Non-PFAS Polymer Processing Aids for Blow Moulding

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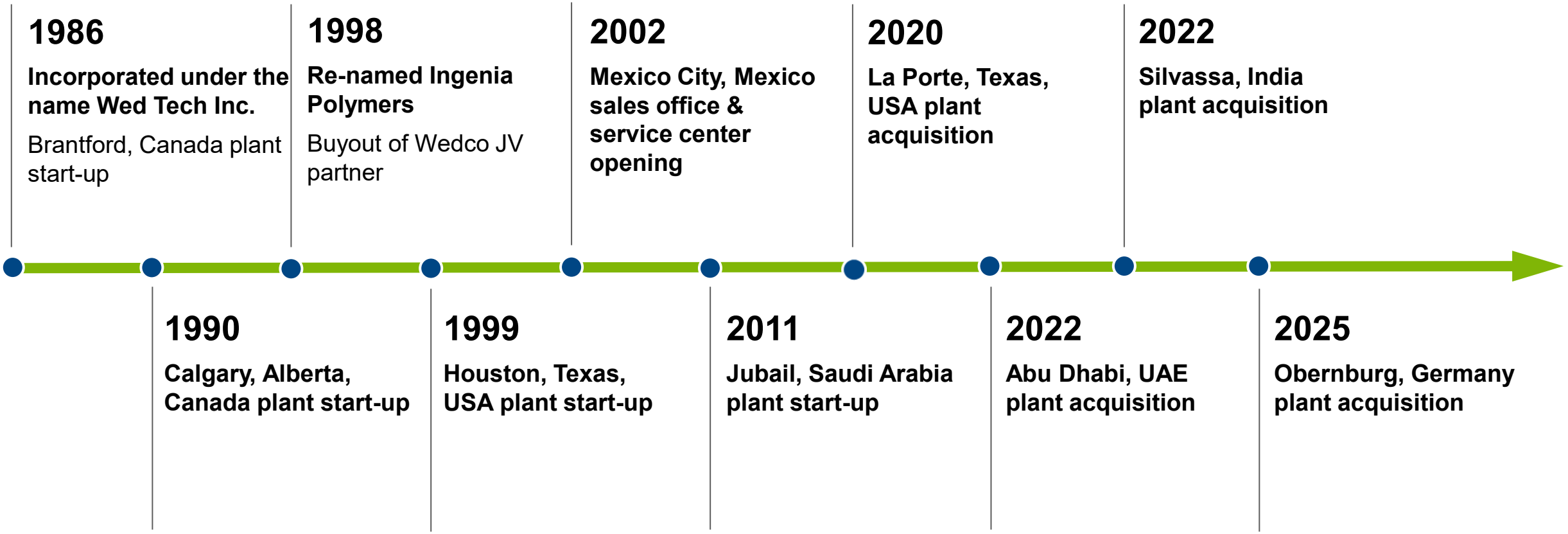
INGENIA
REDEFINING THERMOPLASTICS

Ingenia has a Record of Continuous Growth



Ingenia Locations

Ingenia is Comprised of Two Complementary Business Divisions

Primary Producer Division

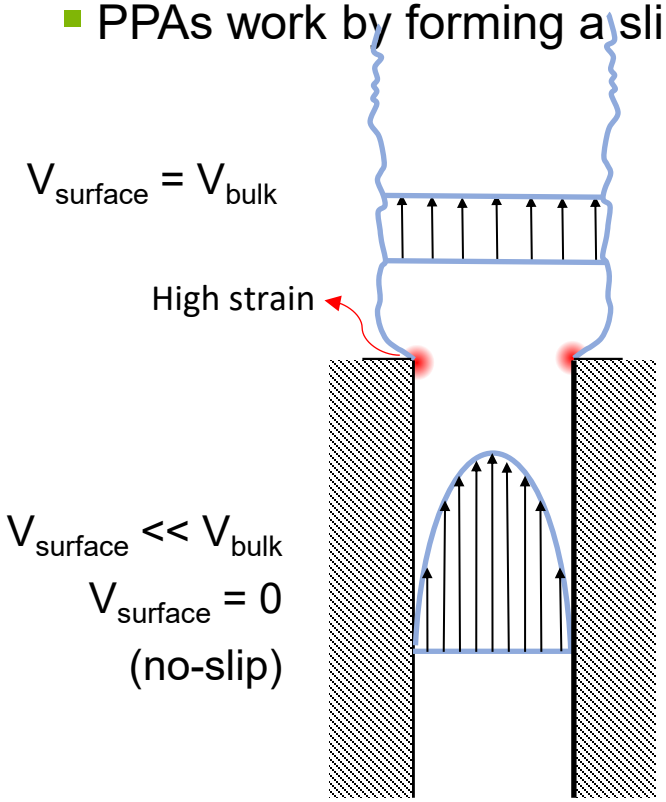
- Servicing resin producers' post-reactor needs on a global scale
- Custom compounding services
- Grinding services
- Raw material supply management
- Distribution and logistics support
- Research and product development support
- Ingenia SuperBlend® technology

Proprietary Products Division

- INCIRCLE® and INBIO® brands – masterbatches to support the circular economy
- Proprietary White and Black Concentrates
- Proprietary Additive Masterbatches
  - Antiblocks, Slips, Process Aids, Antistats, UV Stabilizers/HALS, Antioxidants, Specialty Additives
- Specialty Color Masterbatches
- Superlink® cross-linkable rotomolding compound and specialty rotomoulding products

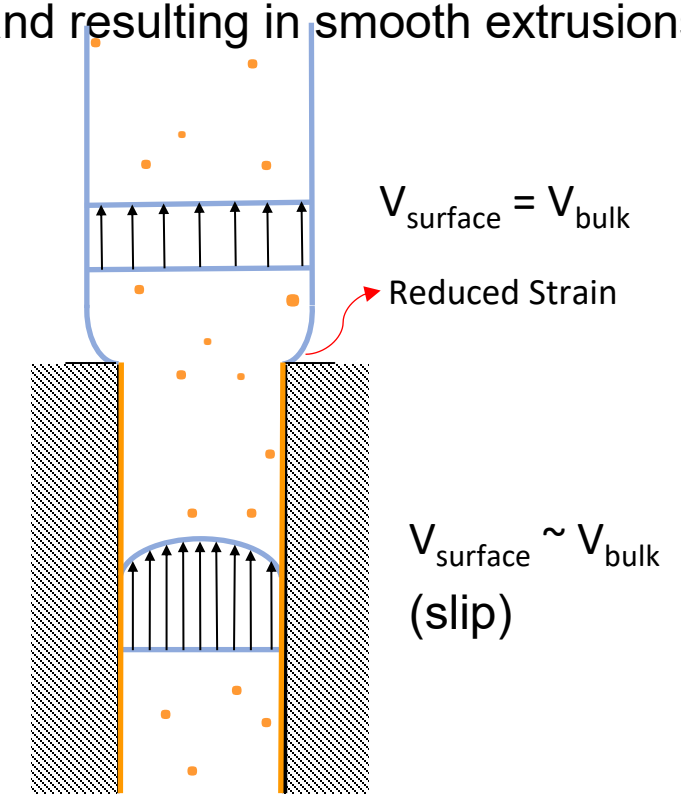
Polymer Process Aids Improve the Surface of Polyolefin Films

