udine in 2017, which gave it stronger connections to the rest of Europe.

**Paccor Acquires EDV Packaging Solutions**

By Tony Corbin, PackagingNews.co.uk

July 25, 2019 — EDV delivers products which require greater protection against oxygen migration and coffee capsules made from polypropylene, as well as made out of advanced bio compostable materials. The acquisition
Thermoforming In The News

EDV Packaging Solutions was founded in 1972 and has been growing successfully in Europe for the last four decades and gradually making an impact on US and Asia markets.

Kohlerberg Closes on Bemis Healthcare Packaging Europe Acquisition, Merges with Nelipak

By Don Loepp, Plastics News

August 9, 2019 — As promised, Nelipak Corp. Inc. is growing globally under its new ownership.

In July, investment firm Kohlberg & Co. LLC acquired the major manufacturer of custom plastic packaging for the health care sector. At the time, Mount Kisco, N.Y-based Kohlberg announced it had plans to leverage the business with “sizeable, global acquisitions.”

Kohlerberg made good on the pledge Aug. 8, when it completed a previously announced deal to buy Bemis Healthcare Packaging Europe for $394 million — then immediately merged the unit with Nelipak.

The combined companies have footprints in both North America and Europe. Products include flexible and thermoformed packaging.

“This will significantly enhance Nelipak’s capabilities with the addition of flexible packaging alternatives for our global customers,” Mike Kelly, president and CEO of Nelipak, said in a news release.

Kohlerberg picked up the Bemis Healthcare business as a result of the year’s packaging megamerger: Amcor Ltd.'s $6.8 billion purchase of Bemis Co. Inc. The European Commission asked the companies to divest the European health care business because of competition concerns.

Industry veteran Peter Schmitt called the Nelipak deal an example of a major “remapping” of the sterile medical packaging market, driven by Amcor’s deal.

“Not too long ago, there were two major public companies in both food and medical packaging: Amcor and Bemis,“ advances Paccor’s position in rigid barrier packaging applications globally.

EDV combines its technology with a complete project management service, ranging from product conception to production and with the delivery of full solutions to customers. It has also developed processes for the efficient manufacturing of barrier applications such as coffee capsules made from polypropylene, as well as advanced bio compostable materials. EDV is also a leader in rigid barrier applications for ready-meals and the world’s third largest producer of fruit bowls (for products such as, compotes).

“We are very happy to welcome EDV Packaging Solutions as a new member of the Paccor worldwide family. Over the past years, EDV has achieved very impressive growth and profitability. We are happy to merge forces in order to jointly capture further opportunities within Europe and outside of it,” commented Andreas Schütte, chief executive, Paccor.

Paccor believes the acquisition will allow both groups to lead the innovative change in manufacturing sustainable packaging and to become the global leader for rigid barrier applications, with EDV becoming Pacoors Center of Excellence for thermoformed products requiring higher oxygen protection. Furthermore, Pacoors will also enter the fast-growing market for coffee capsules in Europe. At the same time, EDV has gained a strong partner for the further support of its market growth in Europe and beyond.

“After 30 years of hard work growing a family business to become the leading European operator of rigid barrier packaging, it is an excellent opportunity for us to be a part of the bigger Paccor family. This is an upscale to become a worldwide player in this fast-growing segment,” summarised Koke Pursals, president of EDV.
said Schmitt, managing director of Montesino Associates LLC in Wilmington, Del. “Indeed, they split the assets of Alcan when Alcan’s packaging division was divested. Now they are merging.”

Bemis and Amcor grew significantly when they split the former Alcan Packaging business in 2010, which had been owned by metals and mining firm Rio Tinto plc.

But when Bemis and Amcor agreed to merge, competition authorities in the United States and Europe asked the two to divest big chunks of their medical packaging business — and private equity firms pounced on the opportunity.

First, Wayne, Pa.-based Tekni-Plex Inc., which is owned by Genstar Capital, bought three manufacturing plants from Amcor’s Flexible Packaging business unit for $215 million to broaden its portfolio of sterilizable medical device packaging. That deal included three U.S. plants.

Now Kohlberg-backed Nelipak has done the same with three Bemis plants in Europe.

Schmitt said the private equity firms are building a portfolio of packaging companies focused only on medical devices or health care, not food.

“The question is, will Amcor be able to focus on both food and medical, and use its size and brand strength to grow its position? Or will this new map of strong and growing sterile medical packaging companies led by private equity challenge Amcor in the medical arena?

“Additional consolidation appears to be likely. Add to that the uncertainty of both trade wars and a possible recession and we will see some interesting moves in the future,” Schmitt said.

Nelipak’s medical packaging operations are growing with the addition of Bemis Healthcare Packaging Europe.

With an estimated $90 million in sales, Nelipak Healthcare Packaging ranked No. 25 among North American thermoformers, according to the latest Plastics News ranking.

The Bemis Healthcare deal adds three more plants and 600 employees. The three plants, in Londonerry, Northern Ireland; Clara, Ireland; and Brigg, England, represented the entire medical packaging business of Neenah, Wis.-based Bemis, and have a combined annual sales of around $170 million.

Kohlberg Highlights Synergies

Kohlberg officials highlighted how combining the two businesses gives Nelipak global scale and a wider range of plastic packaging products.

“Our recent acquisition of Nelipak represented a platform for growth and consolidation,” Seth Hollander, a partner at Kohlberg, said in the release. “The Bemis acquisition provides a unique opportunity to create global scale and diversification across complementary product offerings.”

Roger Previt, operating partner at Kohlberg, added: “This combination provides attractive opportunities for revenue growth from cross-selling and geographic expansion. Mike and his team will be better equipped to serve the company’s customers as a comprehensive partner for their packaging needs.”

Kohlberg bought Nelipak from Milwaukee-based Mason Wells on July 2.

Nelipak’s products include thermoformed trays and blisters used to product Class II and Class III medical devices and pharmaceuticals as well as trays for surgical procedures, such as orthopedic and cardiac implants, and handling drugs, such as auto-injectors, pre-filled syringes and vaccines.

Nelipak by the Numbers

Prior to the merger, Nelipak, which has been in business for 60 years, employed more than 800 at seven production sites. In addition to its headquarters in Cranston, R.I., the company had plants in Whitehall, Pa.; Phoenix; Humacao, Puerto Rico; San José, Costa Rica; Galway, Ireland; and Venray, the Netherlands.
2019 SCHOLARSHIP AWARDS

Samuel Bliesner, Tulane University

Samuel Bliesner received his B.S. degree in Chemical Engineering from Florida State University in May 2015.

During his undergraduate career, Sam served as a co-op at the DuPont site in Richmond, Virginia, performing research in the Kevlar® business area. This work experience introduced Sam to, and sparked his interest, in the polymers industry.

Upon graduation in 2015, Sam returned to Richmond as a contracted reliability engineer in the DuPont Kevlar® pulp business area. After a short time in industry R&D, Sam decided to pursue his PhD. He is currently beginning his fourth-year of graduate school at Tulane University’s Department of Chemical and Biomolecular Engineering. Under the guidance of Dr. Julie Albert, his research focuses on control of semicrystalline polymer thin film morphology via solvent vapor annealing. His career interests include industry research, intellectual property law, and consulting.

Antonia Chin, Kettering University

Antonia is a senior studying chemical engineering at Kettering University in Flint, Michigan. She is completing her thesis, conducting research on plasticizers. Antonia first encountered the coatings industry through a co-op with BASF where she assessed paint quality on automobiles. After observing the myriad of things that can go wrong with the final product, Antonia wanted to learn more and interned at PPG in the dispersions and pigments evaluation lab. During her time there, she worked on U.S. Department of Energy test models for dispersion quality using different resin technology. This experience has fueled her desire to become a coatings engineer.

At Kettering, Antonia serves as the vice president of Student Government and president of the International Club, and has held various leadership roles in the Plastics Engineering Club. Last year, Antonia participated in the 2018 SPE Thermoforming Conference RC Car Race Competition.

