Recycling: A Clear Solution?

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- Using Rheological Tools in Thermoforming
- University RC Car Race Competition
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“20/20” implies normal vision, not perfect vision, as many of us may think. According to the American Academy of Ophthalmology, a person with 20/20 vision “can see what an average individual can see on an eye chart when they are standing 20 feet away.” 20/15 vision, therefore, is sharper vision, meaning that you can see a line in the eye chart from 20 feet that others can only see from 15 feet. Only about 35% of us have 20/20 vision, which means those of us in plastics involved with lenses should have a recession-proof business!

We often try to forecast the future in business. We talk about crystal balls and seeing around the corner, but more often than not we get it wrong. Many financial analysts say that trying to forecast beyond 12 months is a fool’s errand, yet we see plenty of market reports with CAGR estimates for a 5-year period, e.g. “bioplastics set to grow 18% from 2017-2022”. In recent months, we’ve heard a lot about “uncertainty” – tariffs, global threats, Brexit, coronavirus, etc. This doesn’t instill confidence in anyone’s plans.

This year promises more in the way of change, though how it will play out remains to be seen. New regulatory regimes across different US states, and all EU countries, will impact how plastics is manufactured, converted, taxed, and recycled. We are all familiar with the groundswell of support among citizens for action against plastics pollution, but solutions are proving to be difficult. Paradoxically, plastics are proven to be environmentally sound when compared to other materials. Sometimes we have to go back to the beginning to understand some foundational questions. In recycling, for instance, do we even know why the triangles and numbers are there? We explore this on p.38. Results from new recycling-focused collaboration in Europe are presented in pp. 34-35.

Despite the uncertainty, our industry continues to advance. In our lead technical article in this issue, we explore barrier materials in-depth (pp.24-29). Consumer tastes have always been a driver for plastics packaging, with several major macro-level trends playing out around the world: mass customization; new delivery methods; single-serve or portion-based packs; extended shelf-life. What the average consumer uses and discards in the matter of minutes most certainly went through a lengthy and costly process of design, production, and quality control. Manufacturers and converters continue to invest in new technologies that reduce waste, error, and, in the case of automation, labor.

Further upstream in the value chain, scientists are still working on predictive modeling tools to improve the thermoforming process – more science, less black art. Researchers from The Dow Chemical company present findings from a study that was “… undertaken to define new rheological tests that were capable of defining the molecular design required to avoid excessive sag in the heating stage of thermoforming.” The complete report and supporting data are found on pp. 12-22.

In events news, our colleagues in the European Thermoforming Conference will be hosting around 150 people in Geneva, Switzerland next month (March 18-20). In keeping with the global zeitgeist, the key topic is recycling / circular economy. Speakers from Danone and Nissan will headline the event. I encourage you to review the technical program and consider attending this impressive conference. It’s not too late to register.

Signing off,

Eric
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Genpak to Make Food Containers with Bioplastics from Danimer Scientific

Frank Esposito, Plastics News Staff

February 4, 2020 – Bioplastics maker Danimer Scientific will supply thermoforming giant Genpak LLC with material to make biodegradable food containers.

In a Nov. 12 news release, officials with both firms said the eco-friendly foodservice items created by the two companies “will help reduce the environmental impacts of nonbiodegradable packaging produced annually worldwide.”

Over the course of the multi-year agreement, Bainbridge, Ga.-based Danimer Scientific will deliver several million pounds of biodegradable resins that Genpak of Charlotte, N.C., will use in its new GenZero-brand line of food packaging products.

Danimer Scientific will include Nodax-brand polyhydroxyalkanoate (PHA), which officials described as the firm’s signature biopolymer, among the resins that it produces for GenZero food containers. Nodax is a plant-based material that officials said was verified as a reliable biodegradable alternative to traditional petrochemical plastics in a 2018 study led by University of Georgia researchers and members of the UGA New Materials Institute.

“Innovation is a core foundation of our manufacturing philosophy, and it has driven the development of some of our most durable and sustainable packaging items,” Genpak President Kevin Kelly said in the release. “Partnering with Danimer Scientific provides us with the cutting-edge material we need to take the next step in our dedication to our purpose statement of advancing innovative packaging to enhance the human experience.”

Danimer Scientific CEO Stephen Croskrey added in the release that plastic “is a universal material used in countless everyday products, especially in the food and beverage industries, so it’s imperative to broaden the conversation around the type of items we can make with biodegradable materials.”

Genpak’s line of foodservice items are designed for a wide range of applications, including to-go hinged food containers, plates, bowls and platters, serving trays and two-piece food containers. Officials said that the GenZero biodegradable products will build on the company’s focus for sustainable packaging options.


Danimer Scientific holds 125 patents in nearly 20 countries for a range of manufacturing processes and biopolymer formulations. Applications for the firm’s biopolymers include additives, aqueous coatings, fibers, filaments, films, hot-melt adhesives and injection molded items.

Fraunhofer IVV Developing R2R components for New In-Mold, Thermoformed Electronics

First published February 13, 2020 in Converting Quarterly Magazine

The Fraunhofer Institute for Process Engineering and Packaging IVV will present the manufacture of 3D electronics using the roll-to-roll (R2R) process at the LOPEC international fair for printed electronics being held in Munich on March 25-26, 2020 (Hall B0, Stand 411). A
new thermoforming process makes this possible. It allows higher degrees of forming via temperature profiling. It was developed at Fraunhofer IVV Dresden.

Thermoforming is suitable for large batches of products and is combined here with innovative technologies for temperature control to precisely regulate the forming process. Up until now the manufacture of electronic assemblies from structural and functional components has involved production, assembly, and wiring. These are costly steps in terms of time and money.

A collaborative project has now developed forming technology whereby a substrate is first processed in its planar state using established technologies for printing and assembly. Only in the last processing step is the 3D geometry generated by forming. Interactive (operating) panels can, for example, be produced at favorable cost. Applications in robotics, home products, medical technology, and the car and aircraft manufacturing industries will benefit from this. The high requirements on ergonomics, design, and functionality in these industries will hence be optimally met. The new process also offers greater design freedom and flexibility.

