



Volume 1, Spring 2024

Polymer Modifiers & Additives News

A Publication of Polymer Modifiers and Additives Division of Society of Plastics Engineers

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Polymer Modifiers and Additives Division

Promoting scientific and engineering knowledge sharing related to enhanced performance of polymeric compositions by incorporating modifiers and additives



Chairman Message

Dear SPE Polymer
Modifiers & Additives Division Members,



With great pride as we continue to serve the PMAD organization, I am thrilled to share that the latest feat came to us through successful transfer of the PMAD financial accounts to the newly appointed treasurer. Our diligent team members worked tirelessly not only to transfer the account but also to modernize it to the current banking standards. I am grateful for the leadership that Chris Karr demonstrated in this process. Thank you Chris!

One of the primary objective of PMAD division is to advance the learning of our next generation in the field of polymer modifiers and additives field. Two of the most notable way of achieving this objective is by including educational content in our newsletters and through student scholarships. I take pride in sharing that this year we have received about 45 submission, largest thus far. The team will be carefully reviewing and grading the submissions to select the winners. Thank you to the student bodies who participated and assisted with increasing participation.

In its vastness, Polymer Engineering coupled with Modifiers & Additives play a critical role – touching upon almost every segment of life across multiple markets. The limitlessness of plastics engineering and high growth emphasizes on furthering our own development through knowledge sharing and learning. As the industry unites to address sustainability, it is these modifiers and additives that have risen to the challenge of prolonging the service life, reducing microplastics waste, and minimizing consumptions of depleting resources. It is upon all of us who play the quintessential role of learning and educating our peers on importance of responsible choices and how additives are helping build the

the future one molecule at a time. I am confident that each one of you is learning & implementing scientific principles in bursting the myths to promote a future based on strong foundation.

I hope this message finds you during a successful year. In the efforts of continuous learning and sharing, I would like to welcome your suggestions and feedback, thoughts on ways to improve our outreach. Please feel free to reach me directly at Anshuman.shrivastava@geon.com

Counting on your enhanced participation and ideas.



Sincerely,
Anshuman

Upcoming SPE Events

SPE Thermoset TopCon

Tuesday, Apr 30 – Wednesday, May 1, 2024
Madison, Wisconsin

NPE2024 The Plastics Show

Monday, May 06—Friday, May 10, 2024
Orange County Convention Center, Orlando, FL

IME South 2024

Tuesday, Jun 04– Thursday, Jun 06, 2024
Charlotte Convention Center, Charlotte, NC

Automotive Composite Conf & Exhibition

Wednesday, Sep 04— Friday, Sep 06, 2024
Novi, MI

SPE Foams 2024

Tuesday, Sep 17– Friday, Sep 20, 2024
King of Prussia, PA

SPE Color and Appearance Conference

Monday, Sep 23 - Thursday, Sep 25, 2024
Tampa, FL

2024 International Polyolefins Conference



IPOC 2024 Recap

The 2024 International Polyolefin Conference (IPOC) theme was “GLOBAL POLYOLEFINS – Inspiring & Enabling Innovation for Polyolefins”. The conference had nearly 875 people from around the globe who participated either in-person or virtually. There are 50 exhibitors and 11 sponsors this year as well.

Conference technical program included 130+ reviewed presentations, Sunday afternoon tutorials, 2 networking socials and five plenary lectures. As a tradition, there was a student poster competition hosted during the conference as well.

Compared to two PMAD-hosted sessions in previous years, there is four additive session added to this year’s program, moderated by Dr. Hayder Zahalka. It brought up nearly 25 presentations focused on advances in PFAS processing aid replacement, polyolefin additives, and mechanical recycling. The 2025 IPOC conference will again take place at the Galveston Convention Center on February 16-19. Wish you to see you all there!

