

Modified Cyclic Olefin Copolymers As New Cost and Sustainability Tool For Multilayer Packaging Films

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(Revised)

- **COC introduction**
- **How is COC sustainable?**
- **COC elastomer**
- **Impact modified rigid COC**
- **Monolayer nylon vs. impact modified COC films**
- **Nylon replacement in multilayer films**
- **Mechanical property analysis**
- **Target market & applications**
- **Benefits & conclusions**

New Potential for the Packaging Market

Resin Design



Products



Value

- Ethylene copolymer
- Molecular weight
- Comonomer level

**Cyclic Olefin
Copolymers (COC)
Amorphous**



- Shrink
- Thermoformability
- Easy tear
- Downgauging
- Temperature resistance
- Barrier – WVTR, alcohol
- Chemical resistance
- Stiffness
- Gloss and clarity

Unique Resin



Unique Benefits

Sustainability Fit with COC



- **Environmental & Consumer Friendly ----- Yes**
 - Estrogenic activity free (PlastiPure)
 - No halogens or problem additives
 - High purity

- **Recyclability ----- Yes**
 - Compatible with polyethylene

- **Source Reduction ----- Yes**
 - Down gauging
 - Reduced number of feedstocks
 - Enhanced performance

- **Halogen-free for clean incineration ----- Yes**

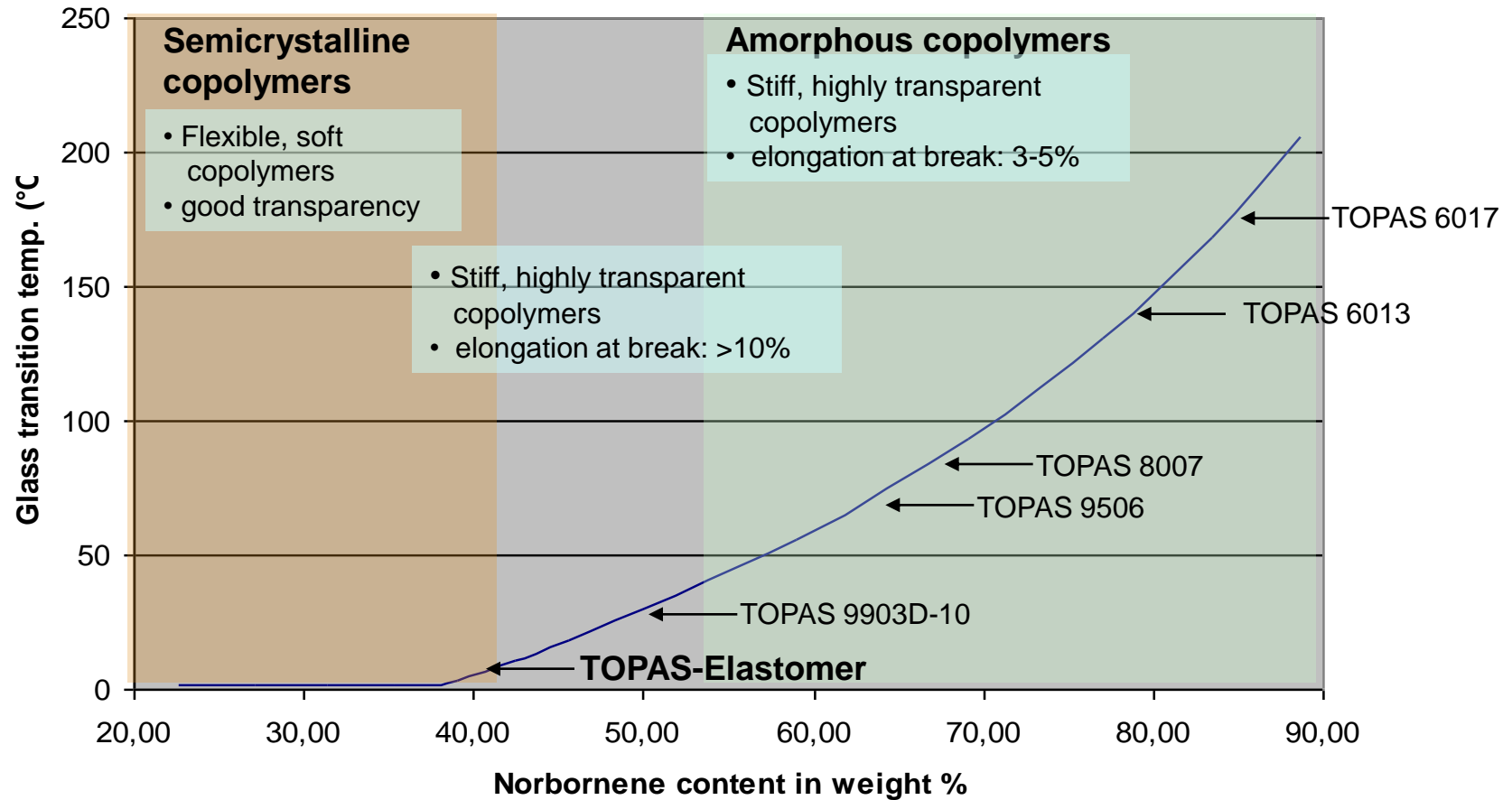
- **Biodegradable ----- No**

- **Compostable ----- No**

COC – Product Map



Comonomer Content & Glass Transition Temperature

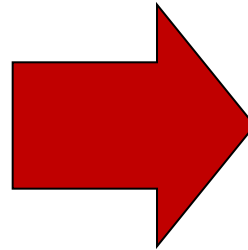


COC Elastomer – Unique Polymer



Features

- Amorphous & crystalline
- Ductile-Brittle Temp < -90°C
- Tg = 6°C; Tm = 84°C
- Good optics
- Polyolefin resin
- Tear resistance
- TOUGHNESS
