

2024 FlexPack PLACE Conference

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Next-Generation Barrier Performance in HDPE

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Milliken Chemical



Milliken™

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PURPOSE

Together we strive to positively impact the world around us for generations to come.

VALUES



Integrity

Do the right thing



Excellence

Set a high bar for performance



Innovation

Reward big thinking



Sustainability

Create a healthy future



People

Empower exceptional teams

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Achieving more with less



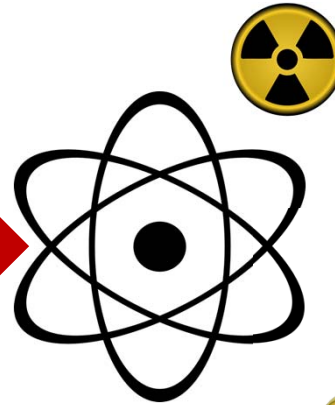
**60W
Incandescent**



**10W
LED**



Wood



Nuclear



**Farming production
on the same land**

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PE solutions help improve barrier properties in finished packages, across numerous markets

Enhance barrier properties for polyethylene beyond industry benchmark:

- Increases product **shelf life**
- Enables opportunities for **resin agility**
- Enables more recyclable **mono-material** constructions
- Other potential benefits; improved physical properties; aesthetics, modulus

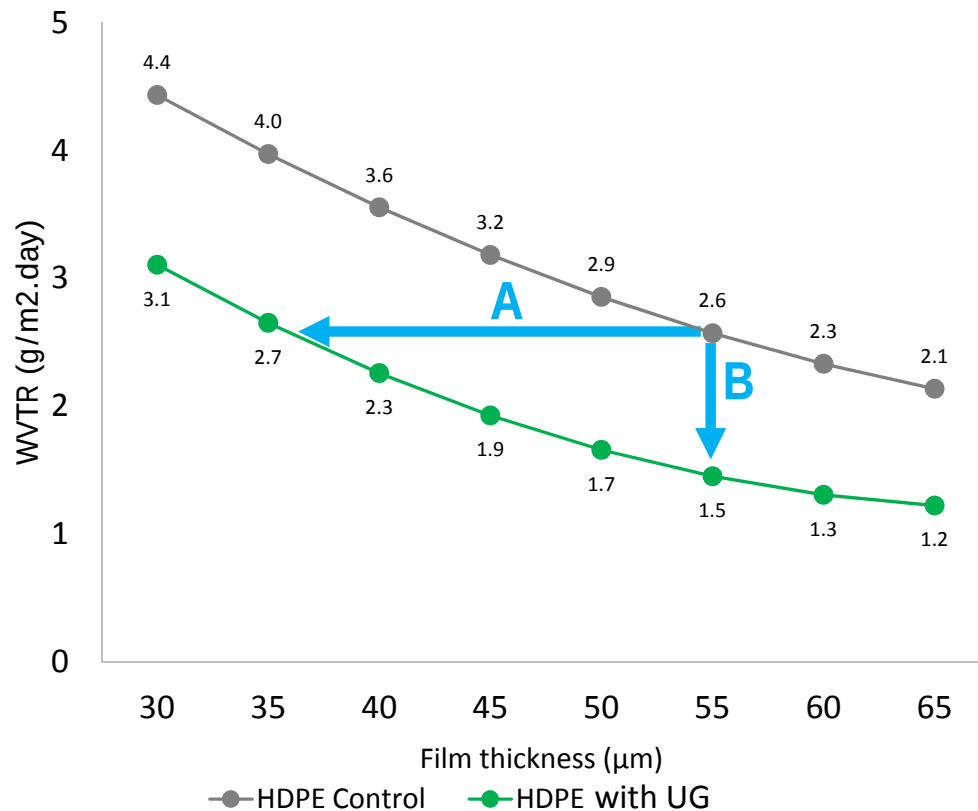


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Solutions for barrier improvement can be used to reduce packaging weight and/or improve product quality/shelf life



A: Thickness Reduction (-33%)

- Same barrier properties
- Weight reduction (sustainability)

B: Barrier Enhancement (+41%)

- Same thickness
- Improved product quality
- Increased shelf life
- Supply chain flexibility
- Improved recyclability



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Milliken®

UltraGuard™ Solutions EXP Natural 10385

Barrier improvements in polyethylene flexible packaging

TECHNICAL DATA

UltraGuard Solutions EXP Natural 10385 is a high-performance concentrate that is formulated to improve barrier performance in polyethylene flexible applications.

Product Use

UltraGuard Solutions EXP 10385 improves the barrier of HDPE and LLDPE resins.

Applications

Extruded films that have at least one polyethylene layer based on HDPE or LLDPE.

Physical Properties

Carrier resin: HDPE

Appearance/Form: Off-white pellet

Guidelines for Use

For flexible applications in polyethylene, a typical loading of 2-4% of UltraGuard Solutions EXP Natural 10385 is recommended.

Recommended maximum processing temperature is 260°C, however, short dwell at temperatures as high as 320°C may be acceptable for extrusion coating/lamination.

- Next generation within the PE barrier improvement product family
- Resin selection and responsiveness is key to ultimate performance
- Potential to provide up to 70% improvement over base resin
- Offers the opportunity to match or outperform existing benchmark options in the market