- PO processors want to run equipment at low temperatures and high speeds to save on production costs.
- High shear stresses lead to stress concentrations which cause sharkskin melt fracture.
- Die lip buildup can also limit productivity as lines need to be stopped to clean extrusion dies
- PPAs work by forming a slip layer on the die wall, reducing stress at the die exit and resulting in smooth extrusions



LLDPE extrusion, no PPA

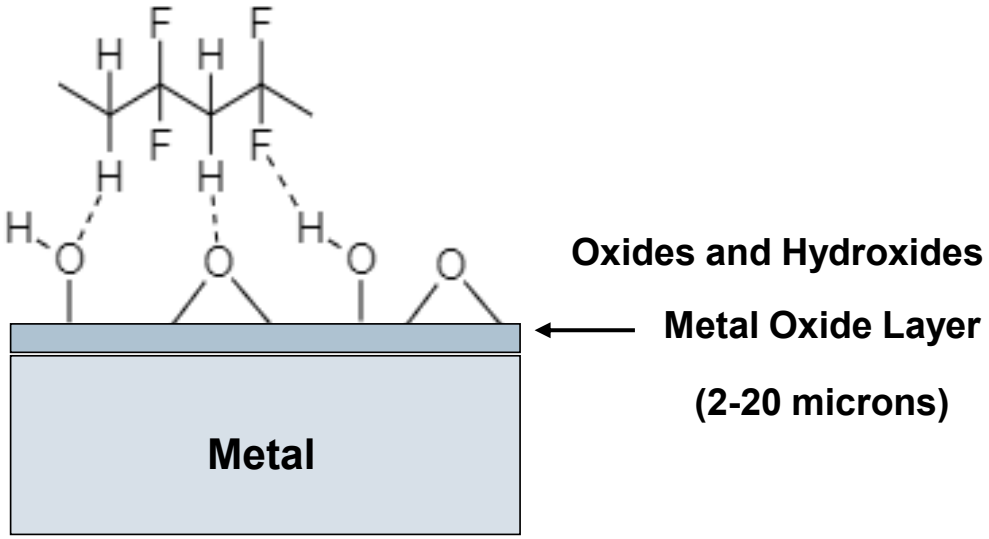
Film without PPA Film with PPA



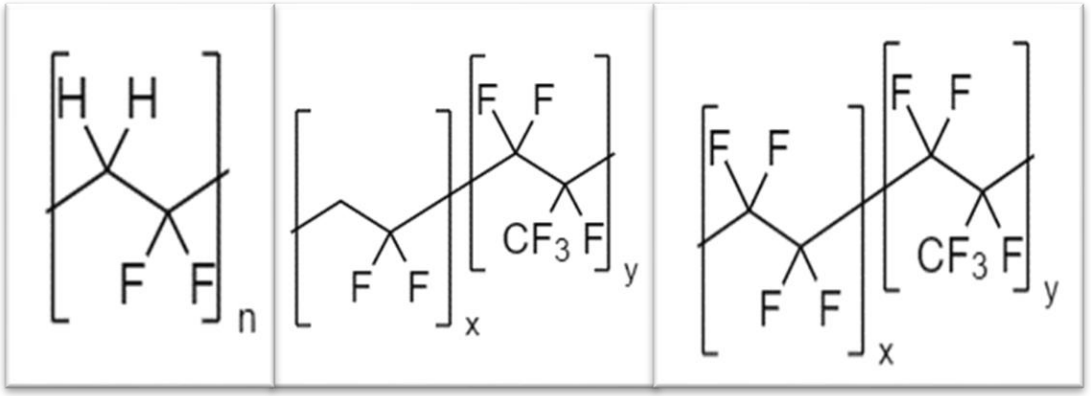
LLDPE extrusion, with PPA

Fluoropolymers – The State of the Art PPAs for 40 years

- Fluoropolymers are the established solution to sharkskin
- Fluoropolymers have unique properties:
  - Localized electron density on the fluorine which facilitates adhesion to the die wall
  - Low surface energy facilitates slip of the PE extrudate



Common fluoropolymers used as PPAs:



PVDF PVDF-HFP FEP

Polymer	PP	PE	PVDF	FEP	PTFE
Surface Energy (dynes/cm)	30	30	25	20	19

Fluoropolymers are classified as PFAS

- 2021 OECD Definition of Per- and poly-fluoroalkyl substances (PFAS):

  Fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom

- This definition captures thousands of substances with a diverse range of physical and chemical properties.
- Concerns around the environmental and health impacts of some PFAS materials have led to increasing regulation of the entire class
- Fluoropolymers used as PPAs are captured by this OECD definition

Per- and Polyfluoroalkyl Substances (PFAS) | US EPA

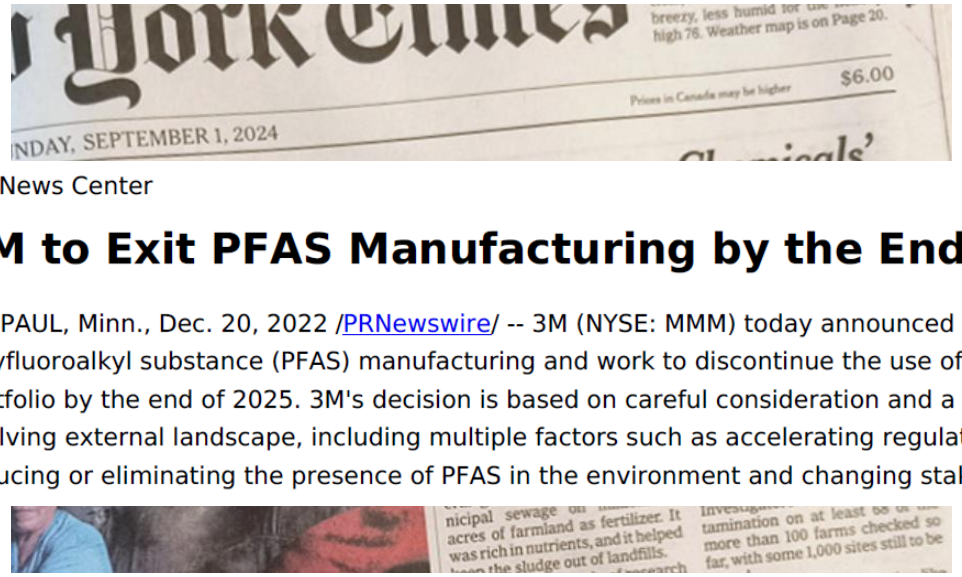
PFAS are Increasingly Regulated

USA Federal Legislation	EPA implementing extensive reporting requirements for PFAS manufacturers & importers. Ongoing FDA review of petitions seeking to ban PFAS.
US State Laws	PFAS in food packaging bans (including plastic): July 1, 2023 – Vermont December 31, 2023 – Connecticut January 1, 2024 – Minnesota Jan 1, 2025 – Rhode Island (formerly July 1, 2024), Oregon 2025: Washington State, Maine bans expand as alternatives identified.
EU	ECHA review to ban PFAS underway. Possible timeline for restriction 2025/2026. PPWR draft published in April 2024. Current draft would ban fluoropolymer use above 50 ppm within 18 months.
Canada	In May 2023 a proposal was put forward to add PFAS to the CEPA schedule 1 list of toxic substances, allowing regulation of all PFAS.