- USP Class VI

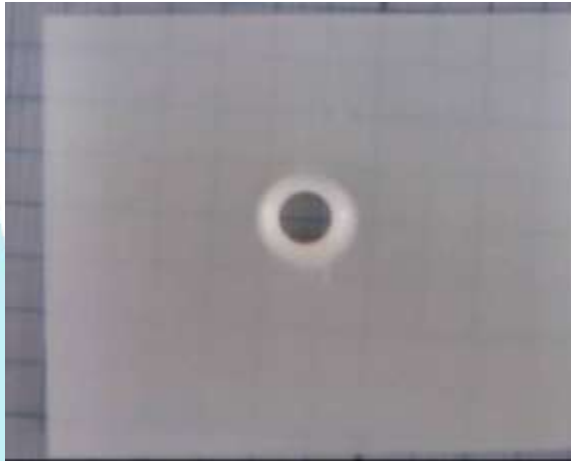


Product Benefits

- COC impact modifier
- Polyolefin compatibilizer
- Sustainability solution
- Reduce haze
- Increase tear resistance
- Excellent low temperature properties
- Broad service temperature

COC Elastomer Toughens Rigid COC

- Compounded rigid COC products with new COC Elastomer.
- Modified COC offers barrier properties, stiffness, strength, heat resistance, transparency plus impact resistance.
- High Speed Impact - Injection molded 2 mm thick plaques:



85% 8007
15% Elastomer
470 lb_f
22.3 ft-lb



85% 9506
15% Elastomer
474 lb_f
22.9 ft-lb



40% 9903D-10
40% 6013M-07
20% Elastomer
436 lb_f
19.8 ft-lb

■ Injection Molded Articles

■ Pros

- Impact resistant
- Ductile failure
- Broad compatibility

■ Cons

- Semi-transparent – Low Tg COC
- Opaque – high Tg COC

■ Film & Sheet Applications

■ Pros

- Transparent – Low Tg COC
- Improved tear resistance
- Impact resistance with 10 – 30 percent COC-E

■ Cons

- Reduced transparency – high Tg COC

Value Proposition - Films



■ Current COC Benefits

- 10 – 30% rigid COC in PE (LLDPE, EVA, etc)
- 0 – 20% PE in rigid COC
 - Enable down gauging, stiffness, formability, linear tear, broaden sealant properties, control shrinkage and improve moisture / alcohol barrier

■ Additional Benefits Using Impact Modified COC

- 60 – 90% rigid COC + 40 – 10% COC-E
 - Preserve transparency; lower haze
 - Control tear resistance
 - Improve puncture and impact resistance
 - Improve sub-ambient film durability
 - Enable use of higher Tg rigid COC for improved heat resistance
 - Capture all benefits of COC via discrete layers