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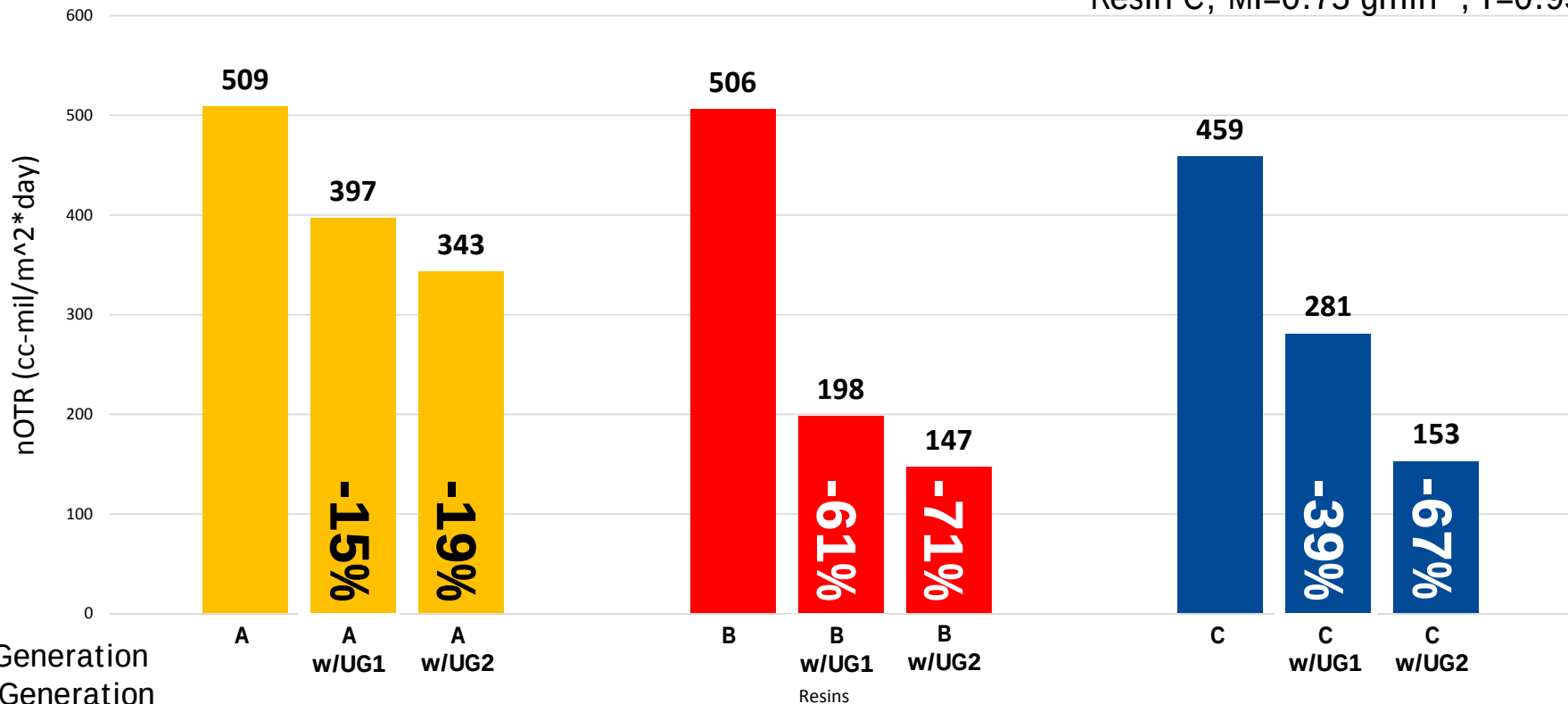


OTR barrier response of 3 commercial HDPE resins with PE barrier improvement generations 1.0 & 2.0

Resin A; MI= 0.7 gmin⁻¹, r=0.961 gcm⁻³

Resin B; MI=2.0 gmin⁻¹, r=0.959 gcm⁻³

Resin C; MI=0.75 gmin⁻¹, r=0.959 gcm⁻³



UG1 - 1st Generation
UG2 - 2nd Generation

Resins
General Business

A-1220246060
B-0620236512
C-0320233515

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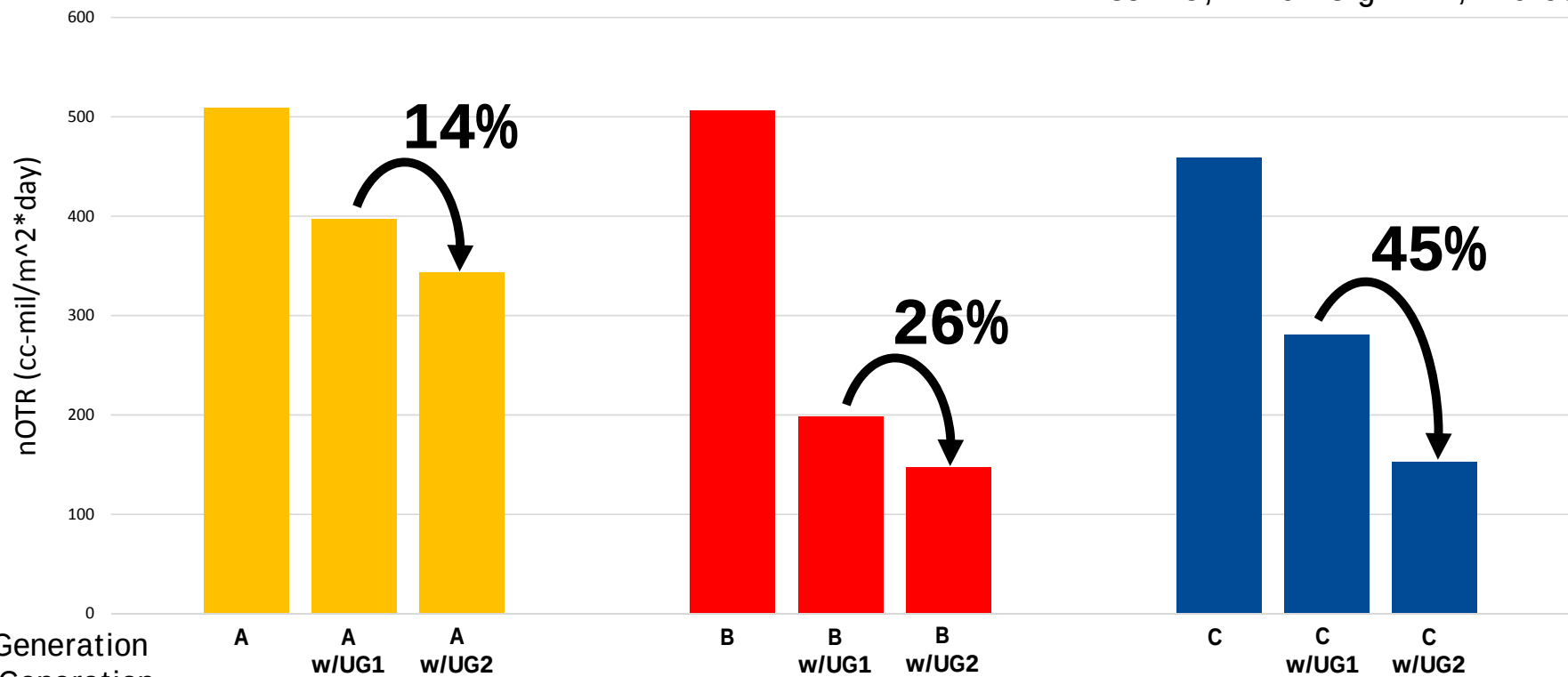


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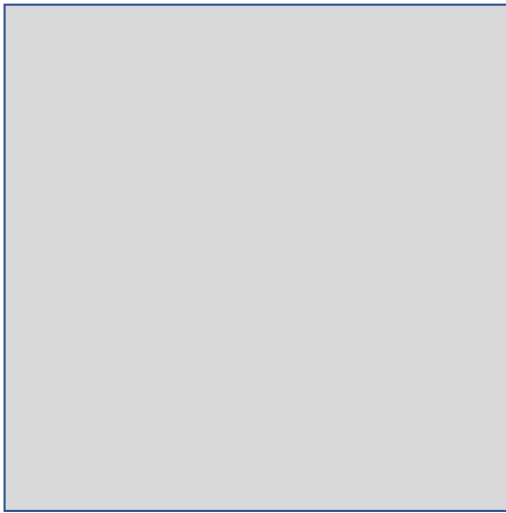
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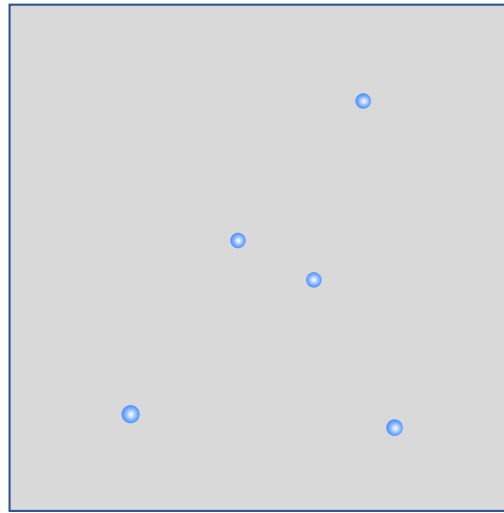


How does nucleation work?