The need for non-PFAS PPAs is clear!

The Public Has Concerns About PFAS

- Environmental and health effects of PFAS pollution came to broad public knowledge in the US via movies such as Dark Waters and a slew of media coverage.
- Contamination surrounding a production facility in Belgium has brought the PFAS concern to Europe.



3M News Center

3M to Exit PFAS Manufacturing by the End of 2025

ST. PAUL, Minn., Dec. 20, 2022 /PRNewswire/ -- 3M (NYSE: MMM) today announced it will exit per- and polyfluoroalkyl substance (PFAS) manufacturing and work to discontinue the use of PFAS across its product portfolio by the end of 2025. 3M's decision is based on careful consideration and a thorough evaluation of the evolving external landscape, including multiple factors such as accelerating regulatory trends focused on reducing or eliminating the presence of PFAS in the environment and changing stakeholder expectations.

The need for Non-PFAS PPAs is clear!

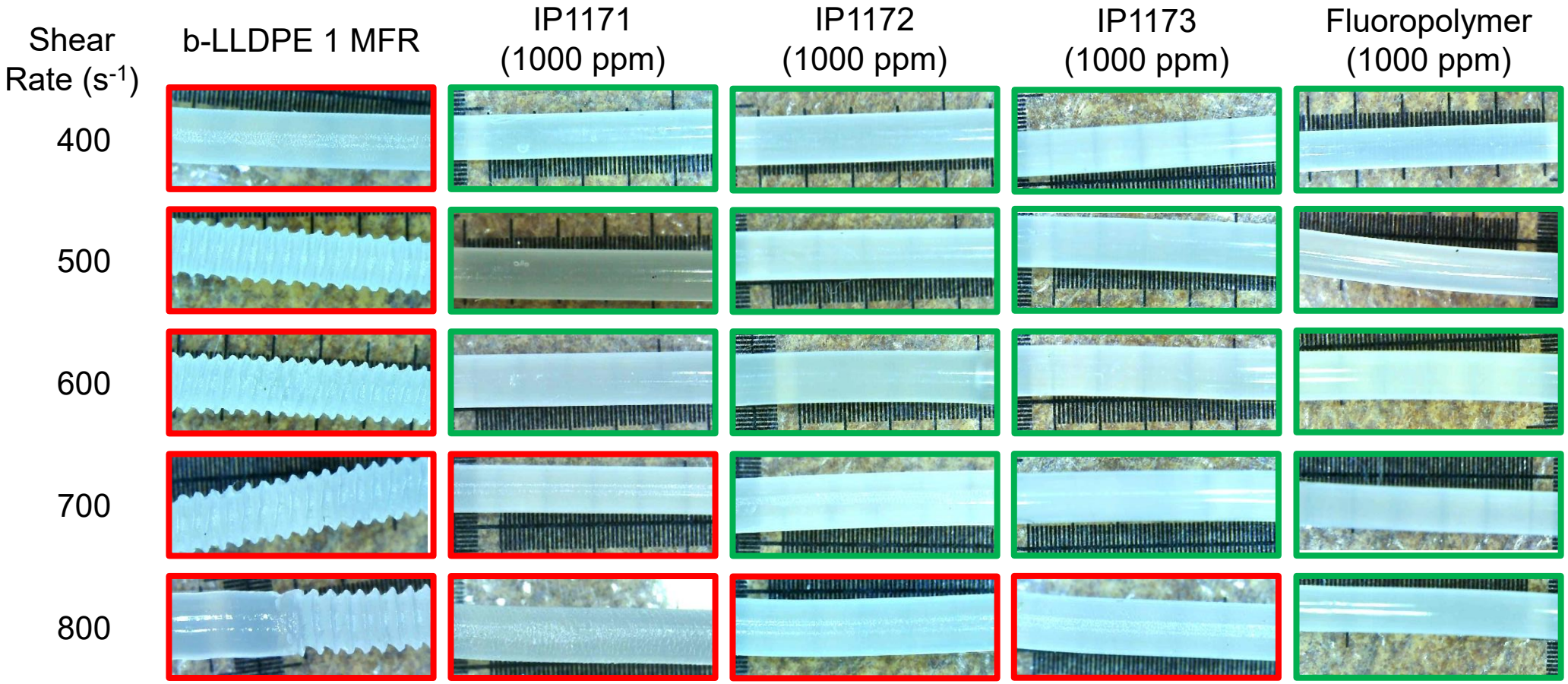
References:
https://www.epa.gov/pfas; https://www.theguardian.com/environment/2024/may/01/rapidly-rising-levels-of-tfa-forever-chemical-alarm-experts;
https://www.nytimes.com/2024/08/31/climate/takeaways-pfas-sludge-fertilizer.html; https://news.3m.com/2022-12-20-3M-to-Exit-PFAS-Manufacturing-by-the-End-of-2025

Non-PFAS PPAs Are Commercial and Proven in Industry

Non-PFAS PPA	Stage of Development	Food Contact Status	Performance
IP1171 (ITZ-536)	Commercialized August 2023	EFSA, FDA (A-H), China, Mercosur, Japan compliant.	Highly efficient PPA. Fastest time-to-clear. Excellent die lip build-up performance.
IP1172 (ITZ-526)	Commercialized 2024	EFSA, FDA (A-H), China, Mercosur, Japan, compliant.	Improved performance in narrow MWD metallocenes and plastomers. Improved die lip build-up performance.
IP1173 (ITZ-526C)	Commercialized 2024	EFSA, FDA (A-H), China, Mercosur, Japan, compliant.	Performance comparable to IP1172. Improved application to resin production.

- Ingenia's non-PFAS PPAs are in extensive commercial use in blown film and cast film applications.
- Performance testing has been extended to HPDE blow molding applications.
- Let's look at the performance data…

Capillary Rheology Demonstrates Delay in Onset of Sharkskin with Non-PFAS PPAs



190 C, 0.8 mm die, 20 L/D, precoating until constant ΔP at 350 s^{-1}.

Analyzed the onset of sharkskin under microscope.

