Grease Resistant Multilayer Polyethylene Films

Presented by:
Shivendra Goyal
Principal Engineer

Centre for Applied Research
NOVA Chemicals Corporation
Calgary, Alberta
Canada

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Outline

- Background and introduction
- Grease resistance method development
- Grease barrier studies:
  - **Screening** experiments – Multi-material films
  - **Validation** of results – 3 layer all-PE films
  - **Real world** designs – 9 layer all-PE films
- Summary and conclusions

Background

- **Significant growth in flexible packaging** of grease-containing materials that were traditionally packaged in:
  - metal cans
  - glass bottles
  - rigid plastic containers

- Factors driving conversion
  - Supply chain and package **cost reduction**
  - **Sustainability** improvements
  - Consumer **convenience**

Progression of Grease Barrier Packaging

Rigid Containers

Longer supply chain
Warehousing & transportation
Expensive

*

Multi-Material Flexible

Multi-step process
Non-recyclable
Costly

All-PE Flexible

Simple process
Fully recyclable
Cost effective

*Photo credit Robert Kneschke

Opportunity/Challenge

The Challenge

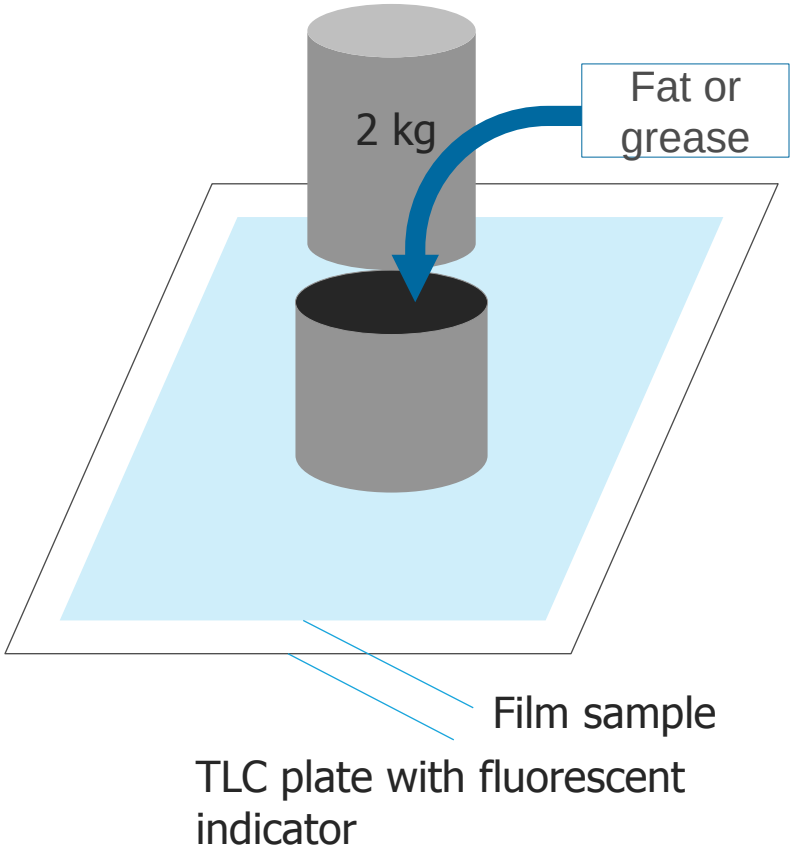
- Develop "*All PE*" film structures that provide:
  - ✓ Good grease resistance
  - ✓ Desired film properties
  - ✓ Improved sealability
  - ✓ Excellent processability
  - ✓ Recyclability of packaging after its intended use; and
  - ✓ Cost effective solutions