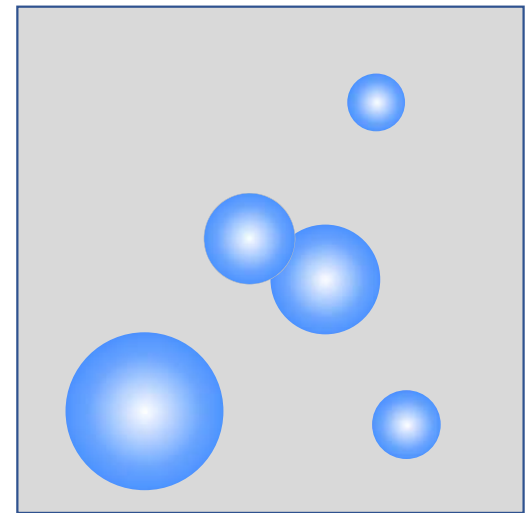
Melt Phase



Nucleation Phase



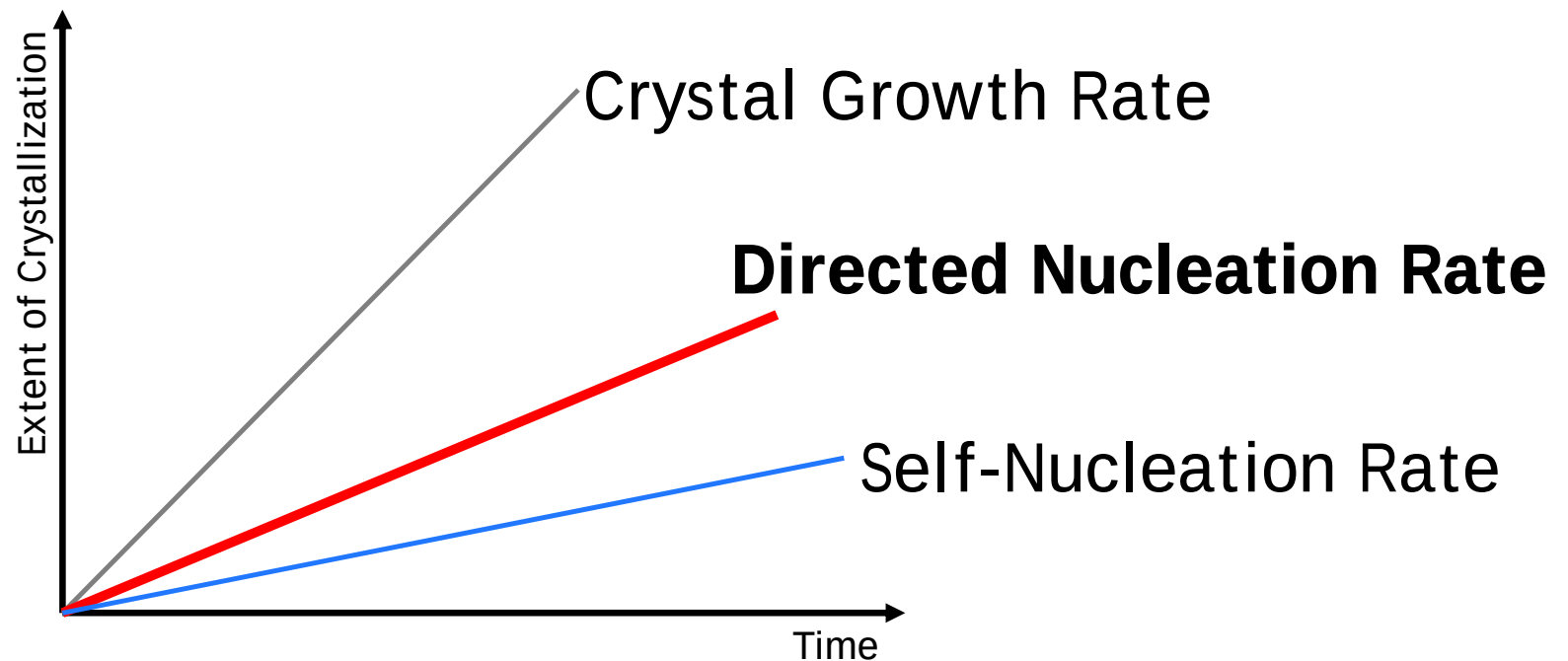
Crystal Growth Phase



- Crystallization; a natural phenomenon. When not directed or controlled with an additive, polyethylene will self-nucleate and grow spherical crystals.