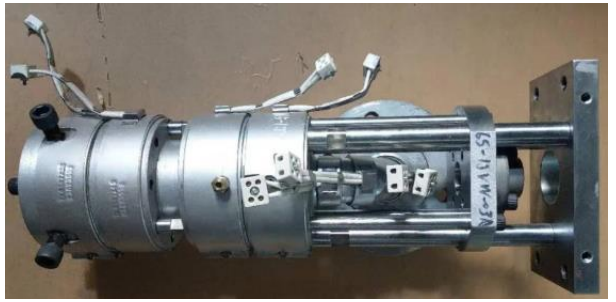
Blow Molding Trials Were Carried out on Scalable Pilot Equipment

- Testing was performed in two different resins:
  - Resin 1:0.3 MFR, 0.954 g/cc blow molding resin. (Sabic B5429 HDPE)
  - Resin 2: 0.35 MFR, 0.955g/cc blow molding resin. (Chevron HHM 5502BN)
- Trials were carried out at the Higher Institute of Plastic Fabrication (HIPF*)
  - On a Kautex KCC10 Blow Molding Machine with a half liter mold under conditions with a nominal output of ~ 257 cycles per hour (~14 s cycle time).
  - Initial processing was carried out in the absence of PPA at 180 °C.
  - Temperature was reduced to 170 °C.
  - PPA was introduced via masterbatch and the system was run for a minimum of 30 minutes with PPA to reach equilibrium.
  - Processing conditions (P, T) were taken and samples were collected for surface characterization.
  - Before each trial the system was purged with silica rich polyethylene for 20 min, then the test resin without PPA for 10 min.

Half Liter Blow Molded Bottle

* https://www.hipf.edu.sa/en/

Blow Molding Machine – KAUTEX KCC10 at HIPF



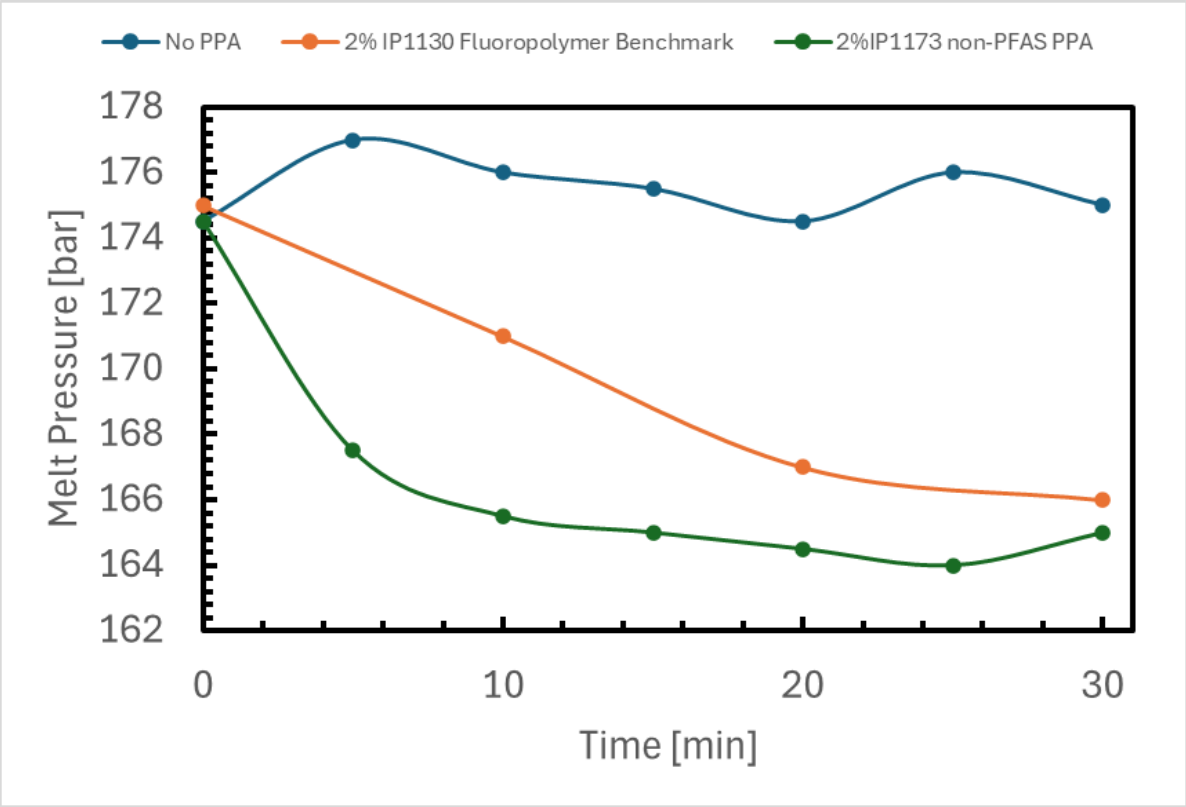
Model : Kautex KCC10 (15 units)
Closing Force: 100 kN (10 tons)
Screw Diameter: 50 mm(L/D = 25)
Extruder Speed: 14.5 rpm

Capacity: Plastic Bottle up to 5 liters
Extruder Motor: 18.5 kW (25 hp)
Output: ~257 bottles/hr @14 sec CT (0.5L mold)
Die: 27.5 mm I.D., 30.5 mm O.D