Selected Paper Abstracts

Wall Slip Performance of PFAS-Free Polymer Processing Aids — Jason Yang, Ingenia Polymers

Per- and polyfluoroalkyl substances (PFAS) are materials that have unique properties and have been employed extensively in a plethora of industrial applications. In plastics production, fluoropolymers, which fall under the broad class of PFAS, have been used as polymer processing aids (PPAs) to improve processing efficiency and quality of plastic products. For example, in plastic film extrusion, it is well known that PFAS PPAs can delay and/or eliminate sharkskin melt fracture (MF) instabilities thus allowing for increased production rates, reduced die build up and improved film clarity. However, evolving regulations and consumer demands limit the use of PFAS in food packaging

applications. The industry has developed a range of PFAS-free PPA solutions. Slip velocity measurements have been carried out on these new PFAS-free PPAs using capillary and parallel plate rheometry and the results are being used to elucidate observations from time to clear experiments in blown film extrusion.

Stabilization of PE: Pre or Post-stabilization?

— Lily Liu (BASF); Josh Heidebrecht, Tony Tikuisis (Nova)

A challenging goal of PE mechanical recycling is to maximize the inclusion of recycled content while maintaining the physical properties and aesthetic performance of the extruded article. There are two approaches that the industry has adopted: improve virgin resin recyclability via enhanced stabilization (proactive) or the addition of supplemental stabilization during the rPE recompounding stage (reactive). Both approaches have been proven to be effective, however; there are no studies reported to date that compare the effectiveness of each approach. In this study, we evaluate the proactive and reactive approaches using a general purpose blown film LLDPE resin. The results of the study indicate that incorporating pre-stabilization improves the quality of the rPE compared to post-stabilization. Further, the use of more advanced stabilization technologies not only improves the recyclability of the virgin PE resin but also enables the finished article to incorporate more recycled content.

New Additive Technology to Improve the Chlorine Resistance of Potable HDPE Pipe — Thomas Chirayil, BASF

A new high performance stabilizer solution has been developed for use in HDPE, especially for pipe where exposure to chlorine is anticipated. Chlorine-based disinfectants are known to be extremely effective in eliminating waterborne pathogens in potable water systems but can also contribute to pipe deterioration. Chlorine disinfectants also interfere with stabilizer additive packages which provide pipe longevity. This new plastic additive technology enables HDPE pipes to be used in contact with chlorinated water estimated to have service life-time of more than 50 years. The new technology meets current drinking water regulations and reduces the migration of non-intentionally added substances.

RHEOLOGY MODIFIER ADDITIVE FOR ENHANCED PROCESSABILITY OF POLYETHYLENE FOR BLOWN-FILM APPLICATIONS

Contributed by Alexander Williamson, etc from Dow Inc.
Reference from *J Vinyl Addit Technol.* **2022**;1–15.

Polyethylene is a versatile polymer suitable for a large variety of flexible and rigid packaging applications. Its mechanical and rheological properties can be tuned across a wide range by controlling its molecular architecture, such as the amount and distribution of olefinic comonomers (short chain branching), long chain branching, and molecular weight distribution. Linear low-density polyethylene (LLDPE) is known for its high toughness which enables downgauged film structures and low-density polyethylene (LDPE) is known for its excellent shear thinning and melt strength which enables enhanced processability and high throughput, such as on blown film lines. In order to obtain a balance of toughness and processability on films produced on blown film lines, blends of LLDPE and LDPE are commonly used. [In this paper, we describe additive-based approaches, including a new product, DOWLEX™ (TM = trademark of the Dow Chemical Company (“Dow”) or an affiliated company of Dow) GM AX01, which enhances melt strength and other rheological properties of polyethylene, enabling fabrication of films with lower LDPE content while still maintaining excellent rheological properties and higher toughness versus conventional LLDPE/LDPE blends. The higher toughness enables downgauging without loss of mechanical properties, which in turn reduces consumption of polymer resulting in a more sustainable solution.]