The Method

Grease Resistance Measurement

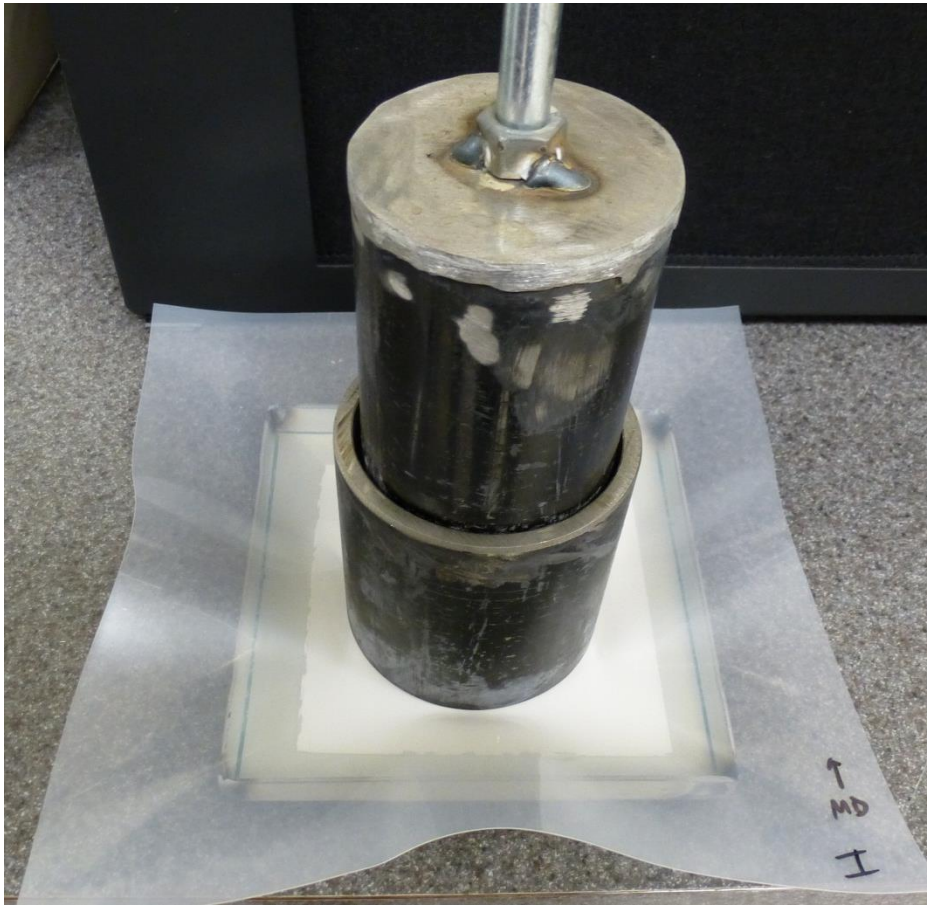
Semi-Quantitative Test Method Development

The Modified Method	
Test description	• Fat source placed on test film that is positioned on a TLC plate • 2 kg weight placed on fat source and assembly put in a oven • After 48h, TLC plate inspected and photographed under UV light
Measurement	• Area of grease penetration
Benefits	• Simple and clear detection system • Enables quantification of grease penetration (stain area) • Repeatable and Reproducible



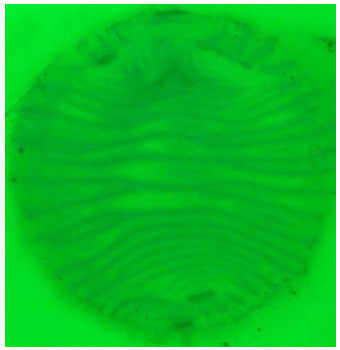
Based on original method developed by Wyser *et al*, Nestlé Research Center, TAPPI PLACE 2002 Conference