Customization of Forming Processes

Fraunhofer IVV is developing innovative heating and forming technologies to realize novel products. Fraunhofer IVV Dresden has a specialist team supporting the development of 3D electronic components and offers assistance to companies with aspects such as product design, material selection, and process configuration. A self-developed characterization method enables process limits and relative industrial load limits to be determined. In addition, a thermoforming test rig enables the flexible manufacturing of products on a trial basis. For this work a range of forming processes and technologies are available. Using experimental and numerical simulation, manufacturing processes and product geometries can be simulated and optimized. The thermoforming test rig allows the Fraunhofer IVV Dresden to form a variety of materials with printed electronics for companies.
STUDENT FROM GEORGIA TECH TAKES HOME THE SECOND ANNUAL RC CAR RACE TROPHY

Content Compiled By Ryan Fuller, Georgia Tech

Last year, students were invited to compete in the 2019 SPE Thermoforming RC Car Race and Design Competition in Milwaukee, Wisconsin. Students were charged with designing, thermoforming, decorating, and racing a 1/10th scale RC car body or “shell.” Ryan Fuller, representing Georgia Tech, returned to compete after an outstanding first-time outing in 2018. For the second year in a row, Ryan won first place in the Student RC Car Race!

Ryan’s car design was inspired by Georgia Tech’s famous mascot, the Ramblin’ Wreck, a 1930 Ford Model A. Throughout the planning of the design, the team examined very distinguishable elements from the Wreck, including the side trims and the steep angular fronts. The team’s sponsor, Robert Browning of The McConnell Company, also lent his help with the design.

Incorporating these design elements while still being able to fit the plastic on top of the chassis would prove challenging. Sample car designs included the Bugatti Grand Sport Vitesse and the Bugatti Veyron.

To generate the files necessary for developing and manufacturing the model, Ryan began with a basic car shape in the CAD software, Fusion 360. By taking advantage of the molding workspace, he gradually broke down each section of the car into more complex forms.

For design inspiration, they looked to develop a vehicle with features from the Wreck while giving it a modern sportscar look.

Once he arrived at a preliminary draft of the model, the next step was to take more detailed features from the inspiration and to tie the whole design together. In the end, the model came out as a cohesive mix between an RC car, The Ramblin’ Wreck, and a sporty design.

Next, it was time to form the plastic sheet. The mold was made using a CNC mill, thanks to the gracious help of Ken Griep from PCM. The sheet was formed from a single large mold. Utilizing resources at Georgia Tech, numerous plastic bodies were formed from the mold using their large thermoformer.
Inspired by the Wreck’s color palette, Ryan settled on the classic Georgia Tech white and gold while combining the Bugatti’s side view and form. He then added an LED kit that would work along with the car’s internal speed control system to give the car realistic lighting. Overall, the mold turned out very nicely, and showcased the design elements Ryan set out to feature.

Fuller’s winning entry

Ryan extends many thanks to Robert Browning of McConnell Co. for his support on the project, to Ken Griep for his machining time and resources, and to Paul Uphaus of Primex for his sheet material.

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Editor's Note: The Thermoforming Division has built an archive for all articles and magazines produced since the inception of our division. The result was a catalog of more than 575 articles over 35 volumes going back to 1975. Though some individual issues have been lost in the mists of time, we now maintain a digital record of contributions to our society. To celebrate our past achievements, we will occasionally republish elements from the archives.

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7. "But you have to run the mold base into the material one or two inches to get a seal. It doesn't hurt the frame."
Running the mold base into the material any further than necessary will bend the frame and then we will have to push further and further into the material and soon we will have a machine that won't operate at all.

8. "But we've done everything and it won't pull." [Usually after 5-20 hours have been expended and the mold has been pulled off the machine.]
The policy of this company is that after the first two (2) pulls, if there is not a good pull, the best experience of this company shall be consulted and a definite plan shall be immediately developed to solve the problem. Never may a mold be pulled of a machine because of failure to pull a good part without prior approval of the plant manager or the production manager.

9. "It's not necessary to make up a new cycle sheet each time a run is made on the same part."
Each run of material is different because the material we receive is slightly different, and the operators are slightly different. We need a new cycle sheet each time a run is made to build up a history of operational information.

SPECIAL STUDENT AWARD

Miss Je Nette Yarwood, a sophomore at Chico State University of Chico, California received an award for her active role in the Golden Gate Section of the SPE. Miss Yarwood is Secretary of the student SPE and majors in Polymer Technology.
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Rheological Method Development: Using Rheological Tools To Predict Thermoformability

Mary Ann Jones, Todd Hogan, Jamie Stanley, The Dow Chemical Company, Midland, MI - Paul Vantol, The Dow Chemical Company, Midland, MI - retired

Abstract

Extrusion thermoforming of very large parts such as those used in the appliance industry can exceed the melt strength limits of a given polymer. This study was undertaken to define new rheological tests capable of defining the molecular design required to avoid excessive sag in the heating step of the thermoforming process and to identify the optimum temperature for forming. Damping factor (tan δ = G"/G’), also known as “tan delta”, can be used as a tool to identify fabrication conditions, molding window size, and the effect of added recycle streams. In addition, we compare polymer families that challenge our ability to thermoform large parts. Semi-crystalline materials must be run at or above their melting point temperature (Tm). Tm is well above the glass transition temperature (Tg) and the temperature delta (Tm - Tg) may exceed the width of any rubber plateau region in the melt state. These rheological characteristics are related back to the entanglement density of a given polymer and compared to the width of the rubber plateau.

Introduction

3D plastic molded parts can be produced through a variety of fabrication processes, including thermoforming, injection molding, blow molding, rotational molding and others. Applications that call for the production of a limited number of large parts are a focus for fabricators that thermoform, in areas such as large appliances, recreation vehicle components, dunnage and others. Thermoforming tooling costs are generally significantly less than those for injection molding. At low volumes, thermoforming is more economical than injection molding. At high volumes, injection molding or blow molding are favored. The breakeven point for the cost of parts and tooling between processing operations varies from project to project, based on the size of the part. A general rule of thumb for the optimum fabrication mode moves from thermoforming to injection molding at an annual production order of 2000 to 5000 parts.

Thermoforming applications require a polymer sheet to have limited sag when heated above Tg, and an ability to withstand the load of its own weight. Many polymer families have grades that have the required rheological characteristics to perform well in extrusion/thermoforming applications. However, many products do not perform well in large, deep draw thermoformed parts (refrigerator liners, automotive flooring, tub and shower surrounds, etc.).