Nucleation and crystal growth rates in polyethylene

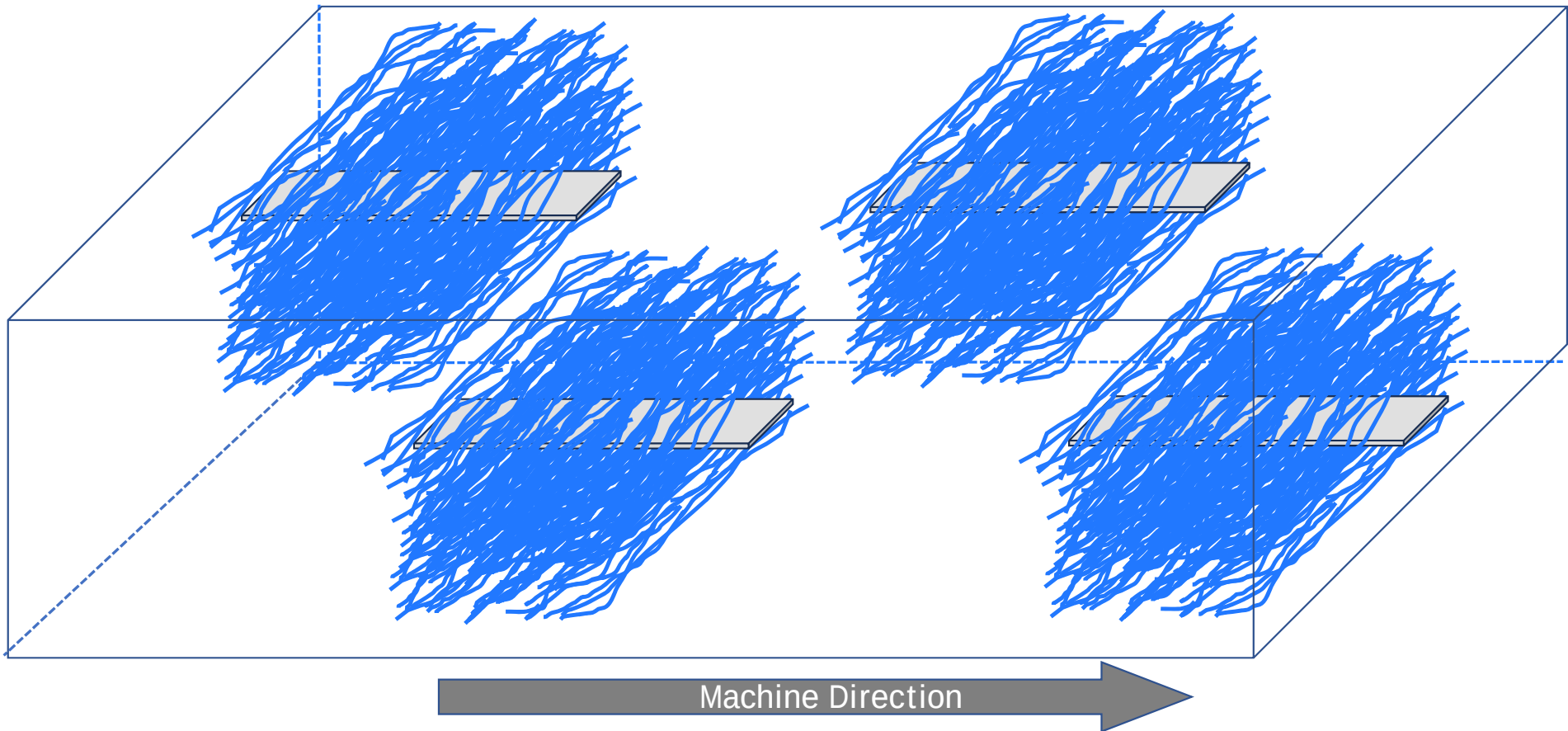


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How does nucleation work?



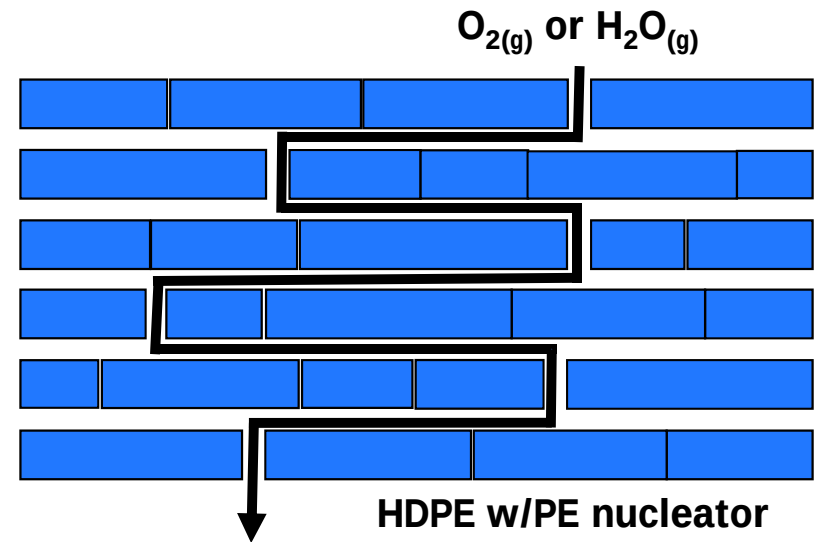
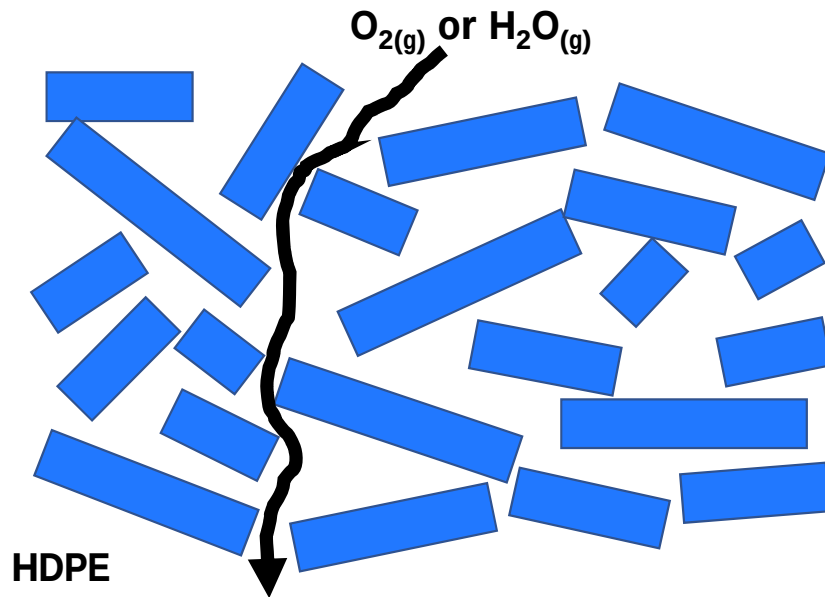
General Business

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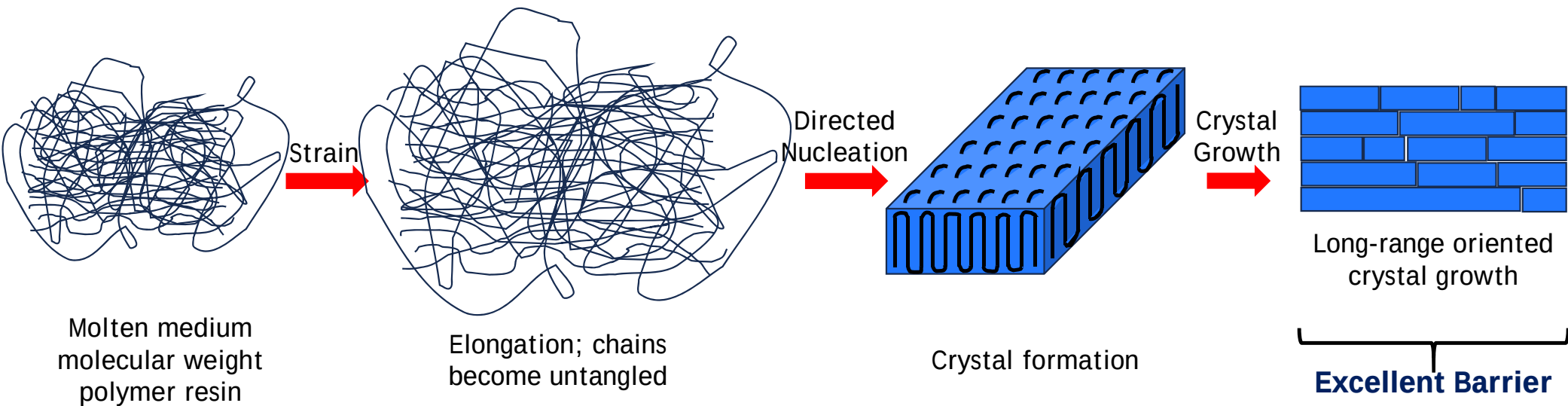
These solutions provide a passive barrier improvement in HDPE and LLDPE