Introduction (selected)

Polyethylene film compositions are often based on blends of linear low-density polyethylene (LLDPE), with LLDPE providing film toughness but with a number of processing disadvantages over high-pressure low density polyethylene (LDPE), including higher power consumption and poorer melt strength, leading to poor process stability. The improved toughness and tear resistance of LLDPE as com-

pared with LDPE is related to the higher tie chain concentrations in the LLDPE. To enhance processability, LLDPE is often blended with LDPE to enable the process stability, but LDPE contributes little toughness due to inherent long chain branching being a key feature of its molecular structure.

The novel technology discussed in this work, based on the use of a free radical generator (FRG), allows an increase in the ratio of LLDPE in typical LLDPE/LDPE formulations thereby imparting higher film toughness without tradeoffs in process stability, production output, or throughput on fabrication equipment such as blown films lines, and shrink force in the case of collation shrink films. By boosting the overall film toughness, this technology allows further downgauging as well as the use of post-consumer recycle (PCR) or post-industrial recycle (PIR) at maximum levels with excellent process stability and higher output.

The rheology and structure of polyethylene in relation to processability during the production of blown film as well as the resultant film abuse properties has been explored. In particular, the rheology of LLDPE/LDPE blends has been an active area of study, with a focus on the synergistic behavior of the blend, resulting in many cases in improved melt strength, processability, and bubble stability over that of the LLDPE or LDPE alone. LLDPE/LDPE melt strength synergy can be explained through the Bersted model and the effects of long chain branching on the low or zero shear viscosity of polyethylenes. For melt strength synergies, a mixture of linear and branched molecules of similar molecular weights is preferred. Addition of LDPE to LLDPE results in melt strength enhancement, generally reaching a maximum as hypothesized in Reference, when the LLDPE concentration in LDPE is low, in this case at about 80% LDPE in LLDPE. Others have shown this melt strength synergy to also be correlated with orientation, tear strength, and relaxation time.

This technology was developed to provide film fabricators convenient way to improve melt-strength in order to enable high throughput film fabrication and enable downgauging without sacrificing mechanical properties. Several of the desired attributes are listed below:

- Rheology enhancing additive in the form of pellets which can be conveniently added by converters at a ratio of their choosing
- Introduction of long chain branches to LLDPE, enough to provide a significant improvement in rheological properties, but not so much as to have a negative impact on mechanical properties, or to form gels
- The optimum kinetics to provide a significant rheological benefit at a wide variety of different temperature profiles and residence times encountered on the extruders of converters' blown-film lines. With the reactivity being slow enough to avoid degradation during storage, or gel formation during extrusion, but fast enough to be completely reacted under a wide range of blown-film line configurations
- No regulatory or safety concerns, with harmless by-products

A method was developed on the Micro-18 twin screw extruder to simulate temperature and residence times on single-screw extruders of typical blown-film lines. An exit die melt temperature, as measured with a hand-held thermocouple, of 215°C was used as a standard condition. A twin-screw extruder (instead of a single-screw extruder) was used in order to obtain good mixing and thus remove uncertainties about the efficiency of mixing.

Experimental (see original paper for more details)

Three liquid free radical generators (FRG) with different decomposition kinetics A, B, and C were also used, the structures of which are confidential.

Results and Discussion (selected)

3.1 | Selection of FRG with appropriate kinetics

The first step was to identify a free radical generator (FRG) with an appropriate kinetic profile. Various free radical generators were compared with each other using differential scanning calorimetry (DSC). For the DSC experiment the FRGs were dissolved in C20H42 solvent at a concentration of 10 wt% for an acceptable signal-to-noise ratio output. The exotherms were analyzed and the kinetic parameters were established. Then, in the temper-

ature range of interest, the half-lives were calculated and presented as a plot of the natural logarithm of the half life versus the temperature. An example of three FRG's is shown in Figure 2.