The thermoforming process consists of heating, part shaping via vacuum or pressure forming, cooling, and trimming. In the applications referred to here, heavy gauge extruded sheet is produced at a thickness of ~0.100 inches. Sheet is cut, clamped around the outside of the part, and shuttled to the oven of the thermoformer. The sheet is then heated in the oven using radiant and/or convection heating to a temperature above Tg, allowing for initial sag of the sheet. At this point, the sheet is removed from the oven and formed in either a negative or positive vacuum forming process.

Figure 1. 1) Negative Vacuum Forming versus 2) Positive Vacuum Forming

General rules of thumb for varying polymers state that the normal thermoforming temperature for an amorphous polymer is directly related to the glass transition temperature, Tg, and with crystalline polymers, the melting point, Tm. A minimum forming temperature for an amorphous polymer is Tg + 20-30°C and the normal forming temperature is Tg + 70-100 °C. 1 Semi-crystalline polymers are often formed at or just above the Tm. Thermoforming forming temperatures can be understood by examining a storage modulus (G') versus temperature...
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plot run at low shear rates. In general, amorphous polymers are thought to be best formed at temperatures occurring toward the end of the rubber plateau range. Polymers that form well will have a characteristic rheological profile at the ideal forming temperature.

The rheological analysis described here was performed in the shear mode on a dynamic mechanical spectrometer. As such, the deformation mode and rates do not directly apply to thermoformability. The value of this dynamic data is in its ability to measure both the viscous and the elastic component to the modulus, and to give a tan δ value that describes the balance between melt strength and viscous flow. That balance, at a given shear rate and temperature, is what can best define a thermoformable material and can also provide insight into the size of the thermoforming temperature window. Melt strength is required, as the extruded sheet is heated and sags under its own weight. A defined viscous component is required as some ease of flow is needed to uniformly draw down around the tool. Rheological analysis can be used to define the suitability of a polymer for large part thermoforming, to define the optimum temperature range, and as a quality control tool.

**Experimental**

Samples were compression molded to a thickness of 1.5 mm. Samples were tested in dynamic mode on an RDSII Rheometrics Dynamic Spectrometer. Samples were analyzed in three ways. First, a Frequency/Temperature sweep approach was used to define the suitability of a material design and the associated thermoforming temperature, using parallel plate fixtures under nitrogen, keeping the strain as low as possible throughout the test while still generating sufficient torque. The data was used to create a master curve using time-temperature superposition principals. Polymer fabrication operating windows were defined through examination of the master curves, understanding the size of the rubber plateau and the slope of the elastic modulus and tan δ curves in the viscous flow region of the curve. The slope of these curves provide information as to how well the processability can be changed through changes in processing temperature or shear rate. These tests are designed specifically to define the melt strength of the sheet after heating but prior to forming, balancing this against the ability to form uniformly in a deep draw part.

Our second mode of analysis was used when comparing materials where a processing temperature has already been defined. In cases of quality control or when testing semi-crystalline materials just above Tm, simple frequency sweeps are run from 0.01 to 100 rad/sec.

Our third mode of analysis was used to a limited extent to examine the effect of molecular weight on the width of the rubber plateau, plotting storage modulus versus temperature. A temperature ramp was performed in torsion up through Tg. Ten degrees was added to the final temperature and data collection was continued using the parallel plate geometry. Testing was performed at a frequency of 1.0 rad/sec.

Data were collected on commercial extrusion resins. A variety of materials were collected that represented differing processing ease in the field. Amorphous resins included both high impact polystyrene (HIPS) and acrylonitrile-butadiene styrene (ABS) that had been or were currently in use in refrigeration applications, as shown in Table 1. Semi-crystalline resins including polypropylene (PP) and high density polyethylene (HDPE) resins are shown in Table 2.

### Table 1. Amorphous Polymers

<table>
<thead>
<tr>
<th>Polymers</th>
<th>Mw (g/mol)</th>
<th>% Rubber</th>
<th>Extrusion/Thermoforming Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS 1</td>
<td>155,000</td>
<td>16.5</td>
<td>extruded and thermoformed well</td>
</tr>
<tr>
<td>ABS 2</td>
<td>155,000</td>
<td>21.5</td>
<td>extruded well / some history of cracking due to built-in stress</td>
</tr>
<tr>
<td>HIPS</td>
<td>192,000</td>
<td>7</td>
<td>thermoformed well / sagging when extruded at higher temperatures</td>
</tr>
</tbody>
</table>

### Table 2. Semi-crystalline Polymers

<table>
<thead>
<tr>
<th>Polymers</th>
<th>Mw (g/mol)</th>
<th>Ms (g/mol)</th>
<th>Mw/Mn</th>
<th>Material Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP 1</td>
<td>412,000</td>
<td>5</td>
<td>6</td>
<td>High crystallinity matrix</td>
</tr>
<tr>
<td>PP 2</td>
<td>450,000</td>
<td>4.5</td>
<td>High crystallinity</td>
<td></td>
</tr>
<tr>
<td>PP 4</td>
<td>390,000</td>
<td>4.1</td>
<td>High melt strength grade (some crosslinking)</td>
<td></td>
</tr>
<tr>
<td>HDPE 1</td>
<td>187,000</td>
<td>1,200,000</td>
<td>13.1</td>
<td>High MW fraction</td>
</tr>
<tr>
<td>HDPE 2</td>
<td>188,000</td>
<td>1,232,000</td>
<td>10.1</td>
<td>High MW fraction</td>
</tr>
</tbody>
</table>
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.
Results and Discussion

The rubber plateau width provides us with an understanding of the size of the molding window for a given polymer and the ideal molding temperature. The rubber plateau region occurs in higher molecular weight polymers, existing in a temperature / frequency range where entanglements do not have the time to relax out stress. 2 These entanglements are acting as mechanical crosslinks and provide both strength in the solid state and melt strength above Tg. The molecular weight between entanglements, Me, is based on the rigidity of the polymer chain as is the Tg. Entanglement molecular weights and thermal transitions for varying polymers are listed in Table 1. Figure 2 illustrates the effect of entanglement density, Mw/Me, on the strength of an amorphous polymer as reflected in a tensile test.