Barrier performance improves with all types of permeants:
Water | Oxygen | Grease | Carbon dioxide | Alcohols | Gasoline | Fragrance



Ideal polymer undergoing relaxation, directed nucleation and oriented crystal growth



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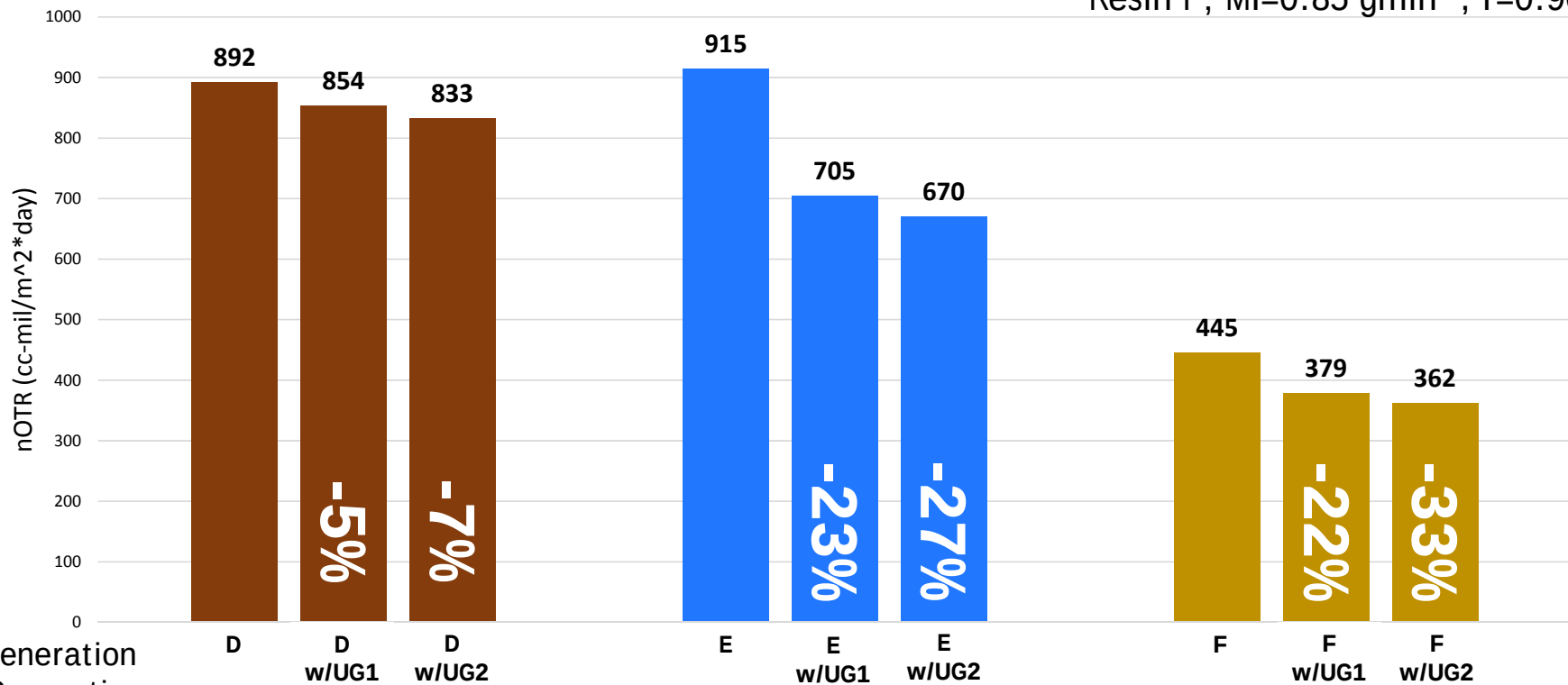


OTR barrier performance of less responsive commercial HDPE resins with PE barrier improvement generations 1.0 & 2.0

Resin D; MI=0.8 gmin⁻¹, r=0.963 gcm⁻³

Resin E; MI=1.2 gmin⁻¹, r=0.960 gcm⁻³

Resin F; MI=0.85 gmin⁻¹, r=0.962 gcm⁻³



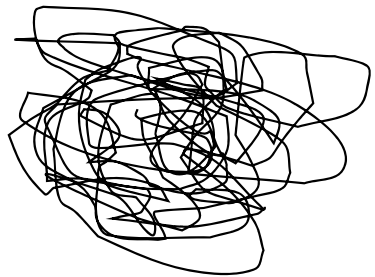
UG1 - 1st Generation
UG2 - 2nd Generation

Resins
General Business

D-1320234898
E-1320235096
F-0120246111

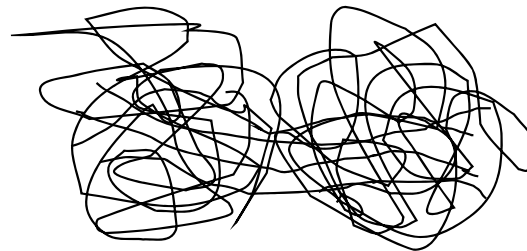


Polymer chains must unwind/untangle enough to allow technology to compete with self-nucleation



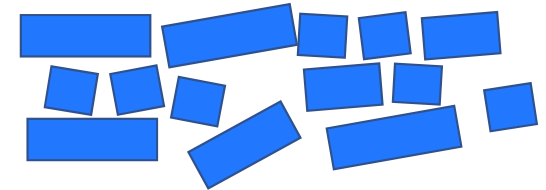
Molten high molecular weight polymer resin

Strain
→



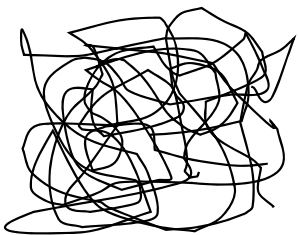
Elongation; sections of chains untangle; some remain tangled