Haven Bontz, Pennsylvania College of Technology

Haven is a senior studying for a B.S. in Plastic and Polymer Engineering Technology and expects to graduate in the Fall of 2019. Since May 2017, he has held an internship with Consolidated Container Company in Oil City, Pennsylvania, where he has executed 5s plans and performed process validations.

Lexington Peterson, Pittsburg State

Lexington Peterson is a junior at Pittsburg State University in Pittsburg, Kansas. She is a double-major in plastics engineering technology and polymer chemistry.

This summer, Lexington is employed in a sustainability-oriented REU program (Research Experiences for Undergraduates, funded by the National Science Foundation) at the University of Maine. During the school year, Lexington is actively involved in the
Nathan Rader-Edkin, Pennsylvania College of Technology

Nathan is a senior studying Plastics and Polymer Engineering Technologies at Pennsylvania College of Technology in Williamsport, Pennsylvania. He currently serves as SPE Student Chapter President, and previously served as secretary. Nathan is also the current chair of SPE’s Next Generation Advisory Board (NGAB). He graduated from Pennsylvania College of Technology in 2015 with an Associate of Science Degree in Business Management.

This summer, Nathan is working as a molding intern with the Manufacturing Development Engineering team of the appliance unit at TE Connectivity’s headquarters in Harrisburg, Pennsylvania. Nathan expects to graduate with a B.S. in Plastics and Polymers Engineering Technologies in December 2019.
Thermoforming on The Chain

Are you on The Chain?

If not, you’re missing out on some great information exchange among thermoformers, sheet suppliers, toolmakers, and other industry experts. We offer a summary of the most followed threads in the past quarter. Questions and responses come from all over the world: US, Canada, Australia, Spain and Mexico.

You can access The Chain as part of your SPE membership benefits. Simply login to your account at www.4spe.org, click on “Conversations”, and join the discussion.

What do you call it?
And how do you fix it?

Thread started by Ed Probst
Posted 04-02-2019 17:23

Please see the attached picture. Almost every thermoformer has seen this condition - folds of excess material. I have two questions:

1. What do your setup or machine operators call this condition?
2. What are the first 3 things your set up staff does to reduce or eliminate it?

Posted 04-03-2019 08:37

Fun post Ed.
We call it webbing.
1. lower heat/screen the heater
2. slow vacuum timing
3. slow mould platten speed

This is assuming the flat area around the mould is required and you can not add any features to stretch the webs out (build a frame around it). We sometimes add web stretcher plates to the outside of the mould to pull the webs out. I’m assuming it has no ability on the equipment for putting an assist in and all the other engineering and modern equipment bells and whistles we have gotten use to using.

Todd Shepherd
Shepherd Thermoforming

Posted 04-03-2019 09:06

I refer to it as webbing. Use a smaller sheet if possible and a plug assist.

Kevin Harris,
Thermoforming Supervisor,
Drader MFG

Posted 04-04-2019 09:47

From the material property viewpoint, this happens when melt strength is low. Using lower MFR (higher melt strength material) material, lowering temperature, cooling this area with air prior to forming, reducing plug speed (allowing an unformed portion to cool), or adding more vacuum holes may help. If pre-stretched, increase balloon height. Interestingly, I heard of this issue in a large deep drawn part just recently when the material supplier was changed.

Amit Dharia, Ph.D.
Are you still producing too much waste?

Do you want to reduce production costs?

If yes contact us at gn@gncanada.com
Industry Practice

Posted 04-05-2019 08:54
We call it webbing. We would build a “moat” around the part. In essence, we would make something like a frame about 1” to 1.5” high a couple inches around the part creating the “moat”. There is usually some trial and error, but it works very well.

Rick Turman,
Reliable Formed Plastic

———

Posted 04-06-2019 12:47
That web can be very problematic when it comes to stacking and packaging the part. We had and still dealing with issues regarding webbing in a part which all started when we changed the supplier of our film. Narrower rolls to stretch out the film may help but you have to accommodate for the thickness. Here is a picture of our webbing as well.

Bruce Fakoory
VF Packaging Ltd

———

Posted 04-08-2019 12:57
A change in supplier could mean two things - the change in raw material or extrusion conditions. Both could have unexpected effects on forming. Not all ABS grades are the same, not all HDPE are the same, not all PET grades are the same. Further, not all semi-finished goods made from the same PET are the same. As they say - It is possible to produce a bad part from good semi-finished stock but impossible to make a good part from a bad semi-finished product.

Experienced thermoformers can always make process or tool changes to make it work but fixing material problems by changing the process often have consequences. It is better to understand the difference in key material properties. Unfortunately, there is not much the thermoformers can do except telling the sheet supplier that there something different.

In the case of webbing, the primary cause is lower melt strength or low melt elasticity, and mismatch TD and MD orientation. When melt strength is low, one can reduce the temperature, increase plug speed, or increase orientation.

The melt strength and melt elasticity changes when the material has degraded during extrusion or when excessive regrind is added. It could also change if the resin (e.g. comonomer type or content, viscosity or molecular weight, molecular weight distribution, filler type or sizing) or additive (e.g. carrier in CC) package has changed.

Technoform Thermoformability test can determine subtle differences in the sheet before forming. I would suggest thermoformers to at least try this test method. Knowing material response is far better and cheaper.

Amit Dharia, Ph.D.

———

Clarity Issues

Thread started by Philip Shelton (June 20, 2019)

Posted 8 days ago
My client is currently forming a round lid of Ø200 x 12mm on their pressure forming machine. The issue presents itself when he changes from PVC to PET. The formed PET lid is dominated by a milky, less opaque appearance as you will note on the image. When forming PVC, the lid has good clarity with no evidence of the milky discoloration.

Sheet thickness is 0.33mm. For obvious reasons, they are wanting to get away from PVC as it doesn’t fit in with their recycling plans.

Thoughts please.

Regards, Phil

———

Posted 7 days ago
You will likely get many similar replies on this. The tea staining is the de-nesting/mould release agent in the material, supplier issue you’ll need to alert them, hopefully you have other PET material you can run to compare with to prove your point, The milky frosted look, some can be related to the tea staining but can also be too much heat and you crystallizing the PET (whitens when this happens, turn up your heaters more and it should worsen). Back off your heaters from what you are at with the PVC and see if clarity improves.

Todd Shepherd,
Shepherd Thermoforming

———
Below what I would check:
1) The PET sheet looks like it has too much silicone for de-nesting. I would try with a different sheet.

2) Too much temperature or too much heating/pressure time will give this haziness appearance. Try to decrease the temperature 5 °C and look the clarity in spite of the well-formed shaped of the part. Then, if the clarity gets better, push the forming pressure up until you have the perfect formed part.

3) On this kind of flat lid with undercut on the perimeter I use to made a trick with the “Baffle” plate. The trick is too cool down the flat areas where you don’t need to form tricky things, and give more heat to the undercut perimeter. It’s risky because you have to cut the baffle plate but I can let you know if 1) and 2) doesn’t help.

Hope it helps,
Kind Regards
Federico Blanco,
PROMACOR SA

Both PET and r-PVC has about similar Tg, PET (70 C) and PVC (77 C). Both are formed in a relatively similar temperature range. PVC 110 C-140C, PET 120 C-140 C. PET has secondary or cold crystallization. If not process properly, this crystallinity will show up as haze or whiteness. If not dried prior to processing, PET will degrade via hydrolysis. A small amount of low molecular weight components such as moisture or monomer will lower Tg and enhance the crystallization rate. Orientation and residual thermal stresses in the sheet will also cause crystallization upon forming. I would check the processing temperature and moisture.
I see many dents and seems like it has either some contamination or moisture.

Amit Dharia, Ph.D.

Hello Phillip,
I couldn’t help but comment on your last statement, that “for obvious reasons, they are wanting to get away from PVC as it doesn’t fit in with their recycling plans.” The only thing obvious to me in reading this thread is that there is a lack of education about the recyclability of PVC, as no one seemed to challenge this assertion. There seems to be a massive myth and misinformation that is out there about PVC being ‘difficult’ or ‘impossible’ to recycle, and that could not be further from the truth. Educating your client on the recycling of PVC may be another non-technical solution to the problem. If you desire, please have your client contact the Vinyl Institute to discuss post-consumer PVC recycling that is already occurring across the country and the world. We can help your client contact any of the 100+ recycling companies in North America who are recycling vinyl materials. Alternatively, we may also be able to work with them on identifying grant funding to pilot recycling infrastructure that might place them as a sustainability leader for their efforts, rather than to focus on material replacement. Hope this spurs some additional thoughts around this issue, and perhaps some good discussion.