<table>
<thead>
<tr>
<th>Entanglement Density, Anionic Polystyrene</th>
<th>Me (g/mol)</th>
<th>Tg (°C)</th>
<th>Tm (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polystyrene</td>
<td>19,000</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>SAN (25)</td>
<td>12,000</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>PMMA</td>
<td>9,200</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>1,800</td>
<td>150°</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Entanglement Molecular Weight and Thermal Transitions 3, 4, 5, 6

Figure 2. Polystyrene Tensile Strength versus Entanglement Density

Anionic polystyrene has a molecular weight distribution of 1.0 and is available at a broad range of molecular weights. Polystyrene (PS) grades were compression molded and tested via dynamic testing, ramping the temperature from 50 to 300°C, testing first in torsion for solid state data and then testing using parallel plate fixtures for the melt state. These PS homopolymer grades have not been previously described. All molecular weight information can be found in the legend of the chart. Commercial grades STYRON 665 and 680 are not anionically produced and have a molecular weight distribution of 2.0 to 3.0. Figures 3 and 4 illustrate the effect of molecular weight and the resulting entanglement density on the width of the rubber plateau (°C).

We are assuming that we must thermoform at temperatures within the rubber plateau region as tested at low frequencies to withstand the temperatures experienced during the heating process. Figure 3 also contains PS with a broader molecular weight distribution for comparison purposes.

Figure 3. Rubber Plateau Width versus Polystyrene Molecular Weight

(The anionic polystyrene samples were obtained from Fisher Scientific.)

Figure 4. Approximate Rubber Plateau Width versus Entanglement Density, Anionic Polystyrene
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Table 4. Effect of Entanglement Density on Rubber Plateau Width and Maximum Thermoforming Temperature, Anionic Polystyrene

<table>
<thead>
<tr>
<th>Mw (g/mol)</th>
<th>Entanglement Density</th>
<th>Approximate Rubber Plateau Length (˚C)</th>
<th>Range Max (˚C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120000</td>
<td>6.3</td>
<td>30</td>
<td>160</td>
</tr>
<tr>
<td>203000</td>
<td>10.7</td>
<td>45</td>
<td>175</td>
</tr>
<tr>
<td>316000</td>
<td>16.6</td>
<td>60</td>
<td>190</td>
</tr>
<tr>
<td>472000</td>
<td>24.8</td>
<td>80</td>
<td>210</td>
</tr>
</tbody>
</table>

This information is provided to establish a clear understanding of the importance of molecular weight and entanglement density to processing conditions where melt strength is required.

**Amorphous Polymers**

Our goal when designing a polymer for deep drawn parts is to resist sag in the heating process while still pulling down over the tool evenly, creating parts without significant built-in stress and without areas of thinning. Ideal molding temperatures can be defined using time-temperature superposition and plotting the tan delta curve. Rheological data gathered on thermoforming products over a number of years consistently places the tan delta between 1 and 2 at a shear rate of 0.01 rad/sec when testing at the preferred thermoforming temperature.

Time temperature superposition has multiple advantages when screening new materials. This analysis approach allows us to evaluate a range of temperatures and it allows us to evaluate tan delta at very low shear rates. It is important to look at the low rates as the sheet undergoing this fabrication mode is not under shear deformation during the heating process. However, it is difficult to accurately test at these low shear rates due to thermal stability issues. In high rubber samples involving ABS, the butadiene phase is not thermally stable for the time required to run the test at these rates and the sample is undergoing crosslinking throughout the test. This results in a great deal of scatter in a shifted plot.

We can also examine the curves to understand how sensitive a material may be to temperature or how likely the sample is to have issues with molded-in stress in the part (Figure 5). The HIPS tan delta changes much more rapidly with temperature and rate than the ABS. We see a very narrow rubber plateau when comparing the Mw of the HIPS tested to that of the polydisperse molecular weight distribution PS in Figure 2. This particular HIPS product has a low entanglement density (Me/Mw = 10), the lowest Mw that would have a maximized tensile strength. A tan delta curve with a high slope indicates the likelihood of a narrower temperature window for forming. The thermoforming temperature needs to be at a minimum 2030˚C above Tg and the rubber plateau width estimated from this entanglement density would be 40 ˚C.

ABS 1 can be formed across a broad temperature range. ABS 2 has limited sag in the thermoforming oven but does tend to store energy to the point that molded parts whitened sitting on the shelf as the rubber particles cavitated over time. Both of these ABS products have an entanglement density of 14. The difference in performance comes from the difference in % rubber. Both ABS grades contain an emulsion polymerized, small particle rubber phase. Rubber phase graft interactions started to occur as the rubber content increased and interparticle distance dropped. Elasticity is a function of the design of the continuous phase. In ABS 2, the dispersed rubber phase begins to be involved in defining the elastic behavior of the polymer.

Figure 6 illustrates our method of using tan delta as a tool to define the optimum thermoforming temperature window for a polymer. A series of Temperature-Frequency sweep Master Curves each shifted to different reference temperatures were plotted. This particular HIPS grade was evaluated on a thermoformer and formed best in the temperature range of 150-160˚C. This is predicted by identifying the associated temperatures for data sets with a tan delta value between 1 and 2 at 0.01 rad/s.
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Thermoformed parts are trimmed to size and the scrap is then used as regrind. It is possible to observe molecular weight degradation after multiple processing steps. Mw loss can vary based on stabilizer packages. Figure 7 illustrates the use of tan delta measurements as a quality control tool. One of the products below increases in tan delta when significant regrind was added, correlating to a loss of molecular weight from the use of regrind. HIPS B appears to be more thermally stable.

Both HIPS and ABS can be thermoformed into deep draw parts without excessive sagging in the heating process. As amorphous polymers, they can be formed close enough to Tg to have sufficient melt strength for this fabrication mode. A desired molecular weight can be defined to produce a sufficiently wide rubber plateau. ABS containing emulsion rubber particles can be formed successfully at lower molecular weights due to contributions of rubber phase graft interactions to elasticity.

**Semi-Crystalline Polymers**

Some semi-crystalline polymers, such as polypropylene (PP), are extremely difficult to thermoform into large deep drawn parts. These materials must be thermoformed at or above the Tm. The melting point may be significantly higher than the Tg and would require a wider rubber plateau region than is typical for a noncrosslinked polymer. PP is more difficult to thermoform than amorphous resins such as HIPS or ABS, even when the high molecular weight is high. Figure 8 contains the tan delta data from frequency sweeps for differing PP grades, run at the lowest temperature possible above Tm. Table 4 describes these varying high molecular weight grades of both homopolymer and impact modified PP. These polymers have an entanglement density of close to 60, however, the only grades that are thermoformable were designed containing some degree of crosslinking or long chain branching. PP is typically formed 165 degrees above Tg.