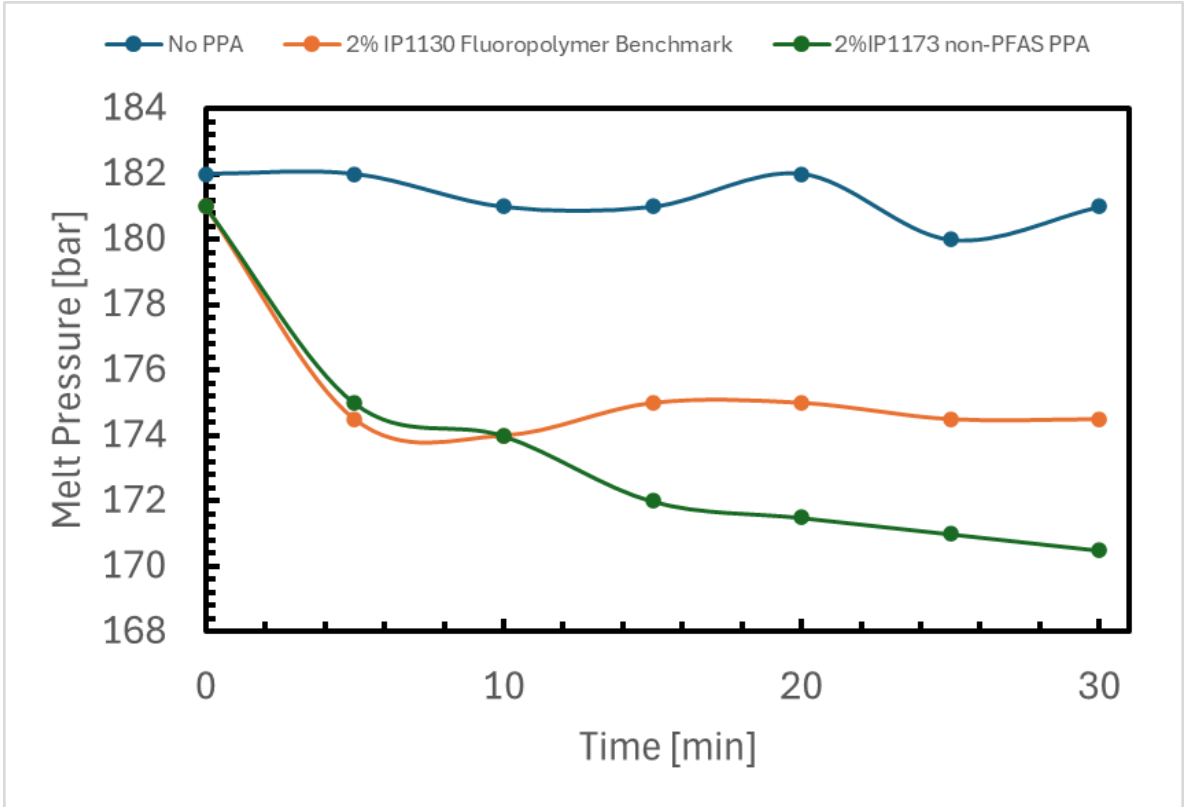
Ref: https://www.hipf.edu.sa/

IP1173 Non-PFAS PPA Reduces Pressure in Blow Molding

RESIN 1



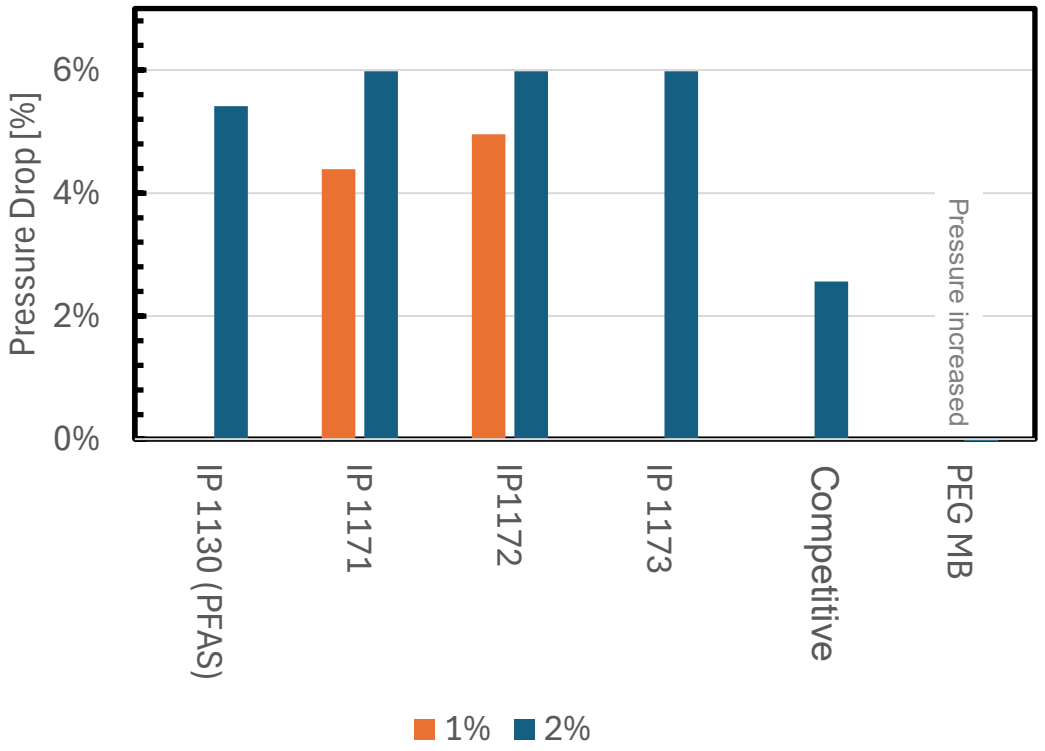
RESIN 2



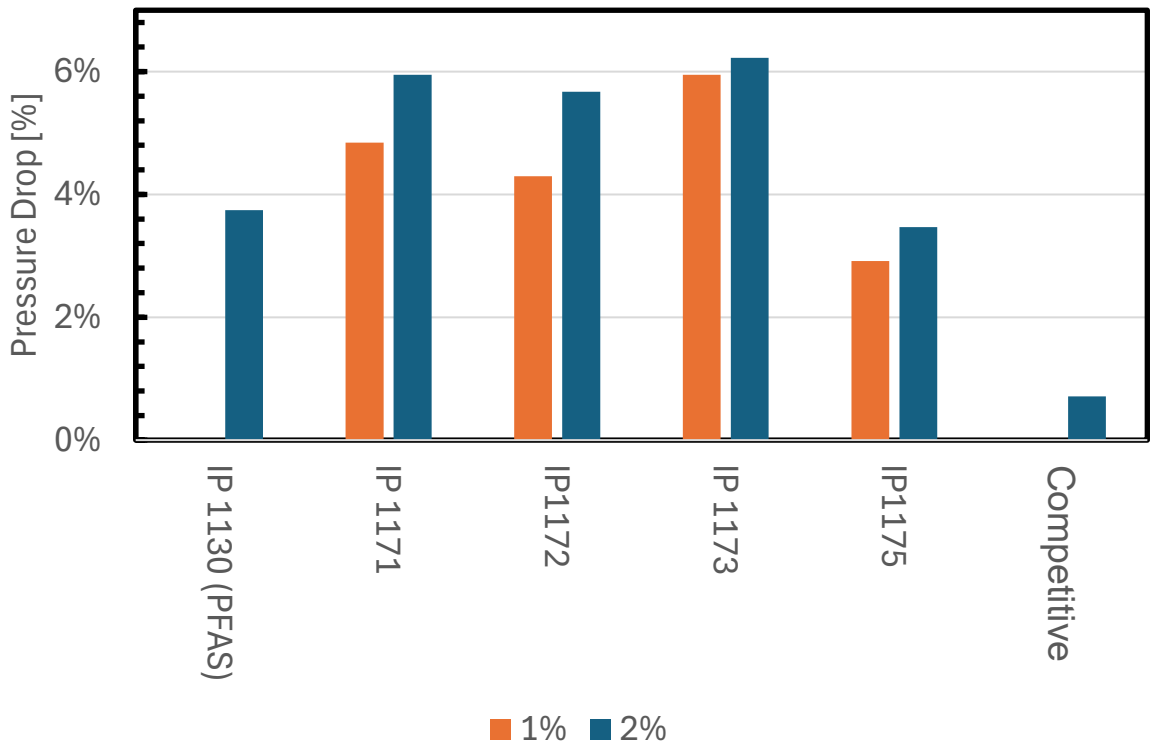
- Fluoropolymer and non-PFAS PPAs demonstrate coating behavior. → Conditioning time required to coat extrusion die.
- Equilibrium reached (minimum 30 minutes) before taking samples and collecting process data.