Best regards, Domenic DeCaria,
Technical Director, Vinyl Institute

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PET: From A to C

Upcycling of Mixed APET Bottle Flakes into Thermally Stable rCPET Food Trays

Enhancing mixed bottle flakes by turning them into extrudable recycled crystalline polyethylene terephthalate (rCPET) was the goal of a joint development project looking to close the gap in the PET recycling system. By successfully producing a sheet made from recycled material suitable for high-quality applications such as thermoformed food trays, Gneuss, Sukano and Illig have demonstrated that this approach is indeed possible.

The recycling of bottle flakes derived from PET bottle collection systems as implemented and practiced in Germany, Austria and Switzerland, for example, has so far focused mainly on transparent and monochrome PET flakes. These can be recycled relatively easily into transparent food packaging. However, multicolored PET flakes (Title figure) are suitable only for inferior applications, because they cannot be re-pelletized and extruded as reproducible homogenous PET due to their different colors. As a result, in the first quarter of 2019 in Germany, for example, multicolored PET flakes had a market value (500 to 700 EUR/t), roughly only half the value of transparent PET pellets made from virgin material (1100 EUR/t), or recycled transparent PET pellets (1300 EUR/t).

This cost-benefit advantage led to a novel collaboration among Gneuss Kunststofftechnik (Bad Oeynhausen, Germany), an extrusion technology company; Sukano (Schindellegi, Switzerland) an additive manufacturer, and Illig Maschinenbau (Heilbronn, Germany), a manufacturer of thermoforming systems for thermoplastics. As initial test results show, the treatment of APET waste materials can close a gap in the current recycling system. The project demonstrated that it is possible to enhance a mixture of APET bottle flakes – that until now has had only a marginal reusable value – to make reproducible, thermally stable rCPET (see Box), which can be extruded and re-formed into food-grade packaging in a thermoforming process (Fig. 1).

A further consideration in the project planning was the discussion about the migration of potentially hazardous substances found in aluminum food trays. Thermoformed
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and oven-safe food trays made out of recycled materials could be a good alternative. A further advantage of thermoforming in this process is the cost-effective production of high volumes of thin-walled, and thus resource-friendly, thermoformed parts that can be made in a short time.

**Homogeneous Melt with MRS Extrusion**

Colored A-PET bottle flake is characterized by wide variations in color, molecular weight and contamination levels, due to their previous lifecycle. This is where MRS technology (MRS = multi rotation extruder) comes in. In a single-screw extruder with a special degassing zone and satellite screws arranged around the main screw, there is a continuous exchange of material between the satellite screws at moderate vacuum conditions of 25 mbar (Fig.2). Thanks to the rapid, continuous surface exchange between the main screw and the satellite screws under vacuum, the surface exchange of the polymer melt is greatly increased, which allows for an extremely efficient devolatilization and decontamination of the polymer melt (Fig.3).

![Figure 2. Multi rotation extruder system with satellite screws arranged around main screw (© Gneuss)](image)

The polymer melt is homogenized, providing excellent material sheet properties for thermoforming in a later step thanks to the very evenly and consistent molecular weight distribution. Moreover, the extremely efficient mixing process in the MRS section facilitates the even distribution of additives such as a nucleating agent into the polymer melt. This procedure of distributing the additive equally into the material has the added benefit of consistent crystallization of the material sheet in the downstream thermoforming process and can thus be predictably controlled.

Because the MRS concept makes it possible to avoid thermal preconditioning of the material prior to extrusion thus eliminating the otherwise typical thermal stress caused by crystallization and drying, the process chain during the processing of the polymer is very short. The polymer melt is processed gently, preserving excellent physical and visual properties like high tensile strength and impact resistance, transparency and a low yellowness index rating (in the case of transparent sheets).

Not only the extruder itself, but also melt filtration is of particular importance for the sheet quality when processing rPET. That is why the Gneuss sheet line includes a process-constant, fully automatic backflush filtration system. The RSFgenius rotary filtration system reliably and efficiently removes contaminants such as solid particles from the polymer melt. For permanent process monitoring, an online viscometer measures the viscosity and thus serves as a quality-assurance instrument (Fig.4.)

Downstream from the MRS extruder unit, an rCPET sheet can be produced on a sheet extrusion line and used directly with an inline thermoforming machine, or wound up on a roll for later offline use.

![Figure 4. The timeline of the dynamic melt viscosity shows an increase from around 800 to 1000 Pas as a result of the addition of 1% rPET IV enhancer (© Gneuss)](image)
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Additives for Color and Crystallization

The properties of the PET bottle flake material is intentionally modified in the extruder by introducing additives. The rPET IV enhancer from Sukano elongates the molecular chain of the polymer and by doing so increases the molecular weight (Fig.5).

![IV-Enhancer](image)

**Figure 5.** Chain-growth polymerization mechanism using the rPET IV enhancer (© Sukano)

The additive also improves the melt viscosity, which benefits the processing of the plastic at a later stage. As for the sheet extrusion, the additive extends the processing window, increases processing speed, and improves the material sheet quality. Moreover, the additive ensures a higher impact resistance of the plastic.

With this treatment, PET is comparable to virgin APET in its physical properties, with the disadvantage of its non-transparency. Because of this, it is not suitable for transparent packaging. However, an oven-safe rCPET tray is normally opaque due to its high concentration of crystallites. Because of this, it makes sense to color the rAPET prepared in the MRS extruder with a masterbatch and to transform it into a sheet suitable for thermoforming using a crystallization agent. Sukano uses its own rPET crystallization masterbatch, which obtains good color results with thermally stable color pigments.

Sukano develops nearly every color the market demands. However, the most typical colors are white, beige and black. Black is a typical color used in rCPET trays, which is also the most widely used color in the production of CPET trays made of virgin material. A radar-camera sorting system developed by Fraunhofer researchers and dubbed “BlackValue” can identify and sort black rCPET and CPET food trays, as well as all other colored plastics, in real time and in large quantities in the stream of falling flakes [1].

The nucleating agent accelerates the crystallization rate of the plastic, making the formed rCPET trays oven-safe: Their form remains stable for at least 20 min at 200°C. Moreover, the nucleating agent is also key in the latter stages of the production chain in controlling the crystallization process during thermoforming, which improves the production stability of thermoforming the trays.

rCPET Food Trays

Gneuss MRS extrusion technology meets the requirements of various food safety regulators worldwide including the FDA, EFSA, Invima, Senasa, Anvisa for hotfill applications, and for room temperature storage. Similarly, Sukano’s rPET additives are suitable for food-grade polymers, ensuring that an rCPET monofilm is well-suited for packaging that has direct contact with foods.

Due to the increased migration at higher microwave and oven temperatures, the sheets used to form rCPET food trays are generally made with a co-extruded functional barrier of virgin materials for protection against contaminants in the sheet. Equally, in the final stages of the production of food trays, the thermoforming systems from Illig also comply with strict hygiene requirements with their integrated Cleanitivity™ concept for hygienically clean production.

Extrusion of the Sample Sheets with Different Additives

For the joint series of tests, Gneuss first produced a sheet without additives as a control sample from a batch of APET bottle flakes. This was followed by four more monofilms, which had different additive concentrations through gravimetric dosing (device type: Guardian, gravimetric batch blender for 6 components; manufacturer: Processcontrol, headquarters Birstein, Germany). All five sheets were 530 mm wide and 0.5 mm thick. An online viscometer monitored the melt viscosity during sheet extrusion, which as expected increased with the addition of the IV enhancer (Table 1). However, the increase in intrinsic viscosity (IV) was less pronounced for sheet 4 compared to sheet 3 at 0.01 dL/g, while a further increase in IV enhancer dosage by the same amount increased the intrinsic viscosity by 0.10 dL/g to 0.83 dL/g (sheet 5). Future testing needs to be conducted to explain the unexpected low effect of the low dosage.