**Polypropylene Design versus Thermoformability**

Figure 9 also contains frequency sweep data, analyzing high density polyethylene (HDPE) grades commonly used for deep draw thermoforming. These grades thermoform well without the need for crosslinking. HDPE has the most flexible polymer chain and so has the lowest Me at 1390 g/mol. 3 The entanglement density based on Mw is quite high for these HDPE products, 136, and both have a high molecular weight tail (Mz > 1,000,000 g/mol).

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The rubber plateau width versus molecular weight cannot be measured for these olefin polymers as the Tm is significantly higher than Tg. We cannot know how the relationship of plateau width to entanglement density of polyolefins compares to that of polystyrene. However, we can compare PP to the ultra-high MW HDPE grades that form well. Table 5 summarizes the relative thermal transitions and the entanglement density across the polymer families. The entanglement molecular weight of PP is 5x that of PE. PP would have an Mw of 940,000 g/mol to be able to match the entanglement density of HDPE. The PP would no longer be easily extruded. Other means of acquiring structure are required such as light crosslinking or long chain branching.

<table>
<thead>
<tr>
<th></th>
<th>PS</th>
<th>HDPE</th>
<th>PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tg (°C)</td>
<td>100</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Tm (°C)</td>
<td>NA</td>
<td>125</td>
<td>160</td>
</tr>
<tr>
<td>Melting Temperature (°C)</td>
<td>150-180</td>
<td>140</td>
<td>165</td>
</tr>
<tr>
<td>Delta above Tm (°C)</td>
<td>50-60</td>
<td>160</td>
<td>165</td>
</tr>
<tr>
<td>Entanglement Density of “high” MW material</td>
<td>16</td>
<td>136</td>
<td>38</td>
</tr>
<tr>
<td>Mw/Mn</td>
<td>2.3</td>
<td>12</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 1. Understanding Thermoformability as it Relates to Thermal Transitions and Entanglement Density

Conclusions

A rheological technique, using dynamic mechanical testing has been developed and validated which permits the detailed analysis of the rubber plateau of amorphous resins and the melting region of semi-crystalline resins to determine suitability for use in deep draw thermoforming. This technique defines the temperature range in which the elastic and viscous components are at the right balance to prevent excessive sagging in the heating process yet form evenly around the part without excessive built in stress. Analysis of entanglement density can assist in defining cases where crosslinking or long chain branching are required to generate structure above and beyond the effects of molecular weight/entanglement density.

References

6. http://faculty.uscupstate.edu/llever/Polymer%20Resources/FactorsTg.htm#stiffness

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* The values presented in the table and charts represent typical properties, but should not be construed as product specifications.

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The use of plastics packaging across a wide range of industry segments is increasing due to plastics’ ability to keep products safe and retain their quality until final use by the end-consumer. The outlook for the global packaging industry forecasts steady growth, with several projections anticipating the industry will near the trillion-dollar mark by 2022. Assessing the value proposition among material options available today must transcend the absolute package cost because of the value today’s consumers put on factors such as sustainability, temperature flexibility, traceability, product safety/counterfeit protection, shelf-life, and convenience. As markets mature and become more reliant on ecommerce and online shopping, the global packaging industry must adapt by focusing on these needs. Creative adaptation of the work being done in material science is essential to finding the perfect balance between environmental responsibility and package functionality. This is especially true in our area of focus, rigid packaging, where the combination of material science and modern multi-layer extrusion technology has pushed the boundaries of barrier packaging to extend both product quality and shelf-life. These enhancements will ensure every market segment, e.g., food, medical, cosmetics or automotive will benefit along with our environment.

**Market Segments of Barrier Packaging**

The global market for plastics packaging can be segmented based on the end-use application, with some larger segments defined as healthcare packaging, consumer goods packaging, and food packaging. The global market is further categorized based on type of packaging such as blister pack base webs, forming webs, stand-up pouches, bags and pouches, wrapping film, and tray lidding film.

A large portion of the food packaging market segment is dedicated to single-serve and portable light-weight packaging that fits into busy consumer lifestyles. One of the main causes of food spoilage, and in turn food waste, is the growth of microbes such as bacteria, yeast and mold that feed and grow on the packaged food product. Extending product shelf life through a combination of packaging material, sterilization systems and customized barrier specifications is critical to maintaining the integrity of the food product, while providing the unique packaging necessary to support brand the differentiation that is essential to continued industry growth and food safety.

**Materials Used in Barrier Packaging**

Barrier properties to consider include moisture vapor permeation, oxygen permeation, material organoleptic properties, UV protection, light permeability, aroma preservation, and the permeability of other gases such as carbon dioxide and nitrogen. Understanding a product’s packaging needs is essential to protect the food product from the various environmental elements that typically cause food to spoil. Some of the most widely used materials found in barrier packaging are metal, paper and paperboard, glass and plastics. The benefits offered by plastic packaging include competitive cost, functional efficiency as a result of physical properties, design flexibility and innovation. These elements coupled with readily available supply and ease of use for both the consumer and converter, often make plastic barrier packages the product of choice when all of the design variables being considered.

The most common plastics barrier packaging materials used in the industry include:

**Polyvinyl dichloride (PVDc)** is a clear and flexible thermoplastic polymer made through the polymerization of vinylidene chloride. It offers excellent optical properties as well as oxygen and moisture barrier properties. PVDc can serve as a barrier and a sealant. It is primarily used in hot-fill and “retort” processes even though it has very narrow extrusion process window. The material can also turn yellow over time. Acceptance of PVDc has declined recently due to the presence of chlorine content and restrictions with recycling (mechanical and chemical recycling systems). PVDc has been used as a barrier for fresh meat packaging for decades but without a solid recycling plan, CPG’s have begun to turn away from PVDc with 62% of brands, retailers and packaging producers committing to eliminating or phasing out the material by 2025 according to the Ellen MacArthur Global Commitment initiative. As a result, post-industrial scrap and post-consumer waste either ends up in landfills or is incinerated. Incineration of this material carries its own concerns as it leads to the release of toxic chemicals such as dioxins, a well-known potent human carcinogen.
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**Ethylene Vinyl alcohol (EVOH)** is a clear, non-chlorine based, flexible and a high gloss thermoplastic semi-crystalline random copolymer made through the copolymerization of ethylene and vinyl alcohol to offer excellent oxygen barrier properties and resistance to oils, organic solvents and hydrocarbons. Because EVOH is semi-crystalline, as the ethylene mol% increases, oxygen barrier properties reduce. EVOH is hydroscopic in nature, and if exposed to moisture, will lose its gas barrier properties. As a result, this material is generally coextruded and/or laminated as a barrier layer sandwiched with PE, PP, PS or PET to protect the material from moisture and offer additional mechanical properties. This material is also very expensive, so use of this material in a coextruded structure helps to control overall cost while also providing necessary barrier properties.