The curves in Figure 2 should be interpreted as relative half-life profiles rather than absolute in terms of correlation with the extrusion process. This is firstly due to the

fact that the viscosity of the C20H42 solvent is much less than that of a polyethylene (PE) melt, and secondly due to the fact that the concentration of 10 wt% used

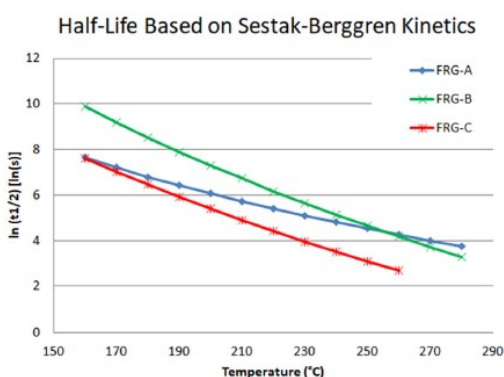


Figure 2 Ln half life vs Temperature

in the DSC experiments was vastly higher than practically used in the PE melt. Both of these effects make the reaction rate slower in the PE melt versus the rates.

The curves show that FRG-C has a steeper dependence of half-life on temperature versus FRG-A which could be favorable for surviving masterbatch preparation at lower temperatures without decomposition of the FRG, while still having good reactivity at the higher temperatures experienced during film extrusion. The curves also show that FRG-C has a higher overall reactivity versus FRG-B.

The second step was to test a selection of these FRG's in a polyethylene melt under processing conditions designed to mimic those encountered in a single-screw extruder of a typical blown-film line. Masterbatches containing FRG-A, -B, and -C in LDPE (prepared on the FlackTek mixer/Micro-18 twin-screw extruder under nitrogen as described in Section 2) were processed with LLDPE-A (2:98 ratio) on the Micro-18 twin-screw extruder with an exit die temperature of 215°C, under air. The target initial concentration of FRG's in the resin blend was 20 ppm for FRG-B and -C, and both 20 and 50 ppm for FRG-A. The 20 ppm loadings were obtained via masterbatches containing a concentration of 1000 ppm FRG, and the 50

ppm loading was obtained via a masterbatch with a concentration of 2500 ppm FRG.

The modification of the PE chains afforded by the FRG strongly increases viscosity at low shear rates, but has minimal effect on the viscosity at high shear rates. In other words, the resins become more shear thinning. Low shear viscosity increase is also related to improvement in shrink force in collation shrink applications. Under these conditions, FRG-C afforded the highest increase in low shear viscosity, melt strength, and reduction in melt index.

It was noted that, weight-for-weight, FRG-B showed more rheological modification under these conditions than FRG-A, despite the fact that the DSC kinetics experiment indicated a shorter half-life for FRG-A at the processing temperature of 215°C. This difference may potentially be due to mechanistic differences between the FRG's, with FRG-A potentially affording more side reactions versus cross-linking between polyethylene chains. It was later found that a significant percentage of FRG-B, as much as 75%, had evaporated from the masterbatch during its preparation. This, in addition to its slower kinetics, likely accounts for the lower degree of modification versus FRG-C.

3.2 | Residual reactivity

Another important requirement of a FRG for rheology modification is that no residual FRG remains in the resin after extrusion on the blown-film line. As even the initial concentration of FRG is low (20 ppm) it is difficult to quantify FRG concentration in the extruded resin by conventional methods such as gas chromatography.

Therefore, time-sweep DMS (dynamic mechanical spectroscopy) experiments were performed on the extruded pellets (same MB preparation and extrusion conditions as above) under nitrogen to determine whether the system was still reactive. The baseline resin (98% LLDPE-A + 2% LDPE) without FRG showed, as expected, no increase in low shear viscosity as a function of time at 190°C. The resin with FRG-A still had residual reactivity resulting in an increase in low shear viscosity as a function of time, indicating that not all the FRG had reacted during extrusion. FRG-C had no residual reactivity after extrusion. FRG-B was not tested as all unreacted

FRG-B was lost due to evaporation during extrusion.