Ingenia's Non-PFAS PPAs Reduce Die Head Pressure

RESIN 1

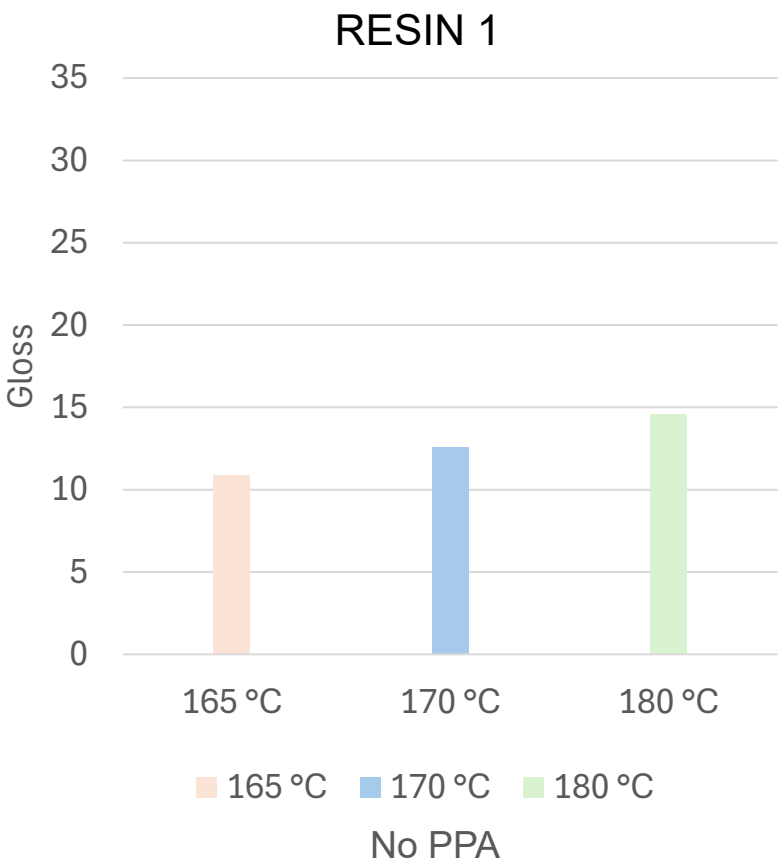


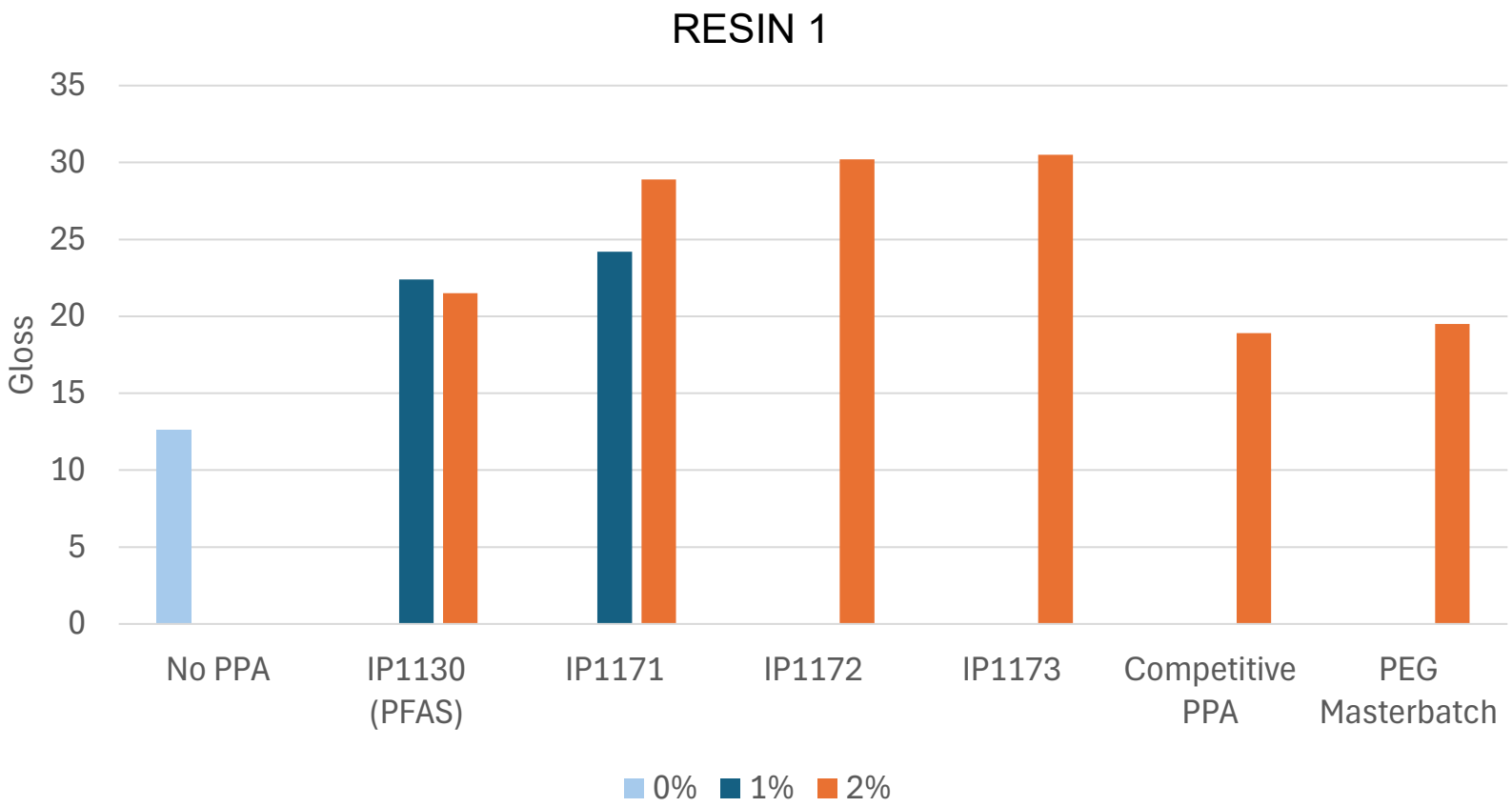
RESIN 2



- IP1171, IP1172 and IP1173 reduce die pressure more than Fluoropolymer or competitive material at 2% addition rate.
- IP1171, IP1172 and IP1173 are effective at only 1% addition rate.
- PEG Masterbatch did not reduce extrusion pressure significantly at 2% letdown for resin 1 and resin 2.