**Polyamide (PA)- PA** (also known as nylon) is a clear thermoplastic polymer with exceptional mechanical properties (impact strength, toughness, low elongation, high tensile) and good oxygen barrier properties. Apart from oxygen barrier, nylon also provides excellent barrier to chemicals, especially flavors and aroma. Nylon also exhibits good resistance to high heat, allowing for use in retort packaging applications even for products that contain fats and oils. Compared to other barrier materials (films in particular), nylon offers easy processing and has an operating temperature range that allows for compatibility in both freezer and microwavable applications.

**Barrier Packaging Substrates:**

When developing the overall rollstock structure for barrier packaging applications, factors including food product, part design, processing conditions, distribution environment and retail conditions must all be considered as each variable ultimately affects shelf-life performance. Once these variables have been defined, further details such as barrier specifications, shelf-life expectations, part geometry, material attributes and part handling must all be considered to refine the design of the thermoformed part and develop a rollstock structure that will deliver optimal barrier performance. Depending on the end-use application and barrier requirements, extruders can formulate customized coextruded barrier rollstock structures using substrates such as polystyrene, polypropylene, and polyethylene to meet the application requirements.

**High Impact Polystyrene (HIPS)** is a form of polystyrene (PS) that carries a higher impact strength. Homopolymer PS can often be brittle, and can be made more impact resistant if combined with other materials. This form of PS typically is produced by adding around 5-10% rubber or butadiene copolymer. This increases the toughness and impact strength of the polymer and results in a very stiff product ideal for packaging applications. Use of HIPS is prevalent in food and medical thermoforming and FFS due to its low cost and easy processability. However, with the implementation of Proposition 65, use of HIPS in food packaging applications is declining.

**Polypropylene (PP)** is a semi-crystalline polymer that is hazy in its natural state, but can be made available as an exceptionally clear and high-gloss material through the use of specialty additives and processes. This material is generally characterized as having a higher stiffness at a lower density, resistance to higher temperatures, and an excellent strength to weight ratio. There are three main grades (homopolymer, random copolymer and impact copolymer) of PP resin which allow for improvement of specific properties as determined by the composition of the polymer chain.

**Polyethylene (PE)** is a low cost, translucent thermoplastic polyolefin material that offers great versatility that spans food, medical, cosmetics, automotive and construction applications for its high impact strength and puncture resistance at temperatures as low as -40C. There are three different grades of PE: high density polyethylene (HDPE), low density polyethylene (LDPE) and linear low density polyethylene (LLDPE). The various grades of polyethylene can be strategically included in package designs in both the substrate and sealing elements. HDPE is easy to process as a substrate and provides excellent moisture and chemical resistance, while LDPE and LLDPE can be used in a multi-layer coextruded structure as a tie/sealing or bonding layer.

**Enhanced Barrier PP and PE materials:**

Polyolefins are one of the most widely used resins in packaging applications (rigid and flexible) for their low cost, excellent moisture barrier, ease of processing, and recyclablility. As the global demand for packaging solutions with improved sustainability and recyclablility continues to take precedence, mono-material packaging structures have emerged as a solution made possible through major advancements in material science. Polyethylene and polypropylene are the most versatile materials used in the plastics industry today, and plans for additional production capacity in the US alone will add nearly 4bn lbs by 2022. Both PE and PP have excellent moisture barrier properties but exhibit poor barrier properties to oxygen and many organic solvents. As a result, currently both PE and PP are widely used either in a coextruded structure or as a
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substrate to an oxygen barrier laminated material or film such as EVOH for applications that require a high oxygen barrier.

ICPG’s enhanced barrier technology can now offer a new mono-material solution for barrier polypropylene structures (both homopolymer and copolymer) with oxygen and moisture barrier enhancement up to 60%, as well as added clarity and low haze compared to traditional polypropylene materials. This material also offers enhanced stiffness to meet or exceed polystyrene standards for snapability, allowing for replacement of PS in form-fill-seal applications as well as potential downgauging opportunities for existing structures. ICPG’s enhanced barrier HDPE offers oxygen and moisture barrier enhancements up to 40% compared to traditional polyethylene grades. Generally, multilayer structures are made using a complex and expensive technology and the final product is not recyclable due to the use of multiple materials (application-dependent). With a mono-material structure, however, packaging solutions are 100% recyclable and can be integrated back in the structures to create a closed loop system.

Considerations for Sealability - when to use a weld seal (lock tight) vs peelable seal (easy peel)?

Regardless of the material or method used to produce the package, distribution of the final product may require the package to be sealed with a lidding film. It is important to choose the right lidding film, considering sealing integrity and barrier characteristics necessary to protect the product’s quality for the targeted shelf-life. Barrier properties of a lidding film must be matched to the barrier demands of the overall package.

Some options include easy-peel and weld-seal (or lock-tight) peeling characteristics. When the product is designed to be consumed within a short period of time or a ready-to-use concept that requires quick and easy access, the outer material is generally formulated such that the lidding film creates an easy peel upon sealing. Weld-seal, in comparison, is a permanent seal that acts similarly to tamper evident packaging where it can only be opened once and cannot be re-sealed. There are a broad range of physical characteristics designed into lidding films, including various barrier properties, clarity, thickness, color, composition, food compatibility, heat resistance, chemical resistance, and sustainability. Properties such as dwell time, temperature, and pressure play an important role in the seal integrity of a package. The substrate material and lidding material combined with above processing variables plays the most vital role in a package’s seal effectiveness.