Process-Controlled Thermoforming Technology

For the production of trays, a multi-dimensional radiant heater is required. This is necessary because the crystallization of PET sheet can only be controlled by precision zonal temperature control in both the lateral and longitudinal directions. The tool technology is also designed specifically for the PET process as a two-step forming tool with heated cavity walls (Tg < Ttool cavity wall < Ts) in the first forming tool and cooled cavity walls in the second tool (Ttool cavity wall < Tg), where Tg stands for glass transition temperature and Ts for crystallite melting
temperature of PET. In the first stage, the tray is given its form, receiving thermal energy for sufficient crystallization through contact with the heated tool cavity walls. The tool opens and the preformed ductile trays are moved along by the material transport into the second cavity with cooled tool cavity walls. The tool closes and in the second forming step the plastic hardens under contact with the cooled tool cavity walls, maintaining its shape while the crystallization process is completed – the formed trays are now oven-safe.

**Striking a Balance between Forming Accuracy and Thermal Stability**

From the five material sheet types, Illig produced food trays on their IC-RDK 80 thermoforming machine using an internal test tool with 2 + 2 cavities. During the entire series of tests, the first tool cavity of the two-step forming process was heated to 160°C and the second tool cavity was temperature-controlled to 20°C. The only exception was for material roll 1, the sample material roll made of 100% bottle flakes, for which the forming tools were temperature-controlled to 20°C. The temperature setting of the upper and lower heating in the machine varied from 245 to 290°C; all other process parameters remained constant.

The level of definition of the formed trays served as an important quality indicator as measured by the visible impressions made by the vacuum holes on the surface of the formed trays. In contrast to thermoforming rAPET, when thermoforming rCPET the forming accuracy decreases in proportion to the amount of heat added. This is because increased crystallinity increases the viscosity of the material sheet. This means, a well-defined formed tray can be an indicator for a low level of crystallization and thus for poor thermal stability of the formed part. When applying an additive in the manufacturing of a material sheet for the purpose of forming rCPET food trays, it is therefore essential to strike a healthy balance between an acceptable degree of forming accuracy and thermal stability.

Table 2 clearly shows that there are hardly any differences between the material rolls 2, 3 and also 4 in terms of their definition. From an upper and lower heater temperature of 270°C, the onset of crystallization seems to reduce the definition of the formed part. The rCPET food trays from material roll 5 are not well defined at the selected temperatures. With 92% PET bottle flakes, test roll 5 has the lowest percentage of raw PET compared to the nucleating agent.

**Oven Tests in Packaging Lab**

The oven tests at 200°C for 20 min were carried out in Illig’s packaging lab. One oven test was conducted immediately after thermoforming and a second test was carried out after an 18-hour storage of the formed food trays at a room temperature of 22°C to determine the influence, if any, of a possible post-crystallization. This proved however to be negligible, as no differences were detected.

The thermoformed food trays from the sample material sheet (APET without additives) were as expected not thermally stable, so that no visual evaluation was possible. The comparison of food trays formed from the sheets with additives showed that at a temperature of 270°C of both the upper and lower heaters, all food trays had a high dimensional stability. The food trays formed from material roll 5 were matte in appearance, which can be explained by having the highest concentration of the nucleating agent.

![Figure 6. Oven tests at 200°C for 20 min: rCPET trays (from left to right: rolls 2, 3, 4, 5); upper heater at 250°C; upper and lower heating, lower heater at 270°C (© Illig)](image)

![Figure 7. rCPET food trays made from material sheet 5 before and after the oven test at 270°C on upper and lower heater (© Illig)](image)
Apparently, as the percentage of nucleating agent increases, so does the thermal stability of the food trays. This effect is especially noticeable at a temperature of 270°C of both upper and lower heaters (Fig.7).

**Conclusion: Potential for High-Quality Applications**

Depending on customer requirements, a concentration of five percent of the nucleating agent from Sukano may already be sufficient to obtain high-quality, oven-safe rCPET food trays from previously low-value APET bottle flakes. Moreover, as the percentage of rPET-IV enhancer increases, so does the food tray’s impact resistance, which shows potential for high-quality applications of thermoformed rCPET containers in the refrigeration and deep-freeze sector.

With the growing demand for recycled pellets, in order to meet minimum recycled content requirements in the final products, the availability of transparent recycled PET is becoming increasingly scarce. One industry that makes use of multicolored PET flakes is the strapping industry, turning the PET flakes into packaging strapping. One of the reasons multicolored PET flakes are used for this purpose is because there are no restrictions in terms of food safety regulations. There is a surplus of multicolored PET bottle flakes on the market, but currently they are utilized only in a limited capacity. The joint development project considered economic, legislative and technical requirements and demonstrated that the recycling of multicolored APET blends into new high-quality products is indeed possible.

Upcycling instead of downcycling – upgrading the recycled plastic into food-grade rCPET is technically easy to implement and fills a gap in the PET recycling system. Thermally stable rCPET food trays as a high-quality final product are only one of many possible applications.

**Amorphous and Crystalline PET**

Polyethylene terephthalate (PET) collected from used bottles that have been shredded into bottle flakes is used as the initial raw material. Generally, a distinction is made between amorphous (APET) and crystalline polyethylene terephthalate (CPET). APET is known for its high transparency, while CPET has the advantage of being heat resistant, a property that enables formed parts (e.g. thermoformed food trays) to withstand oven temperatures of up to 200°C without deforming under the heat.

<table>
<thead>
<tr>
<th>Material roll number</th>
<th>Percentage of multicolor APET bottle flakes</th>
<th>Black nucleating agent</th>
<th>IV enhancer</th>
<th>IV [dl/g]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100% (control sample)</td>
<td>-</td>
<td>-</td>
<td>0.70</td>
</tr>
<tr>
<td>2</td>
<td>95.0%</td>
<td>5%</td>
<td>-</td>
<td>0.69</td>
</tr>
<tr>
<td>3</td>
<td>93.0%</td>
<td>7%</td>
<td>-</td>
<td>0.72</td>
</tr>
<tr>
<td>4</td>
<td>92.5%</td>
<td>7%</td>
<td>0.5%</td>
<td>0.73</td>
</tr>
<tr>
<td>5</td>
<td>92.0%</td>
<td>7%</td>
<td>1%</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Table 1. Material rolls with different additives (source: Illig)

<table>
<thead>
<tr>
<th>Material roll number</th>
<th>245°C</th>
<th>250°C</th>
<th>260°C</th>
<th>270°C</th>
<th>280°C</th>
<th>290°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Sufficient</td>
<td>Sufficient</td>
<td>Poor</td>
</tr>
<tr>
<td>3</td>
<td>*</td>
<td>Good</td>
<td>Good</td>
<td>Sufficient</td>
<td>Sufficient</td>
<td>Poor</td>
</tr>
<tr>
<td>4</td>
<td>Good</td>
<td>Good</td>
<td>Very good</td>
<td>Sufficient</td>
<td>Sufficient</td>
<td>Poor</td>
</tr>
<tr>
<td>5</td>
<td>Sufficient</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
</tbody>
</table>

- Trays not formed
* Propensity of material sheet to stick is too high.

Table 2. Forming accuracy for the thermoforming tests of the sample material rolls (control sample and rCPET) at different temperatures of upper and lower heaters (OHZ/UHZ) (source: Illig)

**Authors**

Sven Engelmann is Head of Product Division PB 2 & Head of Packaging Technology at Illig Maschinenbau GmbH & Co. KG, Heilbronn, Germany; sven.engelmann@illig.de

Christoph Stoye is Packaging Developer at Illig Maschinenbau; christoph.stoye@illig.de

Georg Sposny is Technical Editor Corporate Communications at Illig Maschinenbau; georg.sposny@illig.de

Dr. Carl-Jürgen Wefelmeier is Head of Business Unit Sheet at Gneuss Kunststofftechnik GmbH, Bad Oeynhausen, Germany, carl-juergen.wefelmeier@gneuss.com

Andrea Kossmann is Marketing Manager at Gneuss; Andrea.kossmann@gneuss.de

Daniel Ganz is Global Product Manager at Sukano AG, Schindellegi, Switzerland; daniel.ganz@sukano.com

Nicky Klammt is Senior Account Manager at Sukano; nicky.klammt@sukano.com

Janine Wyss is Marketing Communications Manager at Sukano; janine.wyss@sukano.com

**References**

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Effects of Vacuum Timing and Back Pressure on Wall Thickness Distribution

Harlie Sadler, Pennsylvania College of Technology

Abstract

Vacuum bleed dwell (VBD) and back pressure settings have a severe effect on wall thickness distribution (WTD) in the roll-fed thermoforming process. This speculation is proven in a two-phase experimental process, consisting of two process variables, measured difference in WTD, and design and execution of a design of experiment (DOE) to determine the amount of influence that the variables have on part thickness.