Monolayer Nylon Film



<u>6-mil Films</u>	Description		Nylon 80% Ultramid B33 20% Selar PA-3426
Property	Method	Units	
Total Haze	ASTM D1003-00 B	%	0.4
Gloss (60°)	ASTM D2457	---	163
Impact Resistance	ISO 7765-2 (1994)E	lbf	56.7
Total Impact Energy	ISO 7765-2 (1994)E	ft-lbs	0.833
Tensile Modulus	(1% Secant)		
MD	ASTM D 882-02	psi	222,000
TD	ASTM D 882-02	psi	259,000
Tensile at Break			
MD	ASTM D 882-02	psi	10,100
TD	ASTM D 882-02	psi	9,640
Elongation at Break			
MD	ASTM D 882-02	%	480
TD	ASTM D 882-02	%	420
Tear Resistance			
MD	ASTM D1922-06a	grams	323
TD	ASTM D1922-06a	grams	309
Flex (Gelbo) Durability			
100 Cycles (MD)	ASTM F392-93	# pinholes	5
100 Cycles (TD)	Modified Condition C	# pinholes	4
250 Cycles (MD)		# pinholes	10
250 Cycles (TD)	(Lab Average)	# pinholes	12
500 Cycles (MD)		# pinholes	21
500 Cycles (TD)		# pinholes	21

Many Useful Properties:

- Transparency
- Excellent appearance
- Strength
- Toughness
- Stiffness
- Oxygen barrier
- Heat resistance

Some Limitations:

- Moisture sensitivity
- Poor moisture barrier
- Flex crack resistance
- Tear resistance

Monolayer Nylon vs. COC Films



<u>6-mil Films</u>	Description		Nylon 80% Ultramid B33 20% Selar PA-3426	85% 9903D-10 15% COC-E	70% 9506F-04 30% COC-E
Property	Method	Units			
Total Haze	ASTM D1003-00 B	%	0.4	1.9	11.3
Gloss (60°)	ASTM D2457	---	163	138	125
Impact Resistance	ISO 7765-2 (1994)E	lbf	56.7	48.5	53.9
Total Impact Energy	ISO 7765-2 (1994)E	ft-lbs	0.833	2.54	2.40
Tensile Modulus	(1% Secant)				
MD	ASTM D 882-02	psi	222,000	252,000	229,000
TD	ASTM D 882-02	psi	259,000	152,000	306,000
Tensile at Break					
MD	ASTM D 882-02	psi	10,100	4,340	4,490
TD	ASTM D 882-02	psi	9,640	4,800	6,260
Elongation at Break					
MD	ASTM D 882-02	%	480	210	87
TD	ASTM D 882-02	%	420	370	160
Tear Resistance					
MD	ASTM D1922-06a	grams	323	648	220
TD	ASTM D1922-06a	grams	309	900	225
Flex (Gelbo) Durability					
100 Cycles (MD)	ASTM F392-93	# pinholes	5	3	1
100 Cycles (TD)	Modified Condition C	# pinholes	4	3	2
250 Cycles (MD)		# pinholes	10	15	7
250 Cycles (TD)	(Lab Average)	# pinholes	12	19	12
500 Cycles (MD)		# pinholes	21	25	18
500 Cycles (TD)		# pinholes	21	29	14

Comparison:

- Haze – slightly higher
- Gloss – slightly lower
- Impact resistance is nearly equivalent
- Impact energy is superior
- Modulus depends on composition
- Less tensile strength
- Improved tear and flex crack resistance is grade dependent

New Opportunity for Packaging Films



- **Substitute modified COC for nylon and eliminate tie layers in multilayer coextruded film**
- **Benefits:**
 - **Simplify coextruded film structures**
 - **Create new ALL OLEFIN film structures with PP, HDPE, LDPE, LLDPE and COC**
 - **Cost neutral resin substitution**
- ***Improve sustainability; reduce costs via reclaim and recycling***

Multilayer Nylon & COC Packaging Film Structures



Layer	Structure 1			Structure 2		
	Thickness	Material	Polymer	Thickness	Material	Polymer
A	31.30%	Sclair FP 120C	o-LLDPE	31.0%	98% Exceed 3512CB 2% Ampacet 100622	m-h-LLDPE Antiblock
B	5.30%	Admer SF700A	Tie (elastomer)	10.0%	100% 8007F-400	COC; 80°C = tg
C	26.70%	80% Ultamid B33 20% Selar PA-3426	Nylon 6 Amorphous Nylon	18.0%	Exceed 3512CB	m-h-LLDPE
D	5.30%	Admer SF700A	Tie (elastomer)	10.0%	100% 8007F-400	COC; 80°C = tg
E	31.30%	Sclair FP 120C	o-LLDPE	31.0%	98% Exceed 3512CB 2% Ampacet 100622	m-h-LLDPE Antiblock