Processing of Barrier Packaging Materials

Incorporation of barrier materials into extruded rollstock structures can be achieved through two methods:

Coextrusion is the process in which two or more plastic materials (with similar or dissimilar characteristics and behavior) are extruded as one. In a standard monolayer sheet extrusion process, one material is fed and extruded through a die. The coextrusion process involves multiple extruders and multiple materials (depending on the structure), and the molten material is channeled through the melt pipes to create a laminar flow for the coextrusion feed block and die technology to weld the extrudates into a one-piece structure. When multiple material layers are combined, the end result yields a multi-layer structure deriving distinct properties from each material used in the structure. During extrusion of these materials, the required cooling is achieved by feeding the material through cooling rolls, also known as stack rolls or chill rolls. These rolls deliver the required cooling. They also help to determine the sheet thickness and the surface texture using specialty surface finish rolls like matte, sand matte, hair cell, and more.

Although new and advanced compounded materials are enhancing the properties of traditional plastic materials, coextrusion continues to expand material capabilities for food packaging applications, offering added benefits through the combination of materials in terms of extended shelf-life, cost control, and increased structural properties.

Extrusion Lamination lamination is the process of applying a multilayer coextruded lamination film to a desired substrate such as paper, plastics, ceramic, metal, etc. via heat, pressure or a combination of both. Laminates are very thin extruded film structures that are produced using multiple layers of materials to achieve improved strength, stability, appearance and other enhanced properties. Use of laminates can be used to improve mechanical, barrier or chemical properties, or to enhance the appearance of a substrate. Depending on the required property enhancement, a lamination method is selected to weld the lamination structure and the substrate together such as dry lamination, wet lamination, thermal lamination, etc. Regardless of the lamination method used, in all cases the webs are combined at a lamination nip, i.e., typically two rolls pressed against each other under a controlled temperature, pressure, and gap. Since the web is combined using just the heat and pressure from the stack/chill roll, it is important that the lamination web has low thermal properties (low melting point) so that the preheating caused from the stack roll and pressure will

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thermally laminate and create a strong bond soon after it exits the stack roll and pull roll system.

ICPG offers extrusion thermal laminated materials using PE, PP, PS, the base substrate and desired lamination film web for enhanced properties such as oxygen barrier, UV barrier, and decorative films. Depending the end-use application either of the process can be used to create an effective barrier packaging material with enhanced barrier and other desired properties.

**Benefits of Coextrusion vs. Extrusion Lamination**

Some of the benefits of coextrusion vs. lamination in barrier packaging applications include high productivity, consistent quality, cost savings, and sustainability. The table below summarizes the benefits and considerations of each method:

<table>
<thead>
<tr>
<th>Coextrusion</th>
<th>Lamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>High output rate with exceptional bond and material properties.</td>
<td>Moderate output rate for effective bond strength.</td>
</tr>
<tr>
<td>Complex equipment requiring continued maintenance.</td>
<td>Less equipment to maintain if added on line as extrusion thermal lamination process.</td>
</tr>
<tr>
<td>Longer setup time.</td>
<td>Setup time is short and easy.</td>
</tr>
<tr>
<td>High capital investment for equipment, materials and storage.</td>
<td>Lower capital investment and more diverse range of lamination equipment and film options.</td>
</tr>
<tr>
<td>Shorter lead time as material is readily available in stock.</td>
<td>Longer lead time as lamination films is custom and outsourced.</td>
</tr>
<tr>
<td>Ideal process for cost effective products as reprocessed/recycled material can be easily integrated back in the system.</td>
<td>Less energy consumption compared to multiple extrusion system with coextrusion process, but materials cannot be re-integrated into structure</td>
</tr>
<tr>
<td>Rollstock specifications limited to equipment capabilities for gauge, width, and materials.</td>
<td>Lamination film can be outsourced in varying gauge, width and materials based on application.</td>
</tr>
</tbody>
</table>

Theoretically, the coextrusion process is the more cost effective and ideal method to process and produce a barrier packaging material. But it is important to understand the end-use application, processing method (thermoforming, lamination, in mold labelling), volume, etc., to justify the cost, quality and output rate for coextrusion vs. lamination.

**Designing for the Future**

The environmental and aesthetic demands of today’s consumers related to package functionality as well as the sales growth of a product is well suited to the academic and industry work being done to enhance the physical properties of both polypropylene and polyethylene. In addition, when you consider the US abundance of low-cost natural gas, our crackers’ ability to crack both heavy and light feedstocks combined with the addition of on-purpose polymer-grade propylene projects in development, designing for the future using polyolefins is the most environmentally and cost-effective course of action.

**Author & Company Notes**

Jimmy Shah began his career with Impact Plastics as Extrusion Process Engineer and today is an integral part of the team at ICPG. He is an active member for Society of Plastics Engineering (SPE) and also serves as a Co-Chair for Next Generation Advisory Board (NGAB) that helps connect young professionals to industry veterans. Jimmy has a Master’s of Science in Plastics Engineering from the University of Massachusetts Lowell.

A division of Impact Plastics, ICPG produces custom-extruded rollstock products designed for rigid thermoformed food packaging applications. For more information on our products and services visit www.icpg.co.

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against the formed plastic sheet. The labeled and trimmed parts are then moved with the web to the downstream stacking station, where they are conveyed to a Kilde (Skive, Denmark) Flexpacker automation system and packed into pre-erected cartons.

Figure 8: IML-T lids and labels from ILLIG Thin Gage Thermoforming Configuration #4 Match Metal Form & Trim in Place – the difference between the match metal and the steel-rule knife trim configuration shown above is that a matching punch and die is used within the form tooling to trim the parts. An integral coining feature is usually included in this configuration as the coiner device helps to flatten out the flange of the parts while acting like a sheet clamp. The coiner can be temperature controlled and the coining pressure can be adjusted to allow for thicker or thinner flanges.

Figure 9: Shows the components of a typical match metal trim-in-place tool with integral coining device. The call out bubbles show the position of the punch and die during the forming of the part and then the trim action soon after.

There are many ways in which the formed and trimmed parts can be ejected from the mold cavities, but the most popular is to move the lower tooling half down and away from sheet line with parts still in the mold cavities) and then tilt the entire lower tooling to a part retrieval and stacking device. It is the chosen method to manufacture cups and tubs and other similar part geometries, but not suited for large trays such as salad bowls.

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Cups and trays manufactured from recycled plastic is precisely what Battenfeld-Cincinnati, Illig Maschinenbau, and Der Grüne Punkt (The Green Dot) are producing in a joint project.

The aim was to close the reusable material cycle for disposable packaging made of PP and PET. At their K 2019 booths, the three companies provided information about their latest contributions to sustainability and the conservation of resources, showing a viable way to reach higher recycling rates.