3.3 | Influence of concentration of FRG-C on rheology

In order to study the influence of concentration of FRG-C on the degree of rheological modification, a series of masterbatches of different concentrations were prepared by the standard method. These masterbatches were then processed with LLDPE-A under the standard conditions. The results are shown in Figures 7 and 8. The results show a linear correlation between the concentration of FRG-C and rheological properties in the range of 0 to 37.5 ppm of FRG-C.

3.4 | Influence of vinyl groups and antioxidants on degree of rheological modification

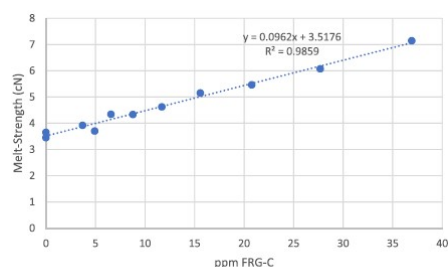


FIGURE 7 The influence of concentration of FRG on melt-strength

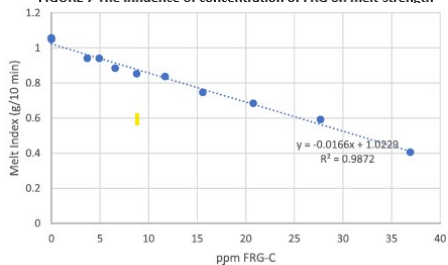


FIGURE 8 The influence of concentration of FRG on melt index

Two of the key mechanisms for modification of polyethylene to build molecular weight, and hence influence the rheological properties, are via combination of radicals on two PE chains, and via reaction of PE chain radicals with terminal vinyl groups in the PE. The base resin used in this study, LLDPE-A,

had ~0.25 terminal vinyl groups per 1000 carbons (via NMR spectroscopy). One gram of LLDPE-A contained ~0.0714 moles of carbon, and therefore ~1.8x10⁻⁵ moles of terminal vinyl groups. If we assume that a concentration of FRG-C of 20 ppm would deliver 1.5x10⁻⁷ moles of PE radicals all at the same time, a PE radical would still be ~120 times more likely to encounter a terminal vinyl group than another PE radical. It is therefore likely that terminal vinyl groups, when present, play a significant role in the PE modification mechanism.

Different grades of commercially available resins contain different types and concentrations of antioxidants. Antioxidants are expected to have a significant hindering effect on the modification of PE by the FRG. Several commercially

available LLDPE resins with different levels of terminal vinyls and antioxidants (AO's) were compared as shown in Table 2. Irganox 1010 and Irganox 1076 are both primary AO's with phenolic functional groups. The phenolic groups react preferentially with oxygen centered radicals on polymer chains that are undergoing oxidative degradation, to form unreactive phenolic radicals (ArO·). Irgafos 168 and TNPP are both secondary AO's with phosphite functional groups. The phosphite groups react preferentially with hydroperox-

TABLE 2 Antioxidant and vinyl levels of several commercially available LLDPE resins.

	I-1010 (ppm)	I-1076 (ppm)	I-168 (ppm)	TNPP (ppm)	Vinyls number
Resin A	-	-	~1000	-	0.261
Resin B	152	231	917	-	0.301
Resin C	-	285	-	1356	0.07
Resin D	-	217	-	737	0.098
Resin E	-	758	486	-	0.09
Resin F	-	267	-	436	0.013
Resin G	-	777	498	-	0.404

ides on polymer chains undergoing oxidative degradation.