Directed
Nucleation
→



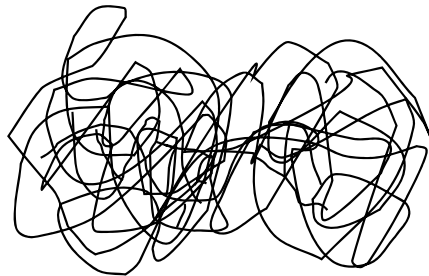
Some long-range oriented crystal growth

Poor Barrier



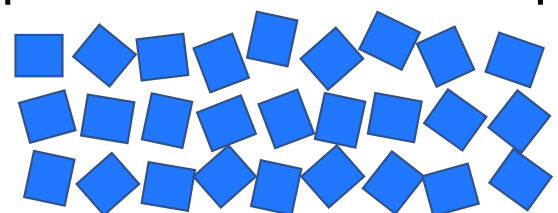
Molten highly branched polymer resin

Strain
→



Elongation; most chains remain tangled

Self-
Nucleation
→



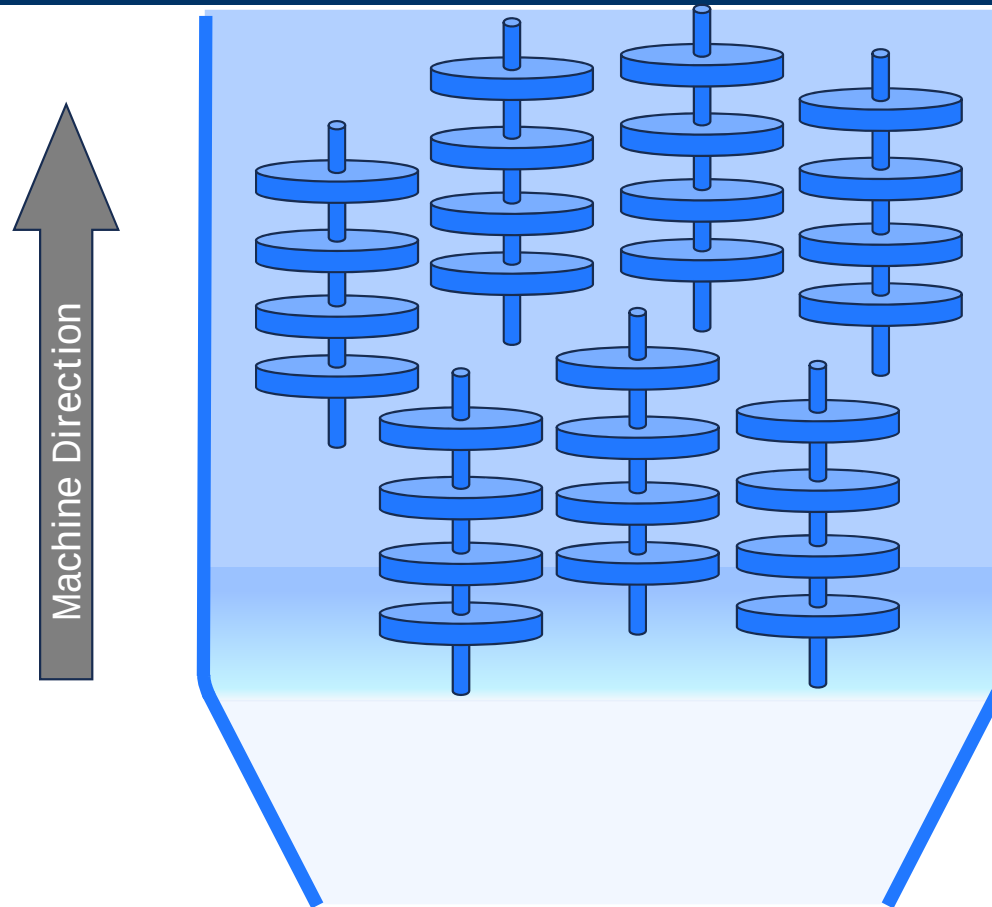
Short-range oriented crystal growth

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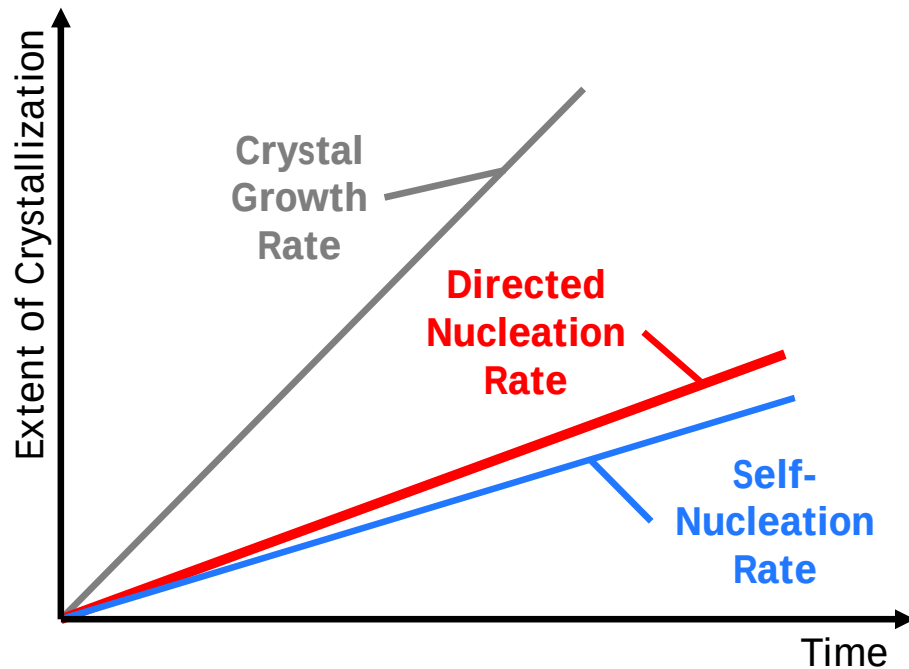
Details of high molecular weight crystallization and branched shish kebab