Grease Barrier Measurement Set-Up



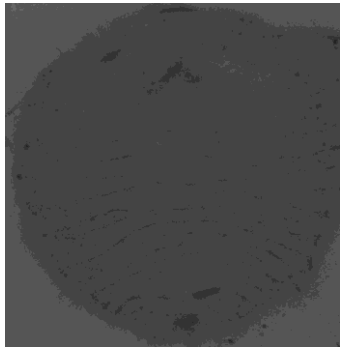
Quantification of Results

Use of ImageJ software*



Photograph under 254 nm UV light

Convert to 8 bit black and white image



Process

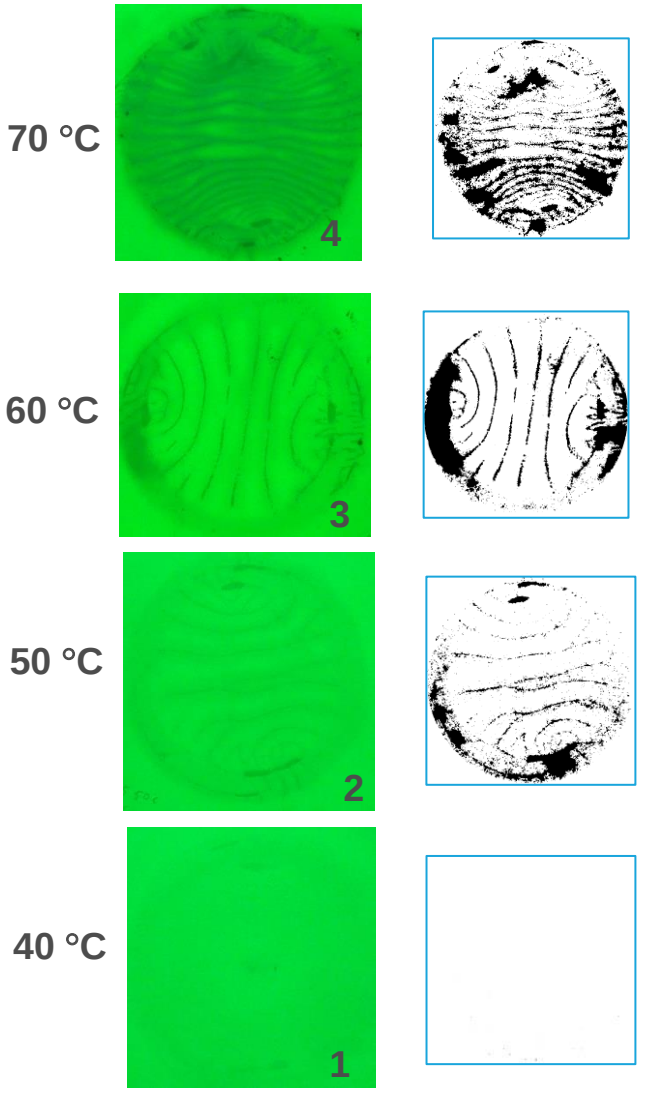
Select best representation and count pixels

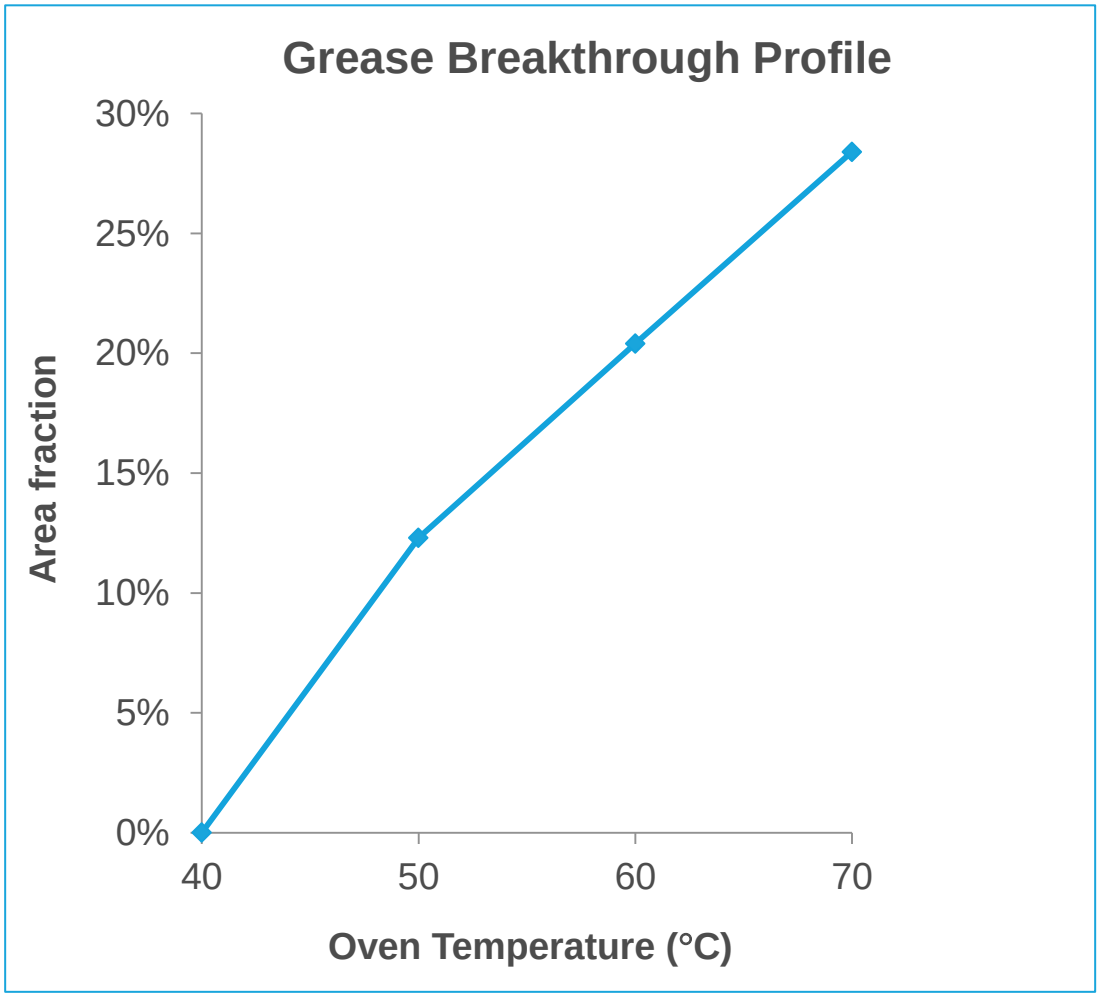
Obtain "area fraction", percent of dark pixels