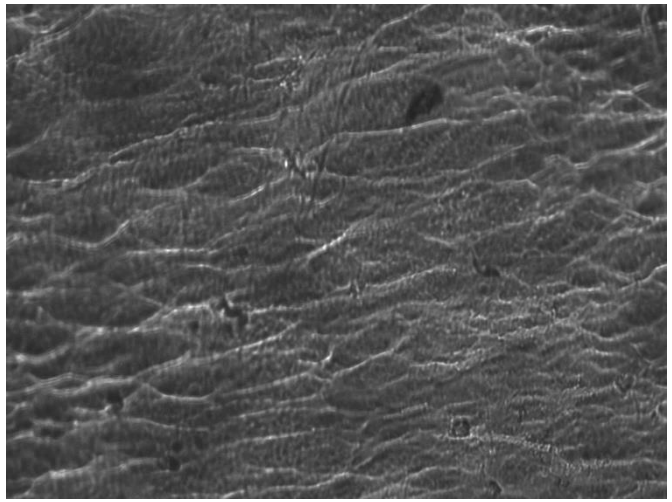
Ingenia's Non-PFAS PPAs Improve 60° Surface Gloss



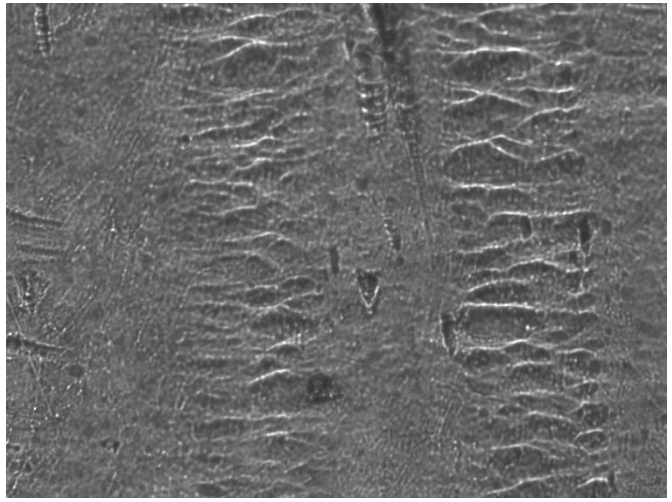


- Higher processing temperature provides a moderate improvement in gloss in the absence of PPA.
- The use of PPA greatly improves gloss.
- Ingenia's Non-PFAS PPAs outperform fluoropolymer and competitive non-PFAS PPAs for improvement of gloss.

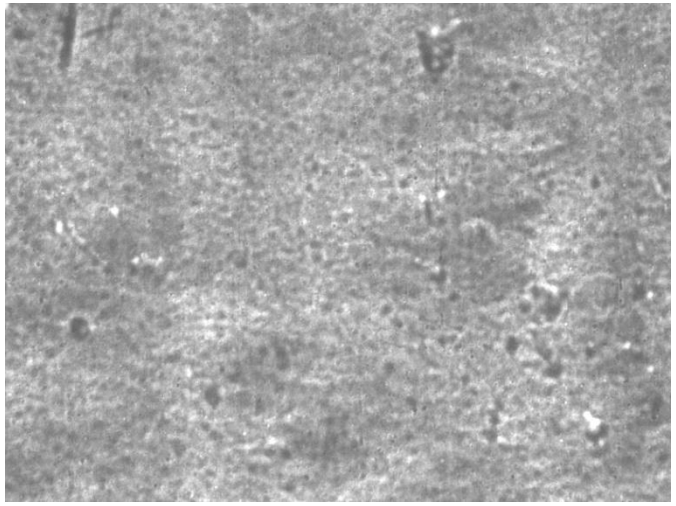
Ingenia's Non-PFAS PPAs Prevent Surface Defects



no PPA

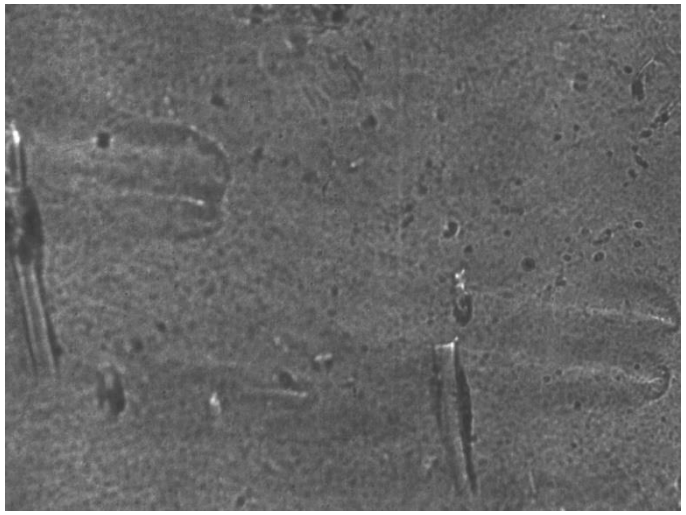


IP1130 Fluoropolymer

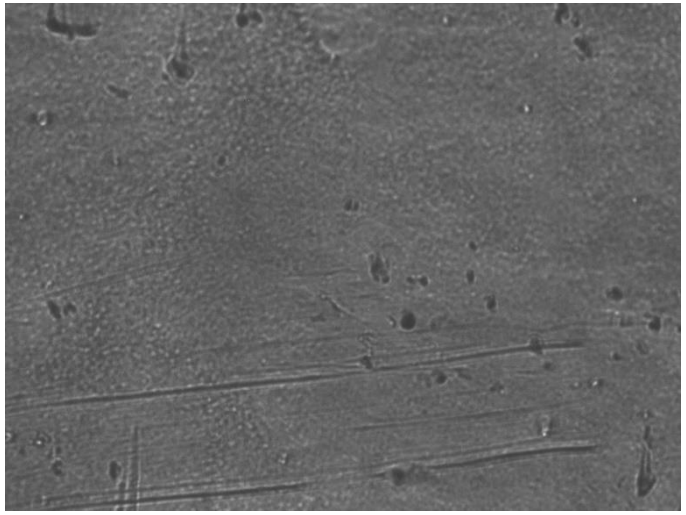


IP1171

Machine direction



IP1172



IP1173

Images of external bottle surface extruded at 170 °C. Micrograph taken with Leica DM2500P at 20x zoom