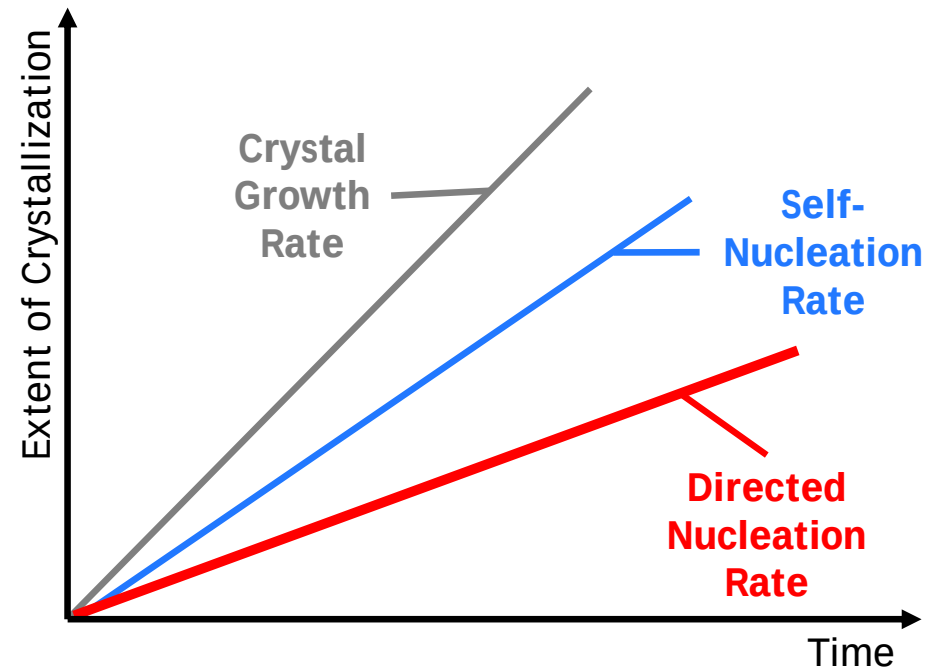


Nucleation and crystal growth rates in polyethylene with high mol wt. or extensive branching

High Mol Wt. Polymer



Extensive Branching



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The polymer structure has a profound effect on crystallization kinetics, largely driven by relaxation time

Resins More Responsive to Nucleation

- Medium-High Molecular Weight
- Little long / short-chain branching
- Narrower MWD
- Bimodal polymer system

Resins Less Responsive to Nucleation

- V. High Mol Wt.
- Extensive branching
- Broader MWD

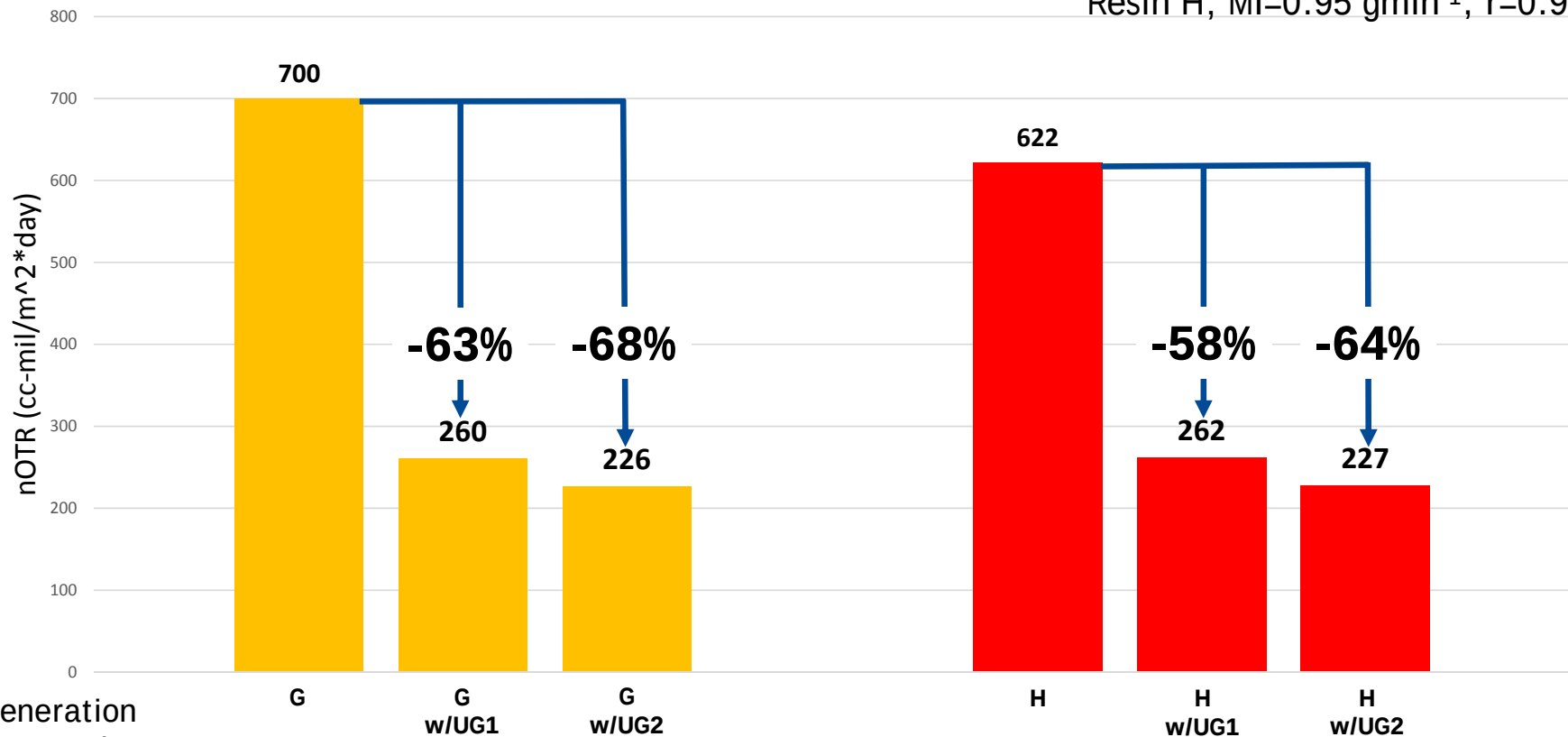
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OTR barrier response of commercial HDPE resins with PE barrier improvement generations 1.0 & 2.0

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Resin H; MI=0.95 gmin⁻¹, r=0.958 gcm⁻³