Introduction

Wall thickness Distribution (WTD) is a significant factor to consider while thermoforming, whether in thin or heavy gauge processing. Because of this, it is important to be able to measure and comprehend the effect that variables have on WTD in a part. Though an optimized cycle may be achieved, a fraction of a second change on any timer settings can cause differences or problems in a running cycle process. The reason that WTD is so important in the thermoforming process is because during processing there is a large amount of biaxial orientation that is provoked, which improves the mechanical properties of the part, which enables the thickness of the final part to be reduced without compromising the final product’s properties [1]. But if there is too much WTD there is a significant impact on mechanical properties evidenced by a large range of thick to thin sections throughout the part.

Once a cycle is optimized with appropriate oven temperature, changes in VBD and back pressure (otherwise known as vacuum venting) can be introduced to observe the difference in WTD. Though the heating profile of the sheet has a great impact on part features, these other variables are equally important to the quality of parts.

Completing a two-phase project has proven just that. Vacuum Bleed Dwell (VBD) and back pressure have significant impact on the distribution of material once the sheet is at the proper temperature to be processed in a mold. Phase I will show the impact of each variable change on the part; whereas Phase II shows the influence of the variable on a like process.

Materials

High Density Polyethylene material has characteristics that make thermoforming relatively difficult when compared to other amorphous materials. Temperature settings must be set higher than other polymers, meaning the sheet must receive more energy to be able to process, which in turn means higher internal processing costs. For example, for a .125-inch sheet, as used in this experiment, the core temperature must reach about 280 degrees Fahrenheit to appropriately form an acceptable part, whereas a .250-inch sheet of HIPS would only require a core temperature of 240 degrees Fahrenheit to form properly [2].

The other material ran but was not measured for wall thickness distribution was High Impact Polystyrene. As stated above, amorphous polymers are much easier to thermoform, because they do not require as much energy to heat up the sheet, and as the sheet is being formed it does not easily tear or cause webbing. HDPE is a much stronger material when compared to HIPS because of the high strength to density ratio [3].

Results and Discussion

Overview

The first part of this project was to optimize an HDPE cycle for 15 and 12 seconds, as a 19 second cycle has previously been optimized. This was an important part of the project as reducing cycle time can save companies money in the long run.
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Phase I

Phase I of this project shows just how the two variables, VBD and back pressure, affect wall thickness distribution on a part. Again, all thickness measurements made in this project were taken at the bottom center of the part. As seen in the graph below, Figure 3, there is a direct relationship between VBD settings and the thickness of the part.

Figure 1: Thickness vs. Cycle Time

Figure 1 shows the relationship between cycle time and part thickness at the bottom center of each part. It is clear that as cycle time decreases, so does the part thickness. Thickness at the 15 second cycle time is only 5% less than the 19 second thickness, and the 12 second cycle time thickness is 8% less than the 19 second cycle time.

Figure 2: Average Weight vs. Cycle Time

Figure 2 shows the relationship between the average part weights and cycle time. Unlike Figure 1 showing the relationship between thickness and cycle times, this graph is quite the opposite. As cycle time decreases, the average weight of a part increases. Though the weight difference looks significant in the graph, the 19 second cycle is only 4% less than the 12 second cycle, and the 15 second cycle is 2% less than the 12 second cycle.

One possible explanation is that more material is being pushed to the sides of the part rather than the bottom, where the measurements in this project have been taken.

Figure 3: Thickness vs. Vacuum Bleed Dwell

Figure 3 shows that as VBD increases, the thickness of the part also increases. This trend is constant between each of the cycle times. The reason is because when the time setting is set to a lower time, the vacuum is initiated before the plug is introduced fully into the sheet. This causes the bottom section to be quite thinner than desired thickness (being the second data point on each line within Figure 3). This is not desired for two reasons: a thin-bottomed part can easily be damaged and that the walls of the part are thicker than normal.

On the other hand, as vacuum timing is delayed, the plug can accurately distribute material. When the vacuum comes on too late, however, the plug is completely indexed into the sheet, causing a thicker bottom than desired. In general, when the bottom thickness is thicker than usual, this means that the material is getting taken away from the sides of the product, creating a thick-bottomed and thin walled part that is out-of-spec.

While VBD is proven to have a direct impact on wall thickness distribution, the results from back pressure are not as assuring. This is proven by Figure 4 below.

Figure 4: Thickness vs. Vacuum Venting

We see that as VBD increased, the wall thickness increased. As the units increase, the thickness both increases and decreases between the different cycle times. Though there is no constant change, it is obvious that vacuum venting...
does make a difference as the line for each cycle time has much difference when going across the graph. The impact of vacuum venting is further explained in Phase II of the experiment.

**Phase II**

Phase II of this experiment was strictly to focus on the DOE that was performed. This phase was completed using the 12 second cycle time after finding an optimized cycle in phase one. The DOE values for VBD were 1450 and 1750 milliseconds, and the vacuum venting valve settings from 0 and 6 (0 being valve closed = maximum backpressure; 6 being valve 100% open = zero backpressure). These values were chosen for the DOE to represent best- and worst-case scenarios. A DOE was performed to calculate the correlation and the impact each factor, vacuum bleed dwell and vacuum venting, has on part thickness. In addition, the measurement locations for Phase II of this experiment were different than Phase I.

In Phase I, all measurements were taken at the bottom center of the finished parts after production. In Phase II, strictly based on WTD, not just one measurement was taken on the finished part. Instead, the WTD was measured around the whole part, from the one side, to the bottom, and to the other side. This allows multiple measurements on the part, and in turn taking the maximum thickness of the part and subtracting it from the thinnest section of the part. This allows a superb WTD measurement that can be used to complete a DOE for this phase. The following graphs are from the DOE experiment spreadsheet that shows the correlation and the effectiveness of the variables in the process.

**Conclusions**

As vacuum bleed dwell increases in time, the thickness of the bottom center of the part also increases. When vacuum venting increases, there is no direct correlation to the thickness. Decreasing cycle time decreases the average thickness of the parts.

**Acknowledgements**

Chris Gagliano, Pennsylvania College of Technology
Kirk Cantor, Pennsylvania College of Technology
Primex Plastics

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A56 TSL Machine OEM

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SPE Thermoforming Quarterly 29
Thermoforming and In-situ Crystallization of Kepstan® PEKK

By Roderick Reber III, Arkema, King of Prussia, PA

Polyaryletherketones (PAEK) are a family of ultra-high performance semicrystalline thermoplastic materials known for their extreme strength, chemical resistance, low flammability, and high use temperatures. The PAEK family includes PEK, PEEK, PEKK, PEEKK and PEKEKK among others. In their semicrystalline state PAEKs have among the best chemical resistance and Heat deflection temperatures (HDT) of as high as 240°C. However, the fast crystallization rate of most PAEKs makes them difficult or impossible to thermoform, especially in applications requiring thick gauge or deep draw ratios.

1. The increased ketone content results in a stiffer backbone and subsequently a higher Tg. PEKK has a Tg of 160-165°C for PEKK versus about 145 for PEEK.

2. PEKK is a copolymer consisting of terephthaloyl (straight) and isophthaloyl (kinked) moieties. By varying the ratio of these two units, the T/I ratio, it is possible to control the melting temperature, crystallization rate, and overall crystallinity of the polymer. PEKK copolymers range from pseudo-amorphous with low melting temperatures (305°C) to highly crystalline with extremely high melting temperatures (365°C+).