Terminal vinyl groups were measured using NMR spectroscopy. Antioxidant concentrations were measured via liquid chromatography after extraction into solvent. The difference in melt index before and after extrusion under standard conditions using 20 ppm of FRG-C is compared. Resin A has both high vinyls and absence of primary antioxidant (AO) and provides the highest reduction in melt index. Resins B and G both have high terminal vinyl content, but both of them contain primary AO, and show an intermediate reduction in melt index. Resins C, D, E, and F all contain primary AO and low vinyl content and provide the lowest reduction in melt index. This supports the hypothesis that high levels of vinyls are beneficial, and that the presence of primary AO is detrimental to modification by this FRG. In order to study the influence of AO's on the effectiveness of FRG-C, a resin without any additives (LLDPE with hexene comonomer, MI = 0.85 g/10 min, density = 0.919 g/cc, LLDPE-B) was imbued with different amounts of AO dissolved in toluene. Different concentrations of AO's in toluene (up to 10 wt%) were used to imbibe the resin with up to 1000 ppm of AO. The toluene solutions were coated onto the resin pellets using a FlackTek mixer and the pellets were left in a fume hood overnight to allow the AO's to imbibe and most of the toluene to evaporate. The resins were then compounded on the Micro-18 twin-screw extruder under nitrogen, with an exit die melt tem-

perature of less than 190°C. The resultant resins containing different levels of AO were then extruded under standard blown-film line simulation conditions together with 2% of a masterbatch containing 1000 ppm of FRG-C in LDPE, to give 20 ppm target concentration of FRG-C in the initial compositions. The low shear viscosities were then measured by DMS and are reported in Figure 10. Figure 10 shows that a fully stabilized resin without any FRG after processing under the same conditions had a complex viscosity at 0.1 rad/s of about 11 000 Pa s (lower red line). A resin without any AO

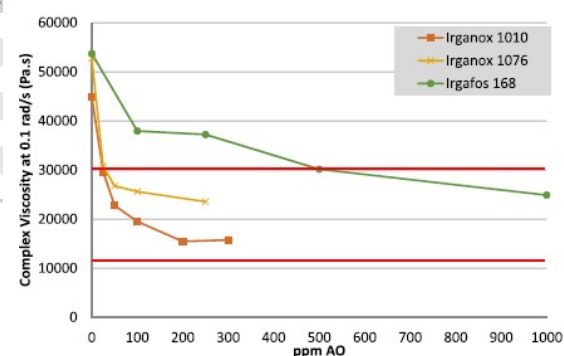


Figure 10 Influence of antioxidant concentration on low shear viscosity by DMS after extrusion with 20ppm FRG-C

or FRG after processing under the same conditions had a complex viscosity at 0.1 rad/s of about 30 000 Pa s, indicating that oxygen-induced

modification will occur in absence of any AO (upper red line). The space between the lower and upper red lines, therefore, indicates the range of low shear viscosities that could be achieved by adjustment of these antioxidants alone, without introduction of any FRG. It is, however, recommended to always have AO present, in order to avoid gel formation. Figure 10 shows that the low shear viscosity imparted by FRG-C decreases significantly on addition of even low levels of AO. The decrease is more extreme for Irganox 1010 than Irganox 1076, likely due to the higher concentration of phenolic functions in the Irganox 1010.

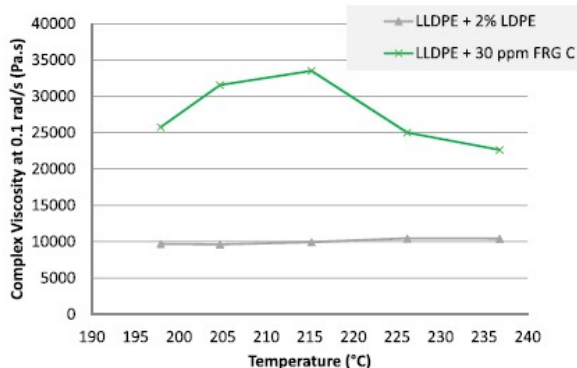
The decrease in viscosity is significantly less with the secondary AO Irgafos 168. For maximum efficacy, it is therefore recommended to use FRG-C in resins with low concentrations of, or no primary AO. In the PE industry, there is a huge variety of grades of resins which contain multiple different types and loadings of AO depending on the target applications. These include many grades that do not contain high concentrations of primary AO and these grades are therefore highly suitable for the use of rheology modifiers such as the ones described in this report. Other resin grades with higher concentrations of primary AO are less suitable, and

higher loadings of rheology modifier may be needed to generate a similar effect.