e.g. 28 %

* ImageJ is a public domain, Java-based image processing program

Application of Results: Breakthrough Profile





The Application

Grease Barrier Studies

Study #1 – Multi-material Screening

Non-PE Resins

Resin Code	Resin Type	Melt Index (dg/min)	Density (g/cc)
EVOH	Ethylene Vinyl Alcohol Copolymer	1.7	1.17
Tie Resin	Maleic Anhydride Modified LLDPE	N/A	N/A
EAA	Ethylene Acrylic Acid Copolymer	1.0	0.938
Ionomer	Zn Ionomer	1.8	0.940

All PE Resins

Resin Code	Resin Type	Resin Name	Melt Index (dg/min)	Density (g/cc)
sLLDPE	Single Site Octene LLDPE	**SURPASS®** FPs016-C	0.65	0.916
sHDPE	Single Site Bimodal HDPE	**SURPASS®** HPs167-AB	1.20	0.966
HDPE-1	Z-N HDPE	**SCLAIR®** 19C	0.95	0.958
HDPE-2	Z-N HDPE	**SCLAIR®** 19G	1.20	0.960
o-LLD	Z-N Octene LLDPE	**SCLAIR®** FP120-D	1.0	0.920
o-VLD	Z-N Octene VLDPE	**SCLAIR®** FP112-A	0.90	0.912