Layer	Structure 3			Structure 4			Structure 5		
	Thickness	Material	Polymer	Thickness	Material	Polymer	Thickness	Material	Polymer
A	31.0%	98% Exceed 3512CB 2% Ampacet 100622	m-h-LLDPE Antiblock	31.0%	98% Exceed 3512CB 2% Ampacet 100622	m-h-LLDPE Antiblock	31.0%	98% Exceed 3512CB 2% Ampacet 100622	m-h-LLDPE Antiblock
B	10.0%	85% 9903D-10 15% COC-E	COC; 33°C = tg COC Elastomer	10.0%	70% 9506-F04 30% COC-E	COC; 68°C = tg COC Elastomer	10.0%	60% 8007-F04 25% COC-E 15% 99D3-10	COC; 80°C = tg COC Elastomer COC; 33°C = tg
C	18.0%	Exceed 3512CB	m-h-LLDPE	18.0%	Exceed 3512CB	m-h-LLDPE	18.0%	Exceed 3512CB	m-h-LLDPE
D	10.0%	85% 9903D-10 15% COC-E	COC; 33°C = tg COC Elastomer	10.0%	70% 9506-F04 30% COC-E	COC; 68°C = tg COC Elastomer	10.0%	60% 8007-F04 25% COC-E 15% 99D3-10	COC; 80°C = tg COC Elastomer COC; 33°C = tg
E	31.0%	98% Exceed 3512CB 2% Ampacet 100622	m-h-LLDPE Antiblock	31.0%	98% Exceed 3512CB 2% Ampacet 100622	m-h-LLDPE Antiblock	31.0%	98% Exceed 3512CB 2% Ampacet 100622	m-h-LLDPE Antiblock