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UG2 - 2nd Generation

Resins
General Business

G-0920230205
H-0120246116

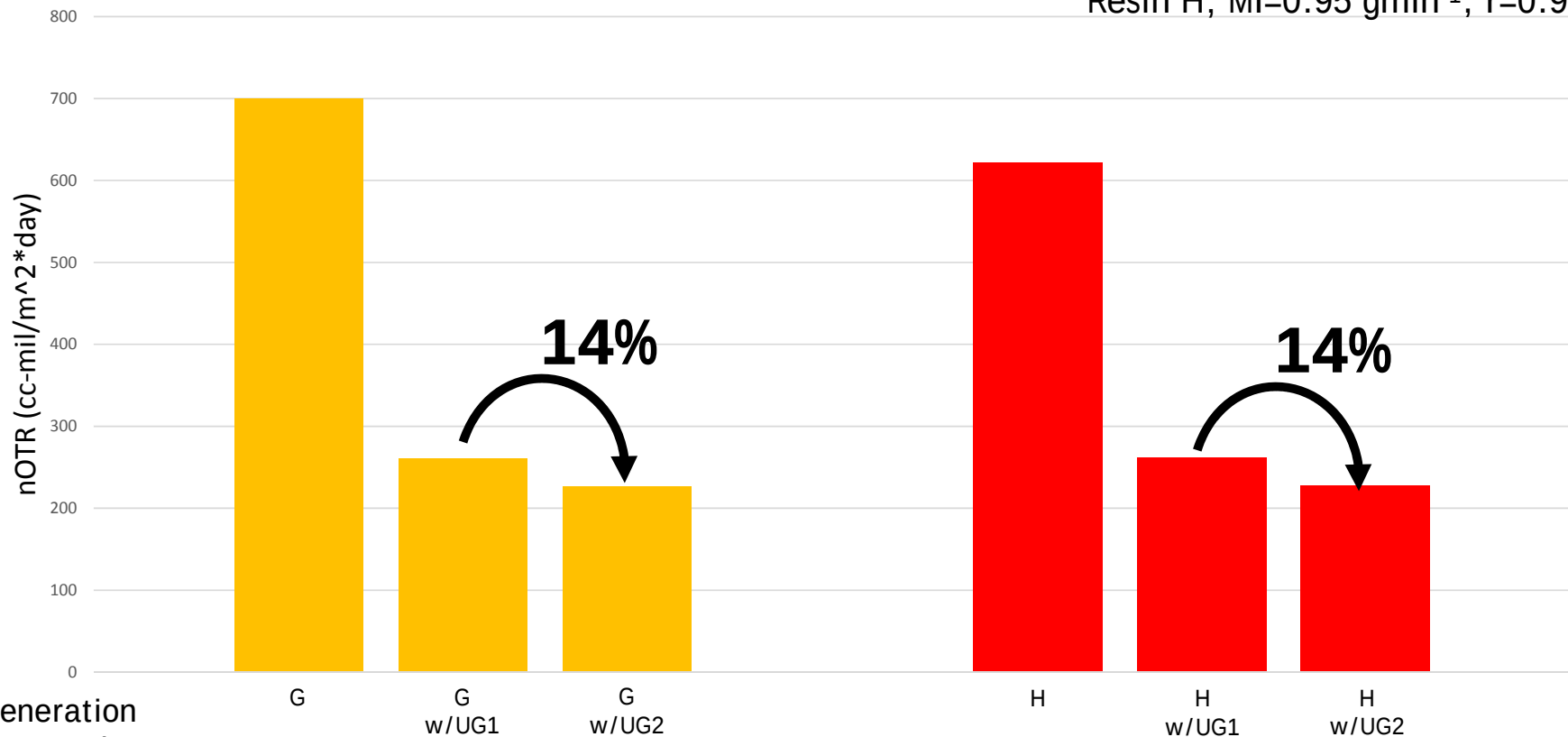
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OTR barrier response of commercial HDPE resins with PE barrier improvement generations 1.0 & 2.0

Resin G; $MI=5.0 \text{ gmin}^{-1}$, $r=0.963 \text{ gcm}^{-3}$
Resin H; $MI=0.95 \text{ gmin}^{-1}$, $r=0.958 \text{ gcm}^{-3}$



UG1 - 1st Generation
UG2 - 2nd Generation

Resins
General Business

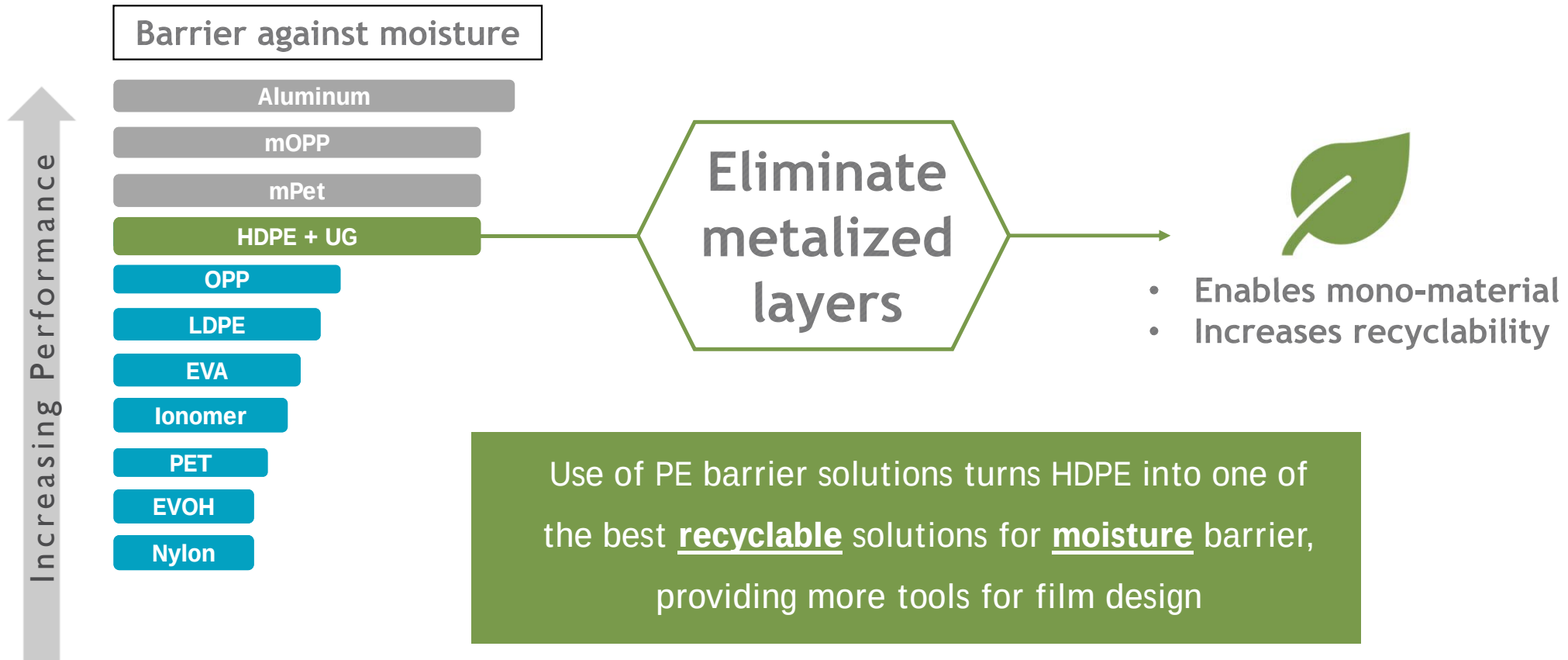
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Design for circular economy



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Summary

- UG 2.0 enables the best of PE barrier technology with up to 70% improvement in responsive resins.
- UG 2.0 can be used to enable film structure innovations for mono-material packaging; market expansion opportunities; optimize properties, minimize complexity.
- UG 2.0 is being commercialized; FDA approved & EFSA pending
- We are eager to help you develop the next generation blown film barrier resins



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Thank you

CONTACT INFORMATION

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The Milliken logo, featuring the word "Milliken" in a stylized, cursive blue font. A small "TM" trademark symbol is located at the bottom right of the word.