By using a PEKK copolymer with the optimum T/I ratio, it is possible to extrude an amorphous sheet that will crystallize slowly enough that it can be formed, but quickly enough that it can be crystallized on a heated mold within a reasonable cycle time. This In-process crystallization is a common practice for many thin gauge materials. For example PET is routinely thermoformed and crystallized during the forming process. The tunable crystallization rate of PEKK opens a new window to utilize the extreme performance of a semicrystalline PAEK in a thermoforming process.

Figure 2 shows the crystallization half time of the PEKK copolymer with a suitable T/I ratio for thermoforming. The process for thermoforming + crystallization is relatively straightforward, the sheet is heated to a temperature range above its Tg where it softens, but crystallization occurs very slowly. In this temperature range, the sheet can be formed to deep draw ratios with a wide enough process window before the sheet begins to crystallize and subsequently stiffen. If the mold is heated to a temperature where crystallization occurs most quickly, the part will quickly begin to crystallize and turn opaque. For many thermoformers accustomed to fully amorphous materials, it may seem counter-intuitive to use a mold temperature hotter than the forming temperature, but once crystallization begins to occur, the sheet undergoes a dramatic stiffening.

Figure 1: PEKK chemical structure terephthaloyl (left) and isophthaloyl (right)

Figure 2: crystallization half time for a suitable PEKK grade.
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To demonstrate the unusual temperature profile used in this process, we recorded the process with a thermal camera. In Figure 3 it is clear that the part is actually hotter at the end of the forming process than when first removed from the oven.

To confirm crystallization had occurred, wide angle x-ray diffraction (WAXD) was performed on the segment of the sheet in contact with the mold as well as a segment of the sheet that had not been formed. Figure 4 shows the formed section developed 29 wt. % crystallinity, almost identical to a value measured on an injection molded part. The crystalline area will have increased stiffness, a higher HDT, and improved chemical resistance.

We have demonstrated this process on both laboratory and production scale equipment on sheet thicknesses from 250 µm through 3 mm (10 mil – 1/8”). The overall cycle time varies, but the rate limiting step with thick gauge sheets is heat transfer through the sheet itself. The process time for thick gauge sheets can be reduced significantly by using a matched mold.

With the simple addition of a heated mold, almost any standard thermoforming equipment can be used to thermoform semicrystalline Kepstan® PEKK parts. The mold temperature required for this process may be slightly outside of the standard processing window, but is accessible with a suitably designed oil or electrical heating required.

Arkema recently announced a major expansion of Kepstan® PEKK capacity with a brand new, world-scale production unit at our Mobile, Alabama site. For more information on in-process crystallization of thermoformed Kepstan® PEKK, please contact Arkema directly. www.kepstan.com.
There is no substitute for the experience we’ve gained by rolling up our sleeves and working through improvements at every stage of thermoforming technology for over six decades. From process design through putting high-output machinery on the floor, innovation is in our DNA.
RelFocus 2019

By Conor Carlin, Editor

The RelFocus Sustainability and Recycling Summit is the flagship environmental conference for PLASTICS, the plastics industry’s trade association. May 2019 marked the 4th annual gathering, held in Grand Rapids, Michigan, and drew over 200 delegates from around the world. With keynote speakers from Aveda and National Geographic, the event covered technical, political, and social developments related to plastics in many forms and many arenas. The continued scrutiny of the plastics industry injected a sense of urgency into the proceedings. Many speakers and panelists presented updates and new developments geared toward “managing the unmet needs of plastic waste.” The event also showcased new innovations in sustainable plastics manufacturing, with 5 awards adjudicated by the SPE Sustainability Division.

The Alliance to End Plastic Waste

Much ink has been spilled in the months following the announcement of the formation of a global consortium to address plastic waste in the environment. A cadre of blue-chip multinational companies have committed $1.5 billion to invest in education, infrastructure, innovation, and clean-up. Several speakers from Alliance members, including Dow, Chevron Philips, Eastman, Sabic, and LyondellBasell, mentioned their company’s role in the project. So far, 360 proposals have been received, with 5 initial projects identified: the creation of a global information platform to share data; strategic partnerships with cities to manage urban waste; funding via Circulate Capital and 2nd Muse; collaboration with the United Nations, in particular with the UN’s Sustainable Development Goals (or SDGs); and the “Renew Ganga” river clean-up project in collaboration with Renew Oceans.

Although the focus of the Alliance’s clean-up projects is in South East Asia, the member companies are mostly based in the US and Western Europe where R&D projects continue apace. Speakers from Dow, Eastman, and Sabic outlined different approaches to managing thorny problems of mixed plastics recycling. Dr. Brian Walther of Dow explained how his team thinks about it: complex chemical architectures are required due to the complexity of mixed polymer structures, e.g., multi-layer barrier films. The mixture of polar and non-polar materials creates inherent incompatibility. A reduction in interfacial tension is therefore required to improve compatibility. Dow’s portfolio of compatibilizers includes polymer modifiers, olefin block-copolymers, and copolymer alloys. This last category (under the tradename “Elvaloy®”) of processing aids can be used to increase the drawability of PET/PE waste streams. In one case study, Walther illustrated how Elvaloy® boosts viscosity levels in PET thermoforms making it easier to reprocess a higher percentage of them in applications where bottles and thermoforms are recycled together. This has important implications for recycling programs that are reconsidering whether thermoformed containers can be accepted in their streams.

LyondellBasel is investing in a portfolio approach that includes vertical integration through the acquisition of mechanical recyclers, development of molecular recycling technology, and the creation of a new bio-based product family called Circulen. A recent collaboration with Samsonite, a luggage manufacturing company, resulted in a new suitcase family made from 100% PCR PP for the outer shell and 100% PCR PET for the interior fabric. The product is currently only available in Europe and is reported to sell for a premium over standard luggage. (Samsonite also has a line of soft fabric suitcases called “Eco-Nu” featuring 100% PCR PET from bottles.) As a global company, LB presented data showing stark differences between the US and the EU when it comes to recycling plastics. Due to extensive landfill bans in the EU (and conversely, the relative lack of regulation in the US), the EU currently recycles or incinerates 73% of plastics vs. 25% in the US. As was pointed out elsewhere at the conference, a significant challenge for US recycling is the smorgasbord of legislative requirements preventing any type of uniform approach that be developed and enforced across state lines.

Eastman presented details on its pursuit of advanced recycling technologies through a carbon renewal approach that converts end-use products from mixed plastics back to carbon and hydrogen molecules. By focusing on polyester-based polymers, the company seeks to make DMT and ethylene glycol at commercial scale. According to company figures, they are 2-3 years away from commercialization.

Sabic announced the launch of a new line of “upcycled compounds” designed to extend the life of PET bottles. The LNP ELCRIN™ iQ portfolio of polybutylene terephthalate (PBT) resins is derived from rPET, essentially taking a single-
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use polymer and transforming it into a durable polymer. This reduces the need for virgin, fossil-based PBT while enhancing circularity efforts for PET. A life cycle analysis shows that between 19% - 66% of the new compound is renewable content. The company has also developed renewable naphtha from 2nd generation cellulosic feedstocks, i.e., materials derived from wastes or residues and that do not compete with food production. Because their existing steam crackers were designed with a degree of flexibility, animal and vegetable oils can be cracked without modification, thus maximizing current assets and avoiding the need for a major capital investment in a low volume application. Sabic uses the ISCC+ certification process to ensure the traceability of feedstocks and to prove the chain of custody along the supply route. The ISCC system relies on a mass balance approach to accounting which generally means that for each ton of circular feedstock fed into a cracker (displacing fossil-based feedstock), a ton of output can be therefore be classified as circular.