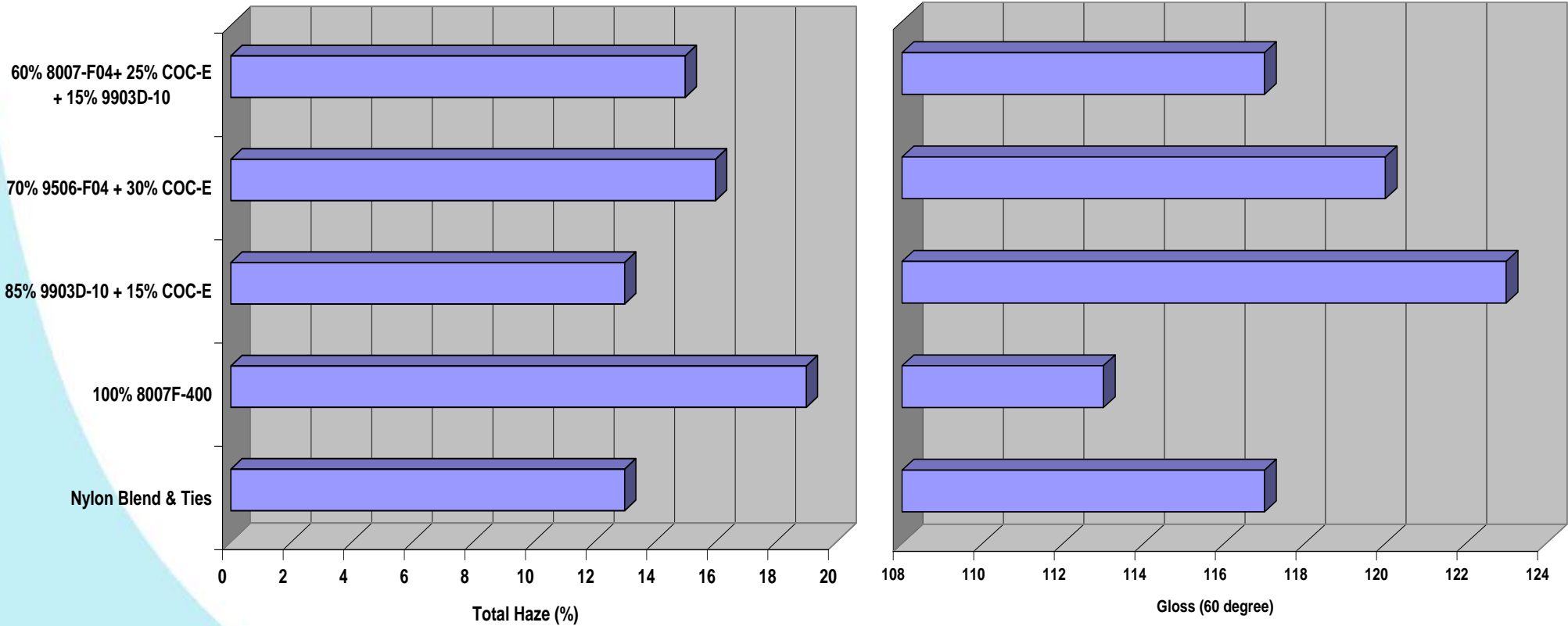
■ Film Structures

- 5.9-mil 5-layer nylon core
- 5.9-mil split layer COC (better properties)
- Equivalent material cost

■ Film Properties

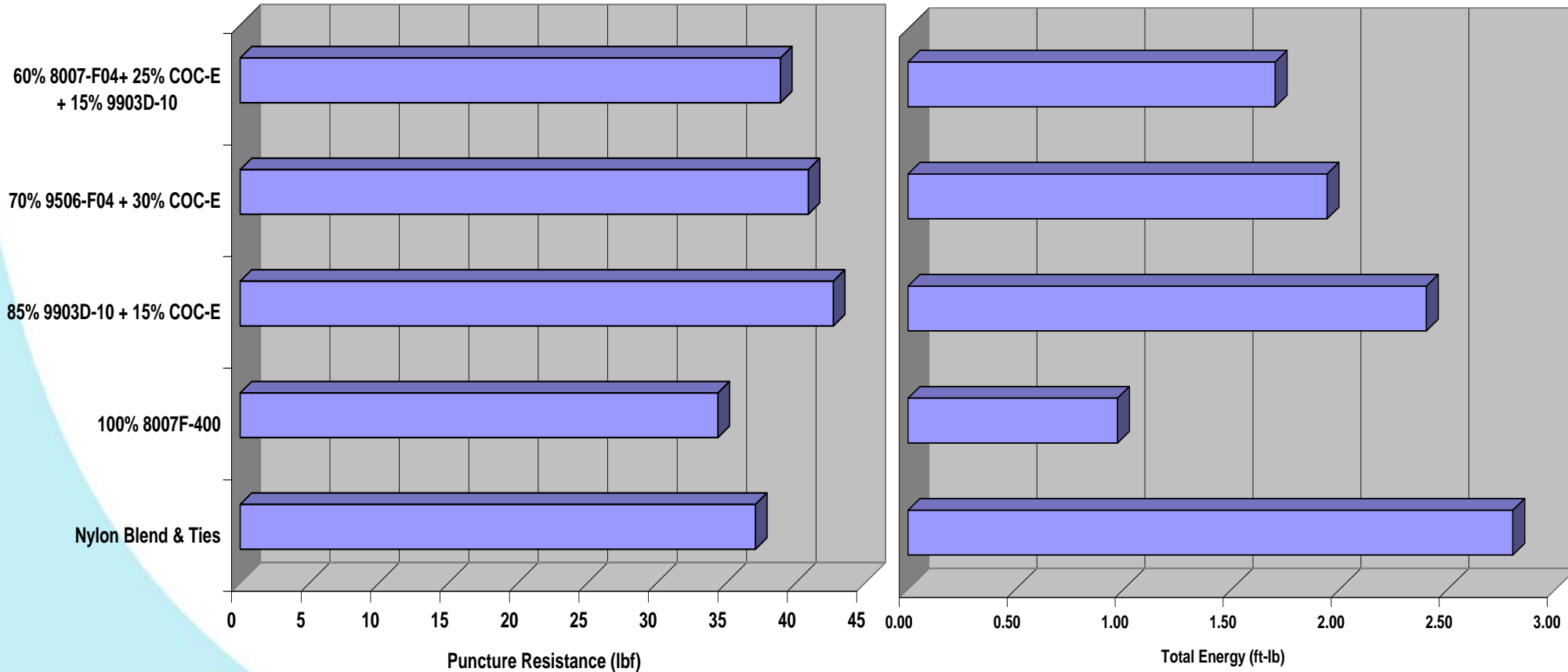
- Total Haze {ASTM D1003} & Gloss (60°) {ASTM D2457}
- Puncture Resistance & Total Energy {ISO 7765-2}
- Tensile Modulus {ASTM D882}
- Elongation at Break {ASTM D882}
- Tear Resistance {ASTM D1922}