3.5 | Dependence of reactivity of FRG-C on processing temperature

In order to determine the optimum processing temperature for FRG-C, an experiment was performed where the same composition of 98% LLDPE-A and 2% of a masterbatch containing 1500 ppm of FRG-C on LDPE was processed at different exit die melt temperatures. The different temperatures were achieved by adjusting the temperatures of the six heating zones along the extruder. Low shear viscosity results are shown in the blow Figure. It shows that the ideal processing temperature range, where the greatest degree of modification occurs, is likely between about 210 and 220°C.

3.6 | Film/application testing



The development described above resulted in the functional additive in which the chosen active principle was the FRG-C, commercially available as DOWLEX™ GM AX01.

The additive was tested at customers' blown film extrusion lines on an industrial scale for a wide variety of applications, such as for industrial liners allowing the elimination of substantial amounts of LDPE in the film formulation compositions, resulting in tougher films, for collation shrink film allowing downgauging, and for agricultural films enabling an increase in the content of PIR in the film composition with increase in the process output.

Industrial liners produced at 90 μ of thickness at a monolayer blown film extrusion line, with an extruder of 80 mm, L/D 30:1, die diameter of 350 mm, die gap of 2.1 mm, and blow-up ratio of 2.55:1, were originally produced with blends of 70% LLDPE +30% LDPE. Two different LLDPE's were compared, (1) LLDPE-B containing hexene comonomer with 0.9 g/10 min melt index (at 190°C, 2.16 kg) and

0.919 g/cc density, and (2) LLDPE-C, containing hexene comonomer with 0.5 g/10 min melt index (at 190°C, 2.16 kg) and 0.920 g/cc density. The latter, having a fractional melt index, can run with no LDPE in the extrusion line depending on the desired output and bubble diameter. Therefore, the original 70/30 references were compared with film compositions produced with 98% LLDPE-B + 2% DOWLEX™ GM AX01 and also with 100% LLDPE-C. The high-pressure LDPE used has 0.3 g/10 min melt index and 0.921 g/cc density, with the primary purpose of providing bubble stability to the film.

No tradeoffs in the process stability were observed when transitioning from the 70/30 references to the formulations with no LDPE, keeping the output of 210 kg/h. An increase of 30 bar in the melt pressure was observed, as expected, since the LLDPE content was increased; yet, it was far below the limit of the extruder.

Comparing the mechanical properties of the films produced, regardless of the LLDPE used, a similar increase of about 23% in dart drop impact resistance was observed when removing LDPE from the formulations. No significant differences between films 98/2 LLDPE-B/DOWLEX™ GM AX01 and 100% LLDPE LLDPE-C was observed.

Films produced with 98% LLDPE-B + 2% DOWLEX™ GM AX01 presented an increase of 20% and 67% in Elmendorf tear resistance in the cross and machine directions, respectively, in comparison with its precursor produced with 30% LDPE, and 27% and 69% in comparison with the film produced with 100% LLDPE-C. Film compositions composed of the additive were qualified for this application and for others when an improvement in the process stability was required.

Another study case performed in the market was the development of a formulation for collation shrink film. Beverage brand owners have been requesting sustainable packaging solutions and an optimal use of resources is one of the avenues being explored by the market. In terms of film formulations, it can be translated to downgauging when an optimized selection and use of PE resins can deliver the same performance as incumbent films but using less amount of