**Addressing the Challenges of Recycling**

Materials Recovery for the Future (MRFF) is a project funded by the American Chemistry Council and managed by Resource Recycling Solutions, a consultancy. In 2016, the group released a report “…showing that automated sorting technologies in use today can be optimized to capture flexible plastic packaging, potentially creating a new stream of recovered materials while improving the quality of other recycling streams.”ii This was notable, in part, because the majority of MRFs in the US are using sorting technologies that were developed before the arrival of so many different types of polymer-based packaging. Cardboard, glass, aluminum and paper were the primary packaging materials at the dawn of the MRF era. Nestle Purina is a research partner in the MRFF consortium. Diane Herndon, VP of Corporate Social Responsibility for the company, presented an overview of a new pilot program that seeks to build on the 2016 project findings. The vision of the MRFF partners is to ensure that flexible packaging is recycled at the curbside and adequately sorted at recovery facilities such that – critically – those members of the supply chain can capture value from it. In other words, short of a profit motive, there will not be an incentive for recyclers to invest in the necessary equipment to separate flexible films from fibers. Of course, given the impact of China’s National Sword policy and the recent passage of the Basel Convention, (not to mention the sight of containers full of waste plastic being shipped from South East Asian countries back to Europe and Canada), contamination levels will have to decline in developed markets in order to satisfy market demands. Still, there are many factors in the US which affect the economic feasibility of flexible package recycling including capital expenditures in new sortation equipment, manual labor costs at MRFs, and regional disparities, especially in the case of landfill tipping fees which heavily influence recycling markets. Yet as Herndon pointed out, improved sortation not only reduces contamination of fiber-based materials leading to higher prices, it also creates a new “rFlex” bale of polymer-based materials. Developing this new class of bale and monetizing it is the goal of the 2019 pilot program which is being run at JP Mascaro & Sons, a large integrated MRF in Berks County, PA.

**Legalize It (or Regulate It)**

Shannon Crawford, Director of State Government Affairs for PLASTICS, provided a summary of current and pending legislation. An increasing number of state governments are taking their cues from both European Union regulations and United Nations efforts to deal with plastics waste. The passage of the Basel Convention, scheduled to be implemented in 2021, will require prior informed consent from recipient countries before plastic waste can be exported. Even though this has international consequences, the majority of bills introduced in the US are driven by local interests at state and municipal levels. 436 bills have been introduced in state legislatures to regulate packaging, and 618 local restrictions are in effect, with 194 more recently passed or under consideration.iii Bags are the single most affected product, with EPS items, straws, and cutlery also being banned.

To address these developments, PLASTICS is introducing the RECOVER ACT (“Realizing the Economic Opportunities and Value of Expanding Recycling”). The act is designed to boost investment in the US recycling sector through EPA grants, state-run programs, and municipal entities. Crawford was cautiously optimistic that the bill will soon have a sponsor in Congress. Yet in her call to action to the audience, it remains clear that private sector investment in technology and equipment is desperately needed now. When one considers that the value of waste feedstocks – 16MM tons worth $5.2bn – have not been fully appreciated by US markets, it seems that our system here faces an imminent reckoning from both economic and regulatory forces. Perhaps the market signals are slowly being recognized: the CalRecycle grant program received requests for $33MM, but could only fund $11MM.
**Enlightenment & Alignment**

National Geographic has done as much as any entity to increase the visibility of the global scourge of marine debris and plastics pollution in our oceans. Their iconic magazine cover has inspired change around the world, with myriad initiatives underway to clean up rivers and seas and to reduce the amount of single-use plastics that reaches the ocean. Valerie Craig, VP of Operating Programs for the National Geographic Society, presented details on multiple new programs. Craig struck an optimistic note, despite the dire images from Haiti, Vietnam, Indonesia, and other countries where infrastructure is lacking or absent. For instance, Manila, capital of the Philippines has 17 jurisdictions for waste management. She stressed that while plastics are not inherently bad, they must be prevented from entering and destroying natural ecosystems. This can be done by identifying points of intervention, one of which is at the materials design phase of production. We simply cannot continue to develop packages that do not consider end-of-life concerns. This point was echoed by Susan Graf, director of the MRFF project where multi-layer spouted pouches were specifically called out as problematic. Brands, in particular, must do more to ensure their designers are fully equipped with the knowledge and tools to incorporate design for environment (DfE) principles into prototypes and ultimately into new commercial packages. Continued work on the “How2Recycle” labels shows promise in this regard and also serves as an example of how to harmonize information and reduce confusion for consumers. Melissa Craig, Senior Manager for Packaging Sustainability at Unilever, stated that her company will have these labels on all of their products by 2021.

The scale of the challenge remains daunting, however, and all panelists at the closing plenary emphasized the obstacles we face in the US given our fragmented recycling laws and systems. This is perhaps the single biggest impediment to overall recycling progress, a fact now recognized by PLASTICS as they seek to drive federal legislation, but where they also face competition in the form of other lobbying groups. Beyond packaging, for example, recycled HDPE pipe is an ideal replacement for concrete, unless you happen to work in the concrete industry.

A quote from Enrico Siewert’s presentation captured the status quo neatly: “When economic self-interests are aligned with public policy and social consciousness, the world changes.” The clock is ticking for many economic self-interests these days, with social license for plastics in the crosshairs of both public policy and social consciousness. Yet the opportunity for recycled plastics is real, if just over the horizon in terms of technology and investments. Projections by McKinsey suggest a compound annual growth rate (CAGR) of 7-17% for chemical and mechanical recycling through 2050iv. It is incumbent on all of us to ensure that alignment happens in the short term.

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i. Sources include ISCC and Sabic websites
ii. www.materialsrecoverforthefuture.com/research-results
iii. “Industry Solutions for Addressing Plastics Waste”, presentation delivered at ReFocus 2019 by S. Crawford
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2019 Thermoformer of the Year

Thomas Haglin

A native of Brainerd, Minnesota, Mr. Haglin is a graduate and Hall of Fame inductee of Brainerd High School and earned his bachelor's degree in Management from the College of St. Scholastica in Duluth, Minnesota in 1987. Upon graduating college, Mr. Haglin began his professional career in sales with Acrometal Companies – LARCO Division in Brainerd, was promoted to Plant Manager and quickly demonstrating his versatility, business acumen and keen eye for opportunity, was entrusted with identifying potential acquisition targets for his employer.

In 1993, Haglin eyed-up one such company: a small thermoforming business - Shovel Lake Industries (Remer, Minnesota) - which among its modest product offering manufactured outdoor air conditioner covers, with annual revenues of approximately $650,000. After in-depth analysis of the company’s margin performance and growth potential proved too good to pass-up, Haglin and his wife, Ellen (nee Darkow), who’ve been married since 1988, made the bold move of acquiring Shovel Lake Industries themselves, secured financing through a local bank, and in the summer of 1993 found themselves the owners of a thermoforming business.

As the acquisition was completed, the nascent entrepreneurs changed the company name to Mid-State Plastics and in May 1994, purchased land in the Baxter Industrial Park. By August 1994, as their new, 12,000 sq. ft. facility was built and fully operational, the Haglin’s decided once again to change the business name, this time adding a more personalized touch by combining letters of their last names – HagLIN and DARkow – to create LINDAR Corporation, which grants the business to this day.

In the ensuing 18 years, LINDAR has since grown to 175 employees and operates nine (9) roll-fed machines, eight (8) sheet-fed formers, six (6) CNC routers, four (4) robotic routers, one (1) label line and one (1) extrusion line in its state-of-the-art, 165,000 sq. ft. manufacturing facility, driving annual revenues exceeding the $35 million mark.

Throughout his years at LINDAR’s helm, Mr. Haglin has maintained a strategic focus on diversification of its manufacturing capabilities, product offering and customer base, alongside whom LINDAR has steadily grown and prospered throughout the past 25 years. It was this desire to diversify that led Mr. Haglin to partner with Daniel and David Fosse of Innovative Packaging to create the Intec Alliance, which eventually was fully absorbed into the LINDAR business.

Prior to establishing this partnership, LINDAR’s manufacturing capabilities revolved primarily around heavy-gauge, sheet-fed thermoforming for its OEM customer base; the Intec Alliance connected LINDAR with a new market opportunity: a proprietary, thin-gauge roll-fed food packaging product line now marketed under the LINDAR brand name.