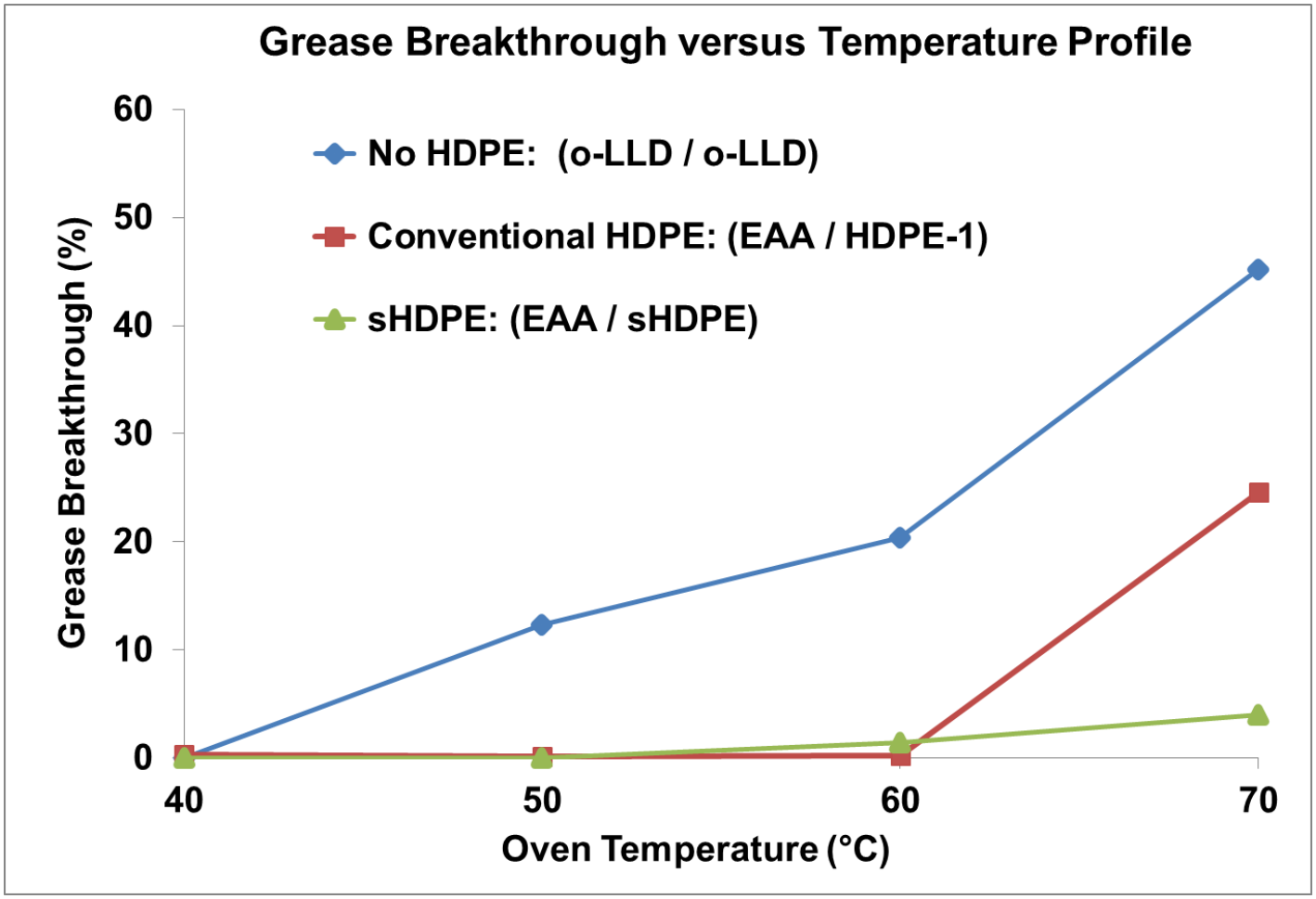
Study #1 – 9 Layer Film Construction

	Film Names	A	B	C	D	Middle	F	G	H	I
EVOH	**EVOH**/ o-LLD	sLLDPE	**o-LLD**	**o-LLD**	**Tie Resin**	**EVOH**	**Tie Resin**	**o-LLD**	**o-LLD**	o-LLD
	EVOH/sHDPE	sLLDPE	**sHDPE**	**sHDPE**	**Tie Resin**	**EVOH**	**Tie Resin**	**sHDPE**	**sHDPE**	o-LLD
sHDPE	**EAA**/sHDPE	sLLDPE	**sHDPE**	**sHDPE**	EAA	**EAA**	EAA	**sHDPE**	**sHDPE**	o-LLD
	Ionomer/sHDPE	sLLDPE	**sHDPE**	**sHDPE**	Ionomer	**Ionomer**	Ionomer	**sHDPE**	**sHDPE**	o-LLD
Conventional HDPE	**EAA**/ HDPE-1	sLLDPE	**HDPE-1**	**HDPE-1**	EAA	**EAA**	EAA	**HDPE-1**	**HDPE-1**	o-LLD
	Ionomer /HDPE-1	sLLDPE	**HDPE-1**	**HDPE-1**	Ionomer	**Ionomer**	Ionomer	**HDPE-1**	**HDPE-1**	o-LLD
No HDPE	**EAA** / o-LLD	sLLDPE	**o-LLD**	**o-LLD**	EAA	**EAA**	EAA	**o-LLD**	**o-LLD**	o-LLD
	Ionomer / o-LLD	sLLDPE	**o-LLD**	**o-LLD**	Ionomer	**Ionomer**	Ionomer	**o-LLD**	**o-LLD**	o-LLD
	o-LLD/o-LLD	sLLDPE	**o-LLD**	**o-LLD**	o-LLD	**o-LLD**	o-LLD	**o-LLD**	**o-LLD**	o-LLD