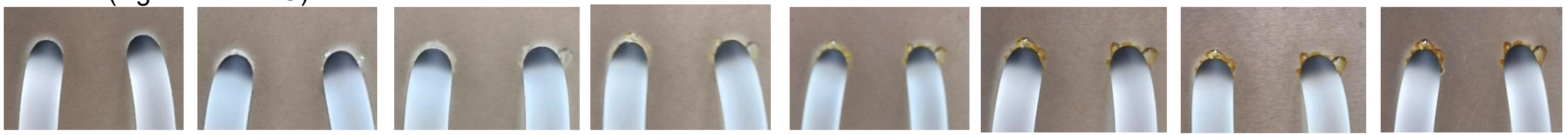
Die Build-Up Study

- System Setup
  - Capillary extrusion on a 25 mm diameter single screw extruder at melt temperature of 190 °C.
  - Extruder fitted with two hole die of 3 mm diameter, nickel-coated steel.
  - Extrusion rate of 220 s^{-1} (apparent shear rate).
- Test resin: HHM 5022BN (MFR 0.35, 0.955 g/cc)
- Test procedure:
  - Line purged and die cleaned between runs.
  - PPA blended in at target loading in test resin and mixture introduced to extruder. Extruder run for 30 minutes – enough time to coat the extruder and die with the test PPA.
  - Extruder stopped and die cleaned again to remove any die lip buildup formed before coating of the die with PPA.
  - Extruder restarted and test begins. Photos taken at intervals for a period of 180 minutes and formation of die lip buildup is assessed visually.

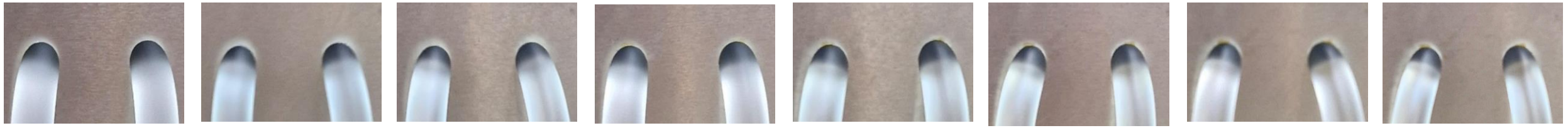
Die Build-Up Studies by Single Screw Capillary Extrusion

- Representative photos of die build up development shown below in system with no PPA, with a fluoropolymer PPA and with a non-PFAS PPA
- Significant die lip buildup in system with no PPA. Both fluoropolymer and non-PFAS PPA are effective in preventing DBU.

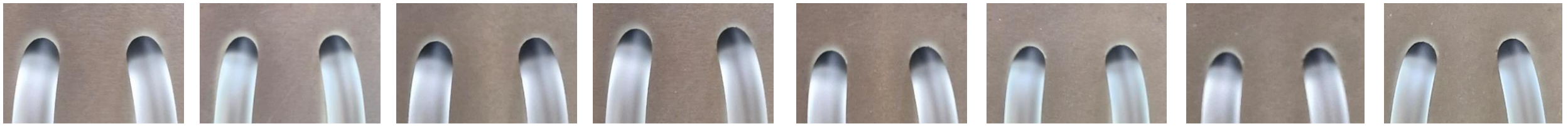
No PPA (significant DBU)



1% IP1130 Fluoroelastomer based PPA (no DBU)

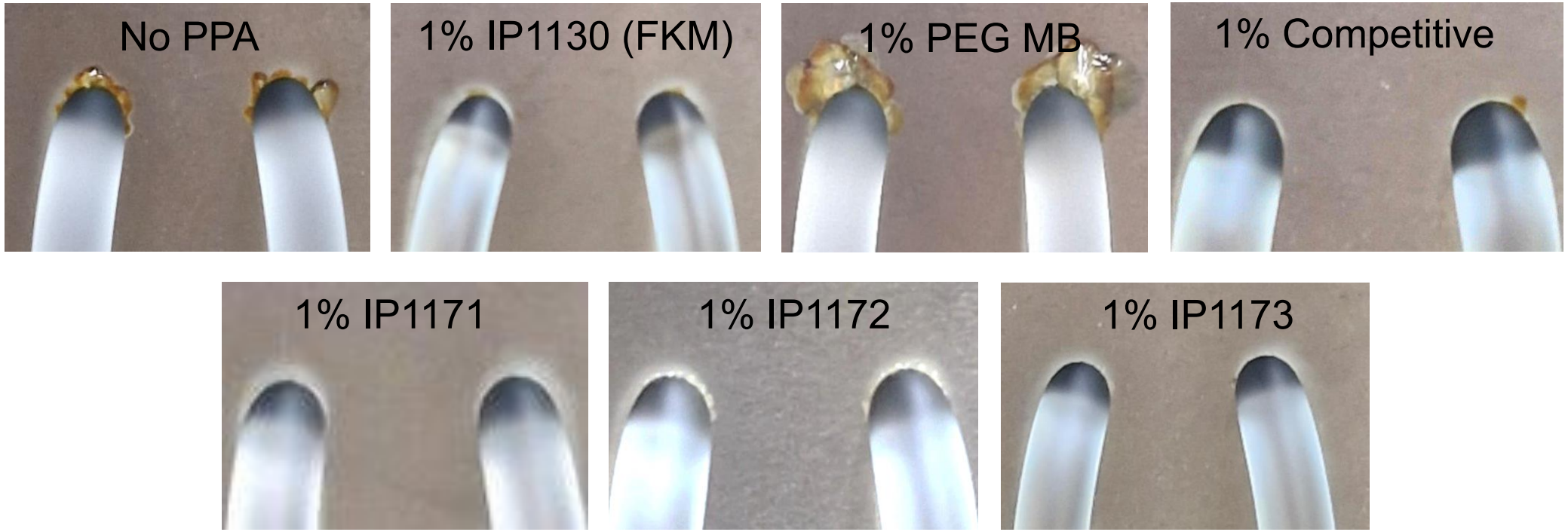


1% IP1173 Non-PFAS PPA (no DBU)



0 Min | 15 min | 30 min | 60 min | 90 min | 120 min | 150 min | 180 min

Die Build-Up Studies by Single Screw Capillary Extrusion – 3 Hours



- IP1171, IP1172 and IP1173 Non-PFAS PPAs all eliminate DBU in Blow Molding Resin 2. Performance comparable to fluoropolymer based solutions
- PEG based PPAs exacerbate die lip buildup.
- Competitive non-pfas PPA reduces, but does not eliminate DBU.

Ingenia’s non-PFAS Polymer Process Aids Improve Blow Molding Processes

- Ingenia’s non-PFAS PPAs provide processing and product improvements in Blow Molding Applications:
  - Reduce die head pressure and allow extrusion at lower temperatures without extrusion defects.
  - Improve gloss and surface finish.
  - Reduce die lip buildup.
  - Are efficient at low loadings and match the performance of traditional fluoropolymer PPAs.
  - Have broad international food contact compliance.