Concurrent with the rapid growth of LINDAR’s proprietary food packaging product line, Mr. Haglin made a significant investment in roll-fed thermoforming equipment, and currently operates nine (9) machines, numerous routers and ancillary equipment to support its food packaging business. Further, in-house grinding and recycling of trimmed, unused and scrap material, widespread usage of bio-based materials and proprietary extrusion capabilities help address environmental sustainability while optimizing manufacturing cost-effectiveness.

As he has built a world-class thermoforming business, and consistent with his deeply engrained desire to give back, Mr. Haglin is closely connected and involved with the Brainerd Lakes area, serving the community in numerous ways.

Further underscoring his commitment to his hometown community, in 2012, Mr. Haglin acquired the then-Lakeland Mold Company (now Avantech) in Brainerd, Minnesota, a pre-eminent supplier of tooling for the rotational molding and thermoforming industries. With a desire to keep jobs in the community, provide continued career opportunity for employees, and add a qualified tool-builder to his business portfolio, Haglin has since made a significant investment in a new, state-of-the-art manufacturing facility in the Baxter Industrial Park (opened in 2016), CNC machining equipment and highly skilled personnel to drive the Avantech business forward.
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Remembering A Long-Time Board Member: Jim Armor

Jim Armor joined SPE as a member of the Thermoforming Division in 1960. He began his career in the plastics industry by selling thermoplastic sheet in 1961. In 1965, Jim and Milo Hanson started Alchem Plastics in California, and facilities in Georgia, Texas, New Jersey and Missouri followed. The company then began co-extruding multilayer sheet in HIS, ABS, Polyethylene and Acrylic ABS sheet, and the organization subsequently developed into a major sheet extrusion company.

Alchem Plastics was sold to Spartech Plastics in 1980, and Jim stayed on as president of Alchem/Spartech until 1984. In 1985, Jim started Agile Enterprises, an extruder of Acrylic, Polystyrene and Propylene sheet, and held the position of President until 1987. Jim then became President of Alplastic, a roll fed thermoformer and sheet extruder, where he remained until the company was sold in 1991. He then joined Primex Plastics as Western Regional Manager and National Marketing Manager. He launched Armor & Associates in June 1998 and sold thermoplastic sheet.

Jim was active in the Thermoforming Division for many years as a long-time board member, and Chair of the Materials Committee. He delivered numerous presentations to SPE groups on various plastic sheet thermoforming applications. Jim was named Outstanding Board Member in 2003, and Emeritus Board Member in 2018. He was also a member of The Plastics Pioneers in California.

Jim resided in Huntington Beach, California, with Linda, his wife of 59 years.

Remembering Past SPE Thermoforming Division Chair: Walt Walker

Past SPE Thermoforming Division Chair, Walter “Walt” James Walker, passed away on July 2.

Walt Walker worked for the 3M Company for 16 years and later retired as the Chief Operating Officer of Prent Corporation, where he spent 28 years of his career. Prent Corporation is a thermoform medical, electronics, and consumer packaging company located in Janesville, Wisconsin.

Over the years, Walt served on the SPE Thermoforming Division Board of Directors and in the role of Division Chairman from 2006-2008. Walt was presented with the SPE Thermoforming Division’s Lifetime Achievement Award in 2008. He also served on the Board of Governors of the Society of the Plastics Industry (now Plastics Industry Association) for three years.

Walt was very engaged in his local area where he served on the boards of the Noon Rotary Club, Blackhawk Technical College, and KANDU Industries. Walt had a fantastic sense of humor with just a touch of that sharp Irish wit. Walt is survived by his wife, Barb, his children and many grandchildren.

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MACHINERY COMMITTEE
James Alongi
MAAC Machinery
590 Tower Blvd.
Carol Stream, IL 60188
T: 630.665.1700
 jalongi@maacmachinery.com

Steven Clark (Chair)
Monark Equipment
PO Box 335
4533 S. Garfield Road
Auburn, MI 48611
T: 989.662.7250
sclark@monark-equip.com

Brian Golden
SencorpWhite
400 Kidd's Hill Road
Hyannis, MA 02601
T: 508.771.9400
bgolden@sencorpwhite.com

Travis Kieffer
Plastics Unlimited, Inc.
303 1st St. N.W.
Preston, IA 52069
T: 563.589.4752
TravisK@plasticsunlimited.com

Brian Winton
PTi
2655 White Oak Circle
Aurora, IL 60521
P: 630.585.5800
E: bwinton@ptietraders.com

MATERIALS COMMITTEE
Juliet Goff
Kal Plastics
2050 East 48th Street
Vernon, CA 90058-2022
T: 323.581.6194
juliet@kal-plastics.com

Roger P. Jean (Chair)
Simona PMC
PO Box 1605
2040 Industrial Drive
Findlay, OH 45840
T: 567.208.9758
Roger.Jean@simona-pmc.com

Phillip Karig
Mathelin Bay Associates LLC
11939 Manchester Road #148
Saint Louis, MO 63131
T: 314.630.8384
karig@mathelinbay.com

Ian Munnoch
MSA Components, Inc.
6556 County Road KP
Mazomanie, WI 53560
T: 812.322.5080
imunnoch@msacomponents.com

Matt O’Hagan
LyondellBasell
7674 Park Meadow Lane
West Bloomfield, MI 48324
T: 248.760.8590
matt.ohagan@lyondellbasell.com

Laura Pichon
Ex-Tech Plastics
PO Box 576
11413 Burlington Road
Richmond, IL 60071
T: 847.829.8124
lpichon@extechplastics.com

Ed Probst
Probst Plastics Consulting
PO Box 26365
Wauwatosa, WI 53226
T: 414.476.3096
ed.probst@probstplastics.com

Eric Short
SIMONA PMC
2040 Industrial Drive
Findlay, OH 45840
T: 567.525.4924
eric.short@simona-pmc.com

Dan Sproles
Sproles Business Consulting
5210 Canton Street
South Bend, IN 60071
T: 574.747.7997
dan@sprolesbusinessconsulting.com

Paul Uphaus
Primex Plastics
4164 Lake Oconee Drive
Buford, GA 30519
T: 1.800.935.9272
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PROCESSING COMMITTEE
Jim Arnet (Chair)
Hagans Plastics Co.
121 W. Rock Island Road
Grand Prairie, TX 75050
T: 972.974.3516
jarnet@hagansus.com

Robert Browning
McConnell Company
P.O. Box 450633
Atlanta, GA 31145
T: 770.939.4497
robert@thermoformingmc.com

Evan Gilham
Productive Plastics
103 W. Park Drive
Mt. Laurel, NJ 08054
T: 856-778-4300, x225
EGilham@productivecompanies.com

Bret Joslyn
Joslyn Manufacturing
9400 Valley View Road
Macedonia, OH 44056
T: 330.467.8111
bret@joslyn-mfg.com

Stephen Murrill
Profile Plastics
65 S. Waukegan
Lake Bluff, IL 60044
T: 847.604.5100 x29
smurrill@thermoform.com

Jay Waddell
Plastics Concepts & Innovations
1127 Queensborough Road
Suite 102
Mt. Pleasant, SC 29464
T: 843.971.7833
jwaddell@plasticconcepts.com

Steve Zamprelli
Formed Plastics, Inc.
297 Stonehinge Lane
Carle Place, NY 11514
T: 516.334.2300
s.zamprelli@formedplastics.com

DIRECTORS EMERITI
Lola Carere
302 Sable Trace Ct.
Acworth, GA 30102-7617
T: 770.883.7055
carerelola@comcast.net

Richard Freeman
Freetech Plastics Inc.
2211 Warm Springs Court
Fremont, CA 94539
T: 510.651.9996
rfree@freetechplastics.com

Steve Hasselbach
CMI Plastics
222 Peps Way
Ayden, NC 28513
T: 252.746.2171
steve@cmiplastics.com

Donald Hylton
McConnell Company
646 Holyfield Highway
Fairburn, GA 30213
T: 678.772.5008
don@thermoformingmc.com

Roger Kipp
Roger C. Kipp Consulting
3C Owens Landing Court
Perryville, MD 21903
T: 717.521.9254
srkipp@msn.com

Gwen Mathis
6 S. Second Street SE
Lindale, GA 30147
T: 706.346.2786
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