Study#1 Results: Grease Breakthrough

		Grease Breakthrough Values %				
	Oven Temperature (°C):	70	60	50	40	Grease Resistance
EVOH	**EVOH**/o-LLD	1				✓
	EVOH/sHDPE	4				✓
sHDPE	EAA /**sHDPE**	4	1	0	0	✓
	Ionomer /**sHDPE**	16				✓
Conventional HDPE	EAA /**HDPE-1**	25	0	0	0	x
	Ionomer /**HDPE-1**	26				x
No HDPE	EAA /**o-LLD**	44				x
	Ionomer / **o-LLD**	60				x
	o-LLD/**o-LLD**	45	20	12	0	x

Study#1 Results: Grease Breakthrough Profiles



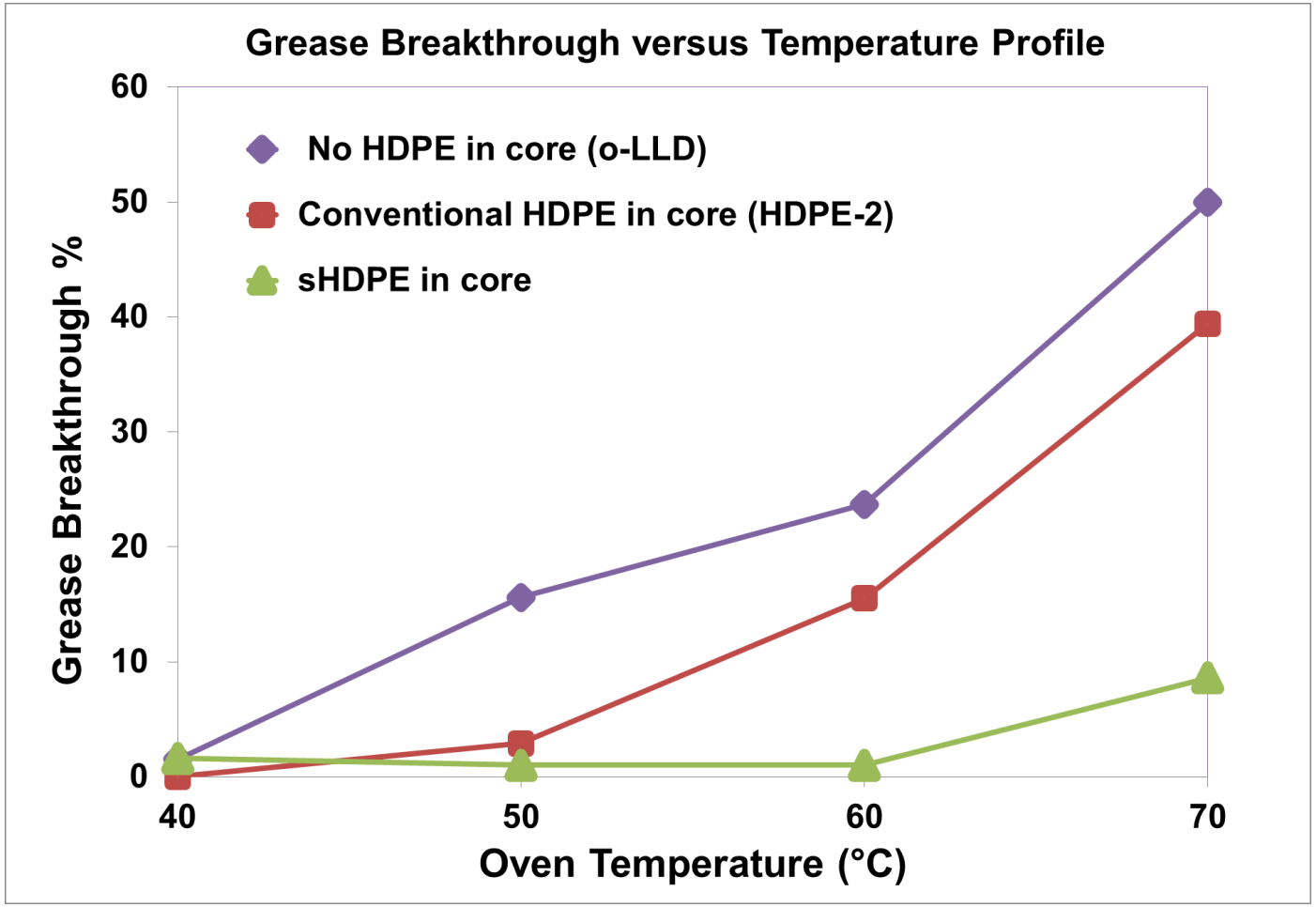
Study#1 Conclusion:

sHDPE provides excellent grease resistance performance

Study #2 – Validation of Results: 3 – layer all PE films

Film Type	A (25%)	B (50%)	C (25%)
Single site sHDPE in core	o-LLD	**sHDPE**	o-LLD
Conventional HDPE in core	o-LLD	**HDPE-2**	o-LLD
No HDPE in core	o-LLD	**o-LLD**	o-LLD

Study#2 Results: Grease Breakthrough Profiles



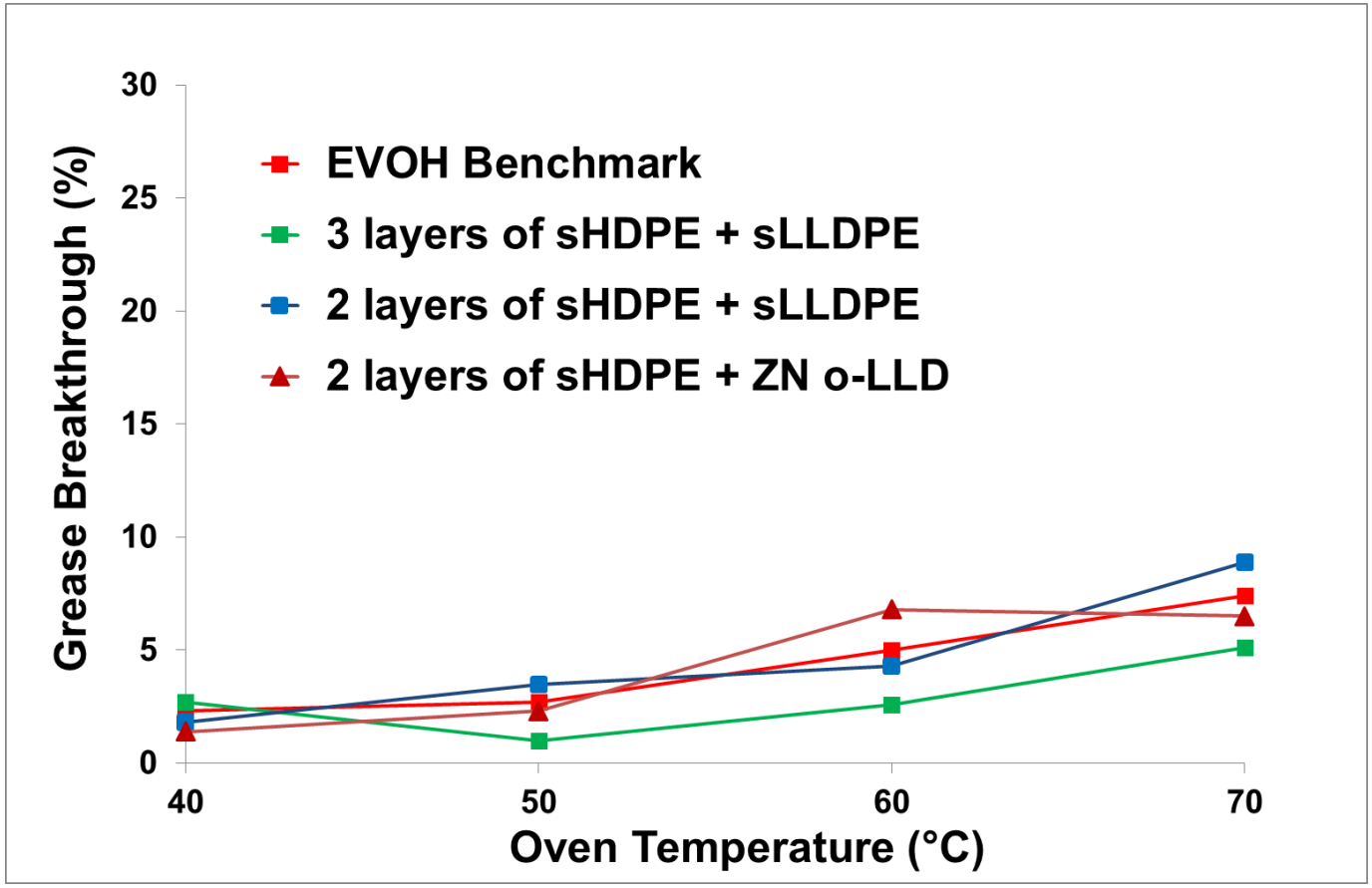
Study#2 Conclusion:

Excellent grease barrier performance of sHDPE in 3 layer all PE films

Study#3: Innovative film structure designs
All PE 9 layer films

Film Structure	A	B	C	D	Middle	F	G	H	I
EVOH Benchmark	o-LLD	o-LLD	o-LLD	**Tie Resin**	**EVOH**	**Tie Resin**	o-LLD	o-LLD	o-VLD
3 layers of sHDPE + sLLDPE	o-LLD	**sHDPE**	sLLDPE	sLLDPE	**sHDPE**	sLLDPE	sLLDPE	**sHDPE**	o-VLD
2 layers of sHDPE + sLLDPE	o-LLD	**sHDPE**	sLLDPE	sLLDPE	sLLDPE	sLLDPE	sLLDPE	**sHDPE**	o-VLD
2 layers of sHDPE + ZN o-LLD	o-LLD	**sHDPE**	o-LLD	o-LLD	**o-LLD**	o-LLD	o-LLD	**sHDPE**	o-VLD

Study#3 Results: Grease Breakthrough Profiles



Study#3 Conclusions:

Equivalent Grease Barrier performance of sHDPE containing films vs. EVOH benchmark film

Physical Properties of All PE 9-Layer Films

Film Structure/Property	EVOH Benchmark	3 layers of sHDPE + sLLDPE	2 layers of sHDPE + sLLDPE	2 layers of sHDPE + ZN o-LLD
1% Secant Modulus - MD (MPa)	417	543	422	449
1% Secant Modulus – TD (MPa)	433	599	470	500
Tensile Yield Strength – MD (MPa)	14.5	16.9	14.4	15
Tensile Yield Strength - TD (MPa)	14.4	17.7	15.1	16
Dart Impact (g)	738	1008	1056	960
Puncture (J/mm)	53	77	74	70
Elmendorf Tear - MD (g)	1242	1224	1788	1914
Elmendorf Tear - TD (g)	2070	1824	2376	2916

Study#3 Conclusion:

Higher film physical properties (stiffness, toughness, dart, tear & puncture resistance) of All PE film structures than the multilayer film containing EVOH benchmark

Summary and Conclusions

- A **quick, semi-quantitative** method to evaluate grease resistance now possible
- *Films containing mixed materials* (e.g. EVOH, nylon) provide good grease resistance, but are **non-recyclable and costly**
- Single site catalyzed bimodal sHDPE resins can provide **effective grease resistance** in multilayer PE films
- Inclusion of single site bimodal sHDPE and sLLDPE resins into grease resistant films provides **numerous design opportunities**
- All PE grease resistant films can be made to have:
  - **excellent physical properties**
  - **easy recyclability**
  - **cost effectiveness**

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Presented by:
Shivendra Goyal
Shiv.Goyal@novachem.com