Multilayer Nylon vs. COC: Appearance



Appearance equivalence: Low total haze & high gloss

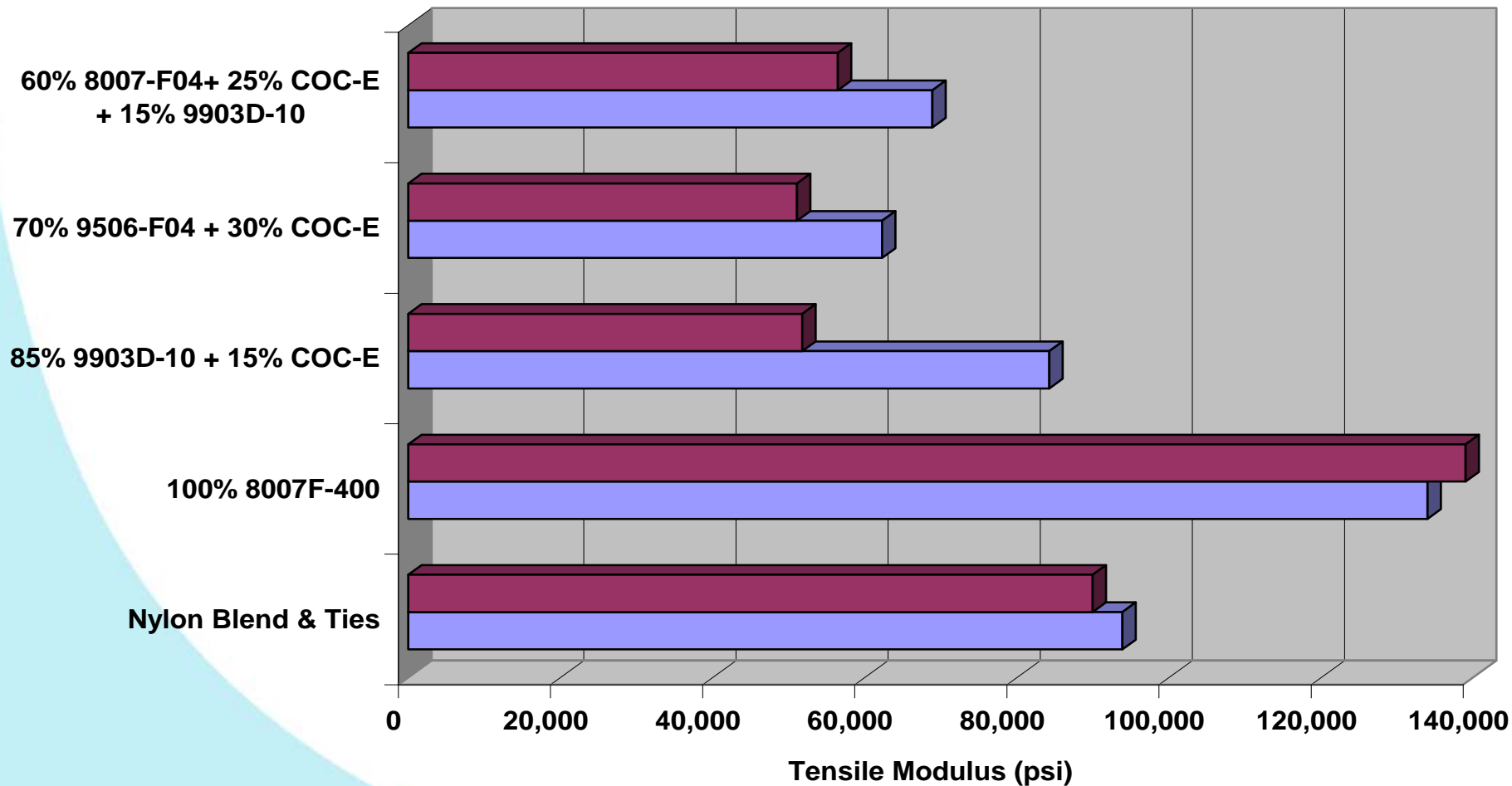
Multilayer Nylon vs. COC: Puncture



Puncture resistance of three COC films exceed nylon film
Total energy of COC films offer significant improvement with COC-E