The materials used to produce the sheet were supplied by Der Grüne Punkt and Germany’s dual system waste collections. To recover the material, the plastic packaging waste first passed through several steps of an elaborate sorting process (NIR, swim-sink and hydro cyclone separation). The PET proportion was cleaned by conventional washing, while the PP was prepared by additional optimised sorting and washing processes, as well as regranulation as Systalen PRIMUS PP.

Der Grüne Punkt has now embarked on a new course by separating the various packaging products according to individual articles in several sorting cascades, thus producing a high-quality fraction of PET trays. This fraction, ground into flakes and sorted again, has served as a raw material.

The sheet used as the initial product for making PP cups or PET trays was produced on the ultra-modern three-layer sheet line in the technical lab of Battenfeld-Cincinnati. This line is equipped with a 75 T6.1 high-speed extruder, which is suited for PP processing, as well as a 120-40 Star extruder for PET.

The ideal thermoforming sheet is then produced by the Multi-Touch roll stack, which is also part of the equipment.

‘Perfect Plasticising’

The compact PP extruder offers low energy consumption and high output rates, whilst the PET extruder has a special process technology combination of a single screw with a central planetary roller section where the melt is subjected to a high level of degassing and decontamination. Both extruders are designed for perfect plasticising and homogenisation of the plastic melt even when 100 per cent regrind is used.

Battenfeld-Cincinnati extruders; Battenfeld-Cincinnati, Bad Oeynhausen, Germany)
With its large number of roll gaps in the recalibration section, it produces tension-free sheet with a high degree of flatness and a transparency which depends on that of the raw material. A two-roll stack takes care of pre-calibration. In this case, it is arranged in a 45° position to suit both PP and PET sheet.

Finally, ILLIG produced cups and trays from the extruded sheet in various test runs at its technical lab. All manufactured end products have proved equal with comparable packaging solutions from virgin material in their profile of attributes. While the monolayer sheet made of PP regrind was processed on an RDM-73K thermoforming line with a cup mold, an RD-74d with a tray mould was used to process the sheet made of PET regrind. In this case, Ilig tested three monolayer sheets and a composite sheet with outer layers made of PET regrind in foodgrade quality with ‘excellent results’ in each.

‘Groundbreaking’
The partners have thereby proved the basic feasibility of re-processing 100 per cent recycling material from domestic waste collection systems into packaging products with the necessary profile of attributes. The next phase will be to test the renewed food grade quality of the packaging, and to optimise the process.

Dr Markus Helftewes, CEO of Der Grüne Punkt, said: “The co-operation with BattenfeldCincinnati and Iilig is a pioneering effort in several respects. This project points to a first-class recovery option for PET trays, a fraction for which no practical recycling possibility has previously existed. We are now able to demonstrate how plastic waste from the Yellow Bag can be transformed again into food-grade plastic packaging. This is groundbreaking, and I am very glad that we, together with our partners, are once more able to set benchmarks.”

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Arrows vs. Triangles: Good Intentions Gone Awry

By Conor Carlin, SPE Vice President, Marketing & Communications

Increased public awareness of plastics and the environment has led to a search for more information about how best to manage these materials at the end of their useful lives. Plastics, polymers, and chemistry are complex, with many branches of knowledge spreading out in different directions. Most people who are not scientists tend to interact with plastics in a utilitarian way – the materials are ubiquitous and useful. In our consumption-driven world, however, plastics can pose problems when they are no longer useful to us. This post is not meant to address waste management, sustainable materials management, or plastics recycling. The goal is to highlight a single, small element to address a larger point: the confusion created by the numbers found on most plastic packaging.

Contrary to popular (though perhaps waning) belief, these numbers are not recycling codes. They are resin identification codes. They do not imply recyclability, though many people assume that they do, causing a chain reaction of problems. In 1988, the plastics industry trade association (then known as SPI, or Society of the Plastics Industry), introduced resin identification codes (RIC) to help materials recovery facilities (MRFs) and recycling facilities sort different types of plastic resin. The “chasing arrows” logo was created with numbers to identify these resins. Prior to 1988, plastic items were not marked or stamped with any identification. In response to rising costs associated with tipping fees at landfills, the plastics industry attempted to create a system that would allow waste management groups to segregate potentially useful, valuable materials. In the US, 39 states adopted the SPI RIC system in some form and created legislation mandating the use of the codes, though slight differences existed among states, e.g. some mandated that all items over 16 ounces required coding, while others started coding at 8 ounce items.

In 2008, the American Society for Testing and Materials (ASTM) took over management of the RIC system. This group issued new guidelines in 2010, including changing the logo from chasing arrows to a solid triangle. The numbers did not change. Because the new standard acknowledges prior regulation, it makes clear that “…existing statutes or regulation will take precedence…” over the new one. In addition, the new regulation only applies to new molds or tooling, though no enforcement mechanism is evident in the text, and modification to older items is not required. This explains why we still see chasing arrow symbols today, despite the authors’ attempts to decouple the RIC system from recycling messages.

Plastic material derived from non-fossil resources such as polylactide (or PLA, which was not fully commercialized in 1998) is still classified as 7 which means it gets lumped in with such diverse materials as acrylonitrile-butadiene-styrene (or ABS, used for Lego bricks) and polycarbonate (or PC, used in many optical applications), and multilayer materials. Paradoxically, the increase in lightweight, multilayer, flexible packaging reduces overall carbon accounting, but poses new and thorny issues for end-of-life management. Some industry participants point out that today’s materials are not compatible with recycling and waste management infrastructure that was mostly developed in the 1990s. Declining municipal budgets and a relative dearth of private investment in the sector have stalled greater technological innovation and improvement. In short, consumption habits – and associated waste streams are – changing faster than infrastructure systems’ ability to manage that waste. Can we ask if the RIC is still relevant? What would a new system look like? Is one even required given advances in high-speed, near-infrared sorting technologies (link from 1993!!) and digital watermark systems?

We don’t all get updates from ASTM in our email inboxes, so it requires some effort to stay current with a topic that overlaps industry, technology, and politics (you can find a good summary here). Yet we must acknowledge that convenience can lead to thoughtlessness, and bureaucratic approaches to fast-moving societal issues are sub-optimal. Much changes with time; we are required to adapt to new rules, regulations, and realities. Little signs on the bottom of empty bottles might not seem worthy of our attention, but sometimes a small change can make a big difference.
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