material—and therefore, savings in carbon footprint can also be achieved. In this case study, the original formulation of a 60 μ collation shrink film was composed of 55% LDPE (0.3 g/10 min melt index, 0.921 g/cc density) + 33% HDPE (0.95 g/10 min melt index, 0.95 g/cc density) + 12% PIR (which is the same collation shrink film recovered). The high percentage of LDPE is justified by its long chain branching and very high molecular weight, factors that provide shrink force and cross directional shrinkage, which are required by the application. The proposed formulation suggests a downgauging of 17%, resulting in a film thickness of 50 μ composed of 37% LDPE + 25% LLDPE-B + 36% MDPE (1.0 g/10 min melt index, 0.936 g/cc density) + 2% DOWLEX™ GM AX01. Films were produced in a 3-layer coextrusion line with 350 mm of diameter, 2 mm of die gap and with a Blow-Up Ratio (BUR) of 3.5:1. Results of optical and mechanical properties, as well as shrinkage at 150°C, are disclosed in Table 3. Even at lower gauge, the optimized formulation with the functional additive resulted in an increase of 20% in Elmendorf tear resistance in CD and 56% in MD, as well as 123% higher puncture resistance. Despite the lower content

TABLE 3 Comparison of properties between collation shrink film produced with 60 μ and the proposed formulation produced with 50 μ with 2% DOWLEX™ GM AX01 in the overall composition

	Shrink reference—60 μ	Shrink with DOWLEX™ GM AX01—50 μ
Result clarity (%)	71	94.6
Tear resistance CD (gf)	668	808
Tear resistance MD (gf)	102	159
Puncture resistance (J/cm ³)	3.1	6.92
Ave load at break CD (MPa)	26.3	36.8
Shrinkage (%) @150°C MD	70	70
Shrinkage (%) @150°C CD	34	29

of LDPE in the overall formulation, the proposed formulation maintained the shrinkage at 150°C in both machine and cross directions, as a result of the long chain branching imparted by the addition of DOWLEX™ GM AX01

to the LLDPE-B resin.

Finally, a further study that showcases the use of the functional additive is for agricultural film, traditionally produced at high gauges of 220-250 μ and produced at high bubble diameters from 8 to 12 meters. In this example, the addition of 3% DOWLEX™ GM AX01 allowed the incorporation of 30% PIR in films, which traditionally reduced output. Moreo-

ver, the functional additive enabled the increase of the extruder's maximum output rate from 1120 to 1250 kg/hr with the same ratio of PIR in the film formulation. As a result, DOWLEX™ GM AX01 has proven to be a booster in process stability even when using PIR in the film composition.

4 | CONCLUSION

A rheology modifier additive, FRG-C, was selected with suitable kinetics to provide significant increases in low shear viscosity and melt strength under temperature and residence time conditions of a single-screw extruder of a typical blown-film line. There was no residual reactivity after extrusion, and the optimal process temperature was between 210 and 220°C. Although FRG-C provides a rheological benefit in a wide variety of resins, it worked best with resins with low AO content (especially low primary AO content), and high vinyl content.

This technology can be used to fabricate films with lower LDPE content while maintaining processability, as well as maintaining shrink force for collation shrink films. The lower LDPE content allows higher LLDPE content, which affords tougher films which enables down-gauging without loss of mechanical properties.

This technology also enables incorporation of PIR without reduction in processability. A new commercial offering by Dow called DOWLEX™ GM AX01 has been launched based on this technology.

About the polymer learning forum

This learning forum is served to provide education in the area of plastic additives and modifiers. If you have any interesting topic you would like to share or you have any specific area you would like to learn from the forum, please reach out and we would like to hear from you. Thank you!

My email address: lili.liu@basf.com

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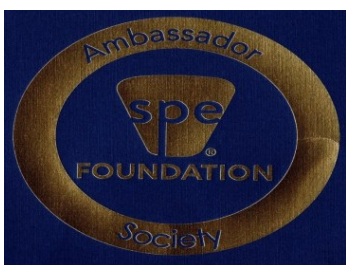
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Our Polymer Modifiers and Additives Division was awarded the Ambassador Award by the SPE Foundation for all the contributions we had made to support students via our Scholarship program.

CERTIFICATE OF APPRECIATION

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SPE Polymer Modifier & Additives Division

In grateful appreciation and sincere recognition for their outstanding generosity and commitment to the SPE Foundation's mission.

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