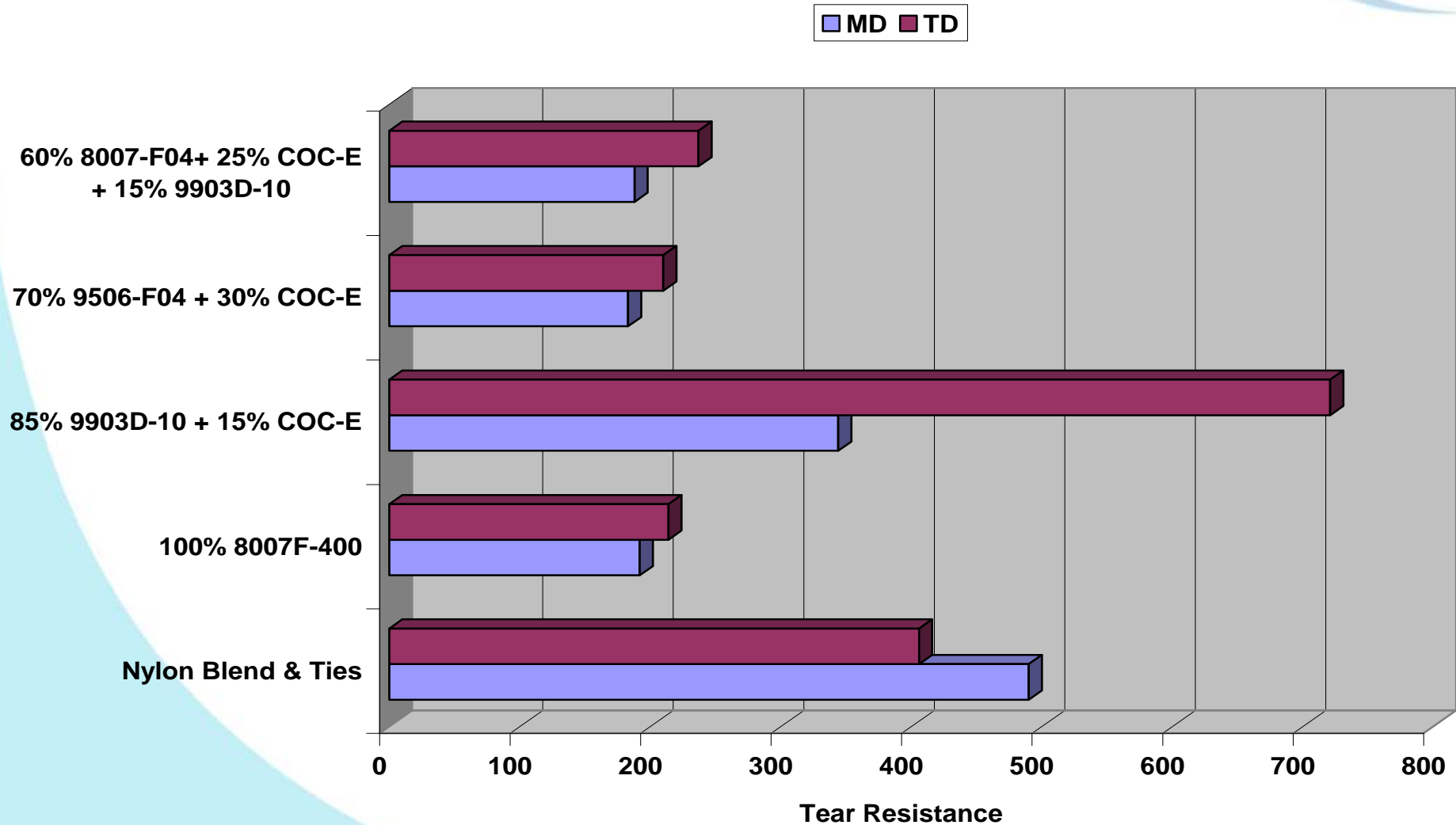
Multilayer Nylon vs. COC: Modulus

MD TD



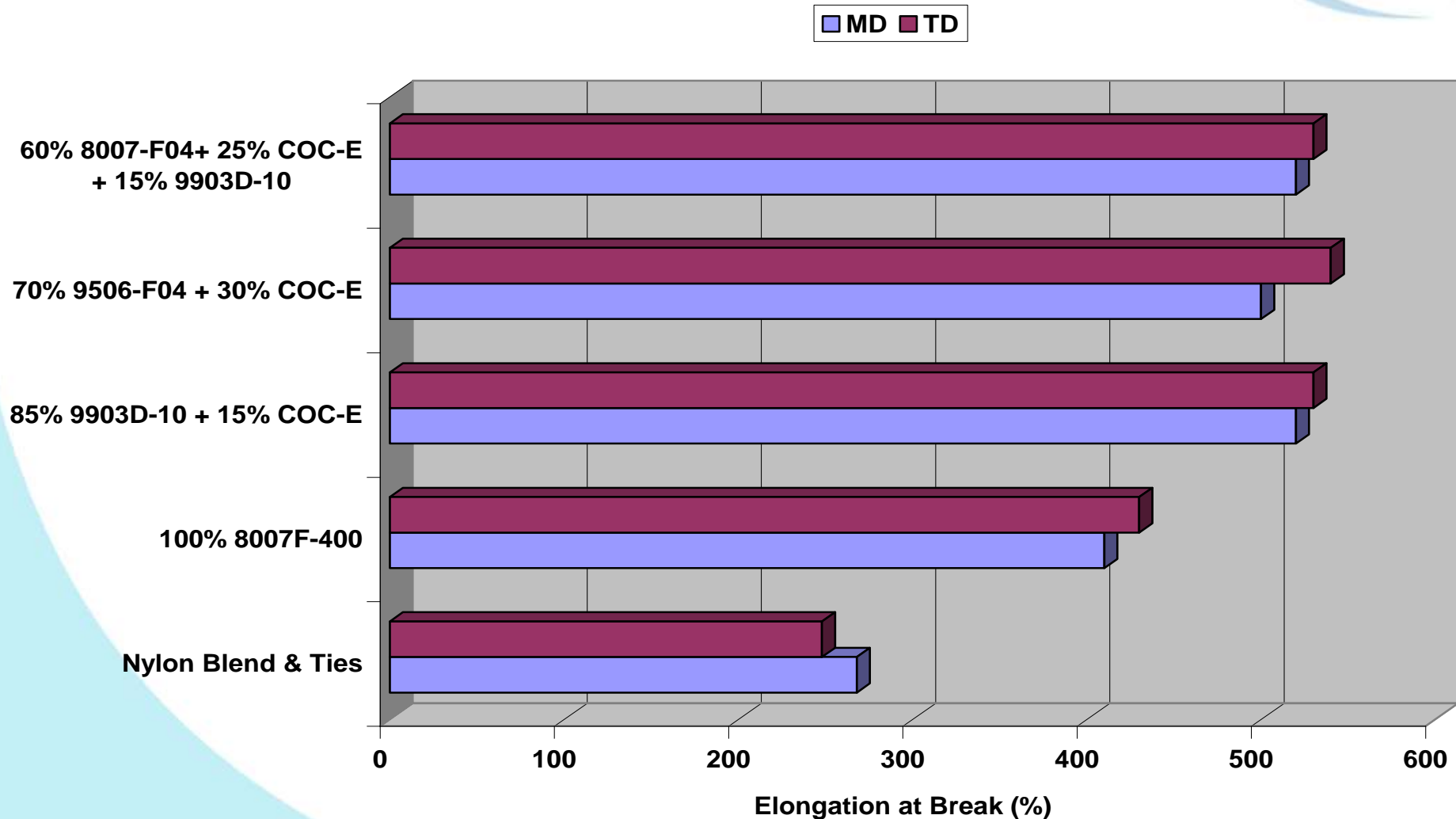
COC-E reduces stiffness of COC films

Multilayer Nylon vs. COC: Tear Resistance



COC films have less tear resistance
TOPAS 9903D-10 & COC-E improves tear resistance

Multilayer Nylon vs. COC: Elongation



COC films have superior ductility
COC-E improves ductility

Target Market and Applications



- **Bag-In-Box**
- **Medical Thermoforming Films**
- **Liquid Soap**
- **Many Others**

Conclusions



- **Cast extruded monolayer films consisting of 9903D-10, 9506F-04 and COC elastomer blends are competitive to monolayer nylon film blend with respect to toughness, tear resistance and appearance.**

- **5-layer modified COC films are good alternatives to multilayer nylon core film.**
 - **Cost equivalence; recycle / reclaim for additional savings**
 - **Similar appearance**
 - **Superior ductility, impact & puncture resistance**

- **New film design options**

- **New class of “ALL” polyolefin films can be made to satisfy sustainable packaging initiatives**

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