# NEW POLYETHYLENE RESINS DESIGNED TO MEET THE DYNAMIC NEEDS OF THE FLEXIBLE PACKAGING INDUSTRY

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## Abstract

Co-extrusion technology is creating tremendous flexibility in designing and manufacturing films for new packaging applications. With co-extrusion technology, the best material can be utilized in one layer of a film construction to satisfy one or two specific functions. ATOFINA has designed value-added MDPE and HDPE grades with unique properties for multi-layer flexible packaging applications. These resins combine stiffness, toughness, clarity, and gloss ideally suited for various flexible packaging applications including stand-up pouches, shrink bundling films and form-fill-seal packaging films.

## Introduction

The *Flexible Packaging Association* estimates that the flexible packaging industry is $20 billion strong and growing. The wide-ranging properties and economical value of polyolefins have propelled their growth in flexible packaging, and new opportunities continue to emerge to replace rigid packaging. Low temperature heat seal materials, retortable materials and advances in barrier properties are just a few examples of innovations that have enabled growth of polyolefins in this market segment.

Co-extrusion technology is creating tremendous flexibility in designing and manufacturing films for these new packaging applications. With co-extrusion technology, the best material can be utilized in one layer of a film construction to satisfy one or two specific functions. Compromises that must be made in monolayer films are no longer constraints when designing co-extruded films. This new flexibility has created opportunities for medium density polyethylene (MDPE) and high density polyethylene (HDPE) in flexible packaging. MDPE and HDPE resins offer higher stiffness, tensile strength and heat resistance than LDPE, LLDPE and single-site LLDPE resins. These properties are beneficial because they improve the printing, converting and filling of films. Unfortunately, MDPE and HDPE resins typically have poor optics (haze, gloss) and poor toughness (impact, tear). Thus, they are not attractive for many flexible packaging applications. ATOFINA has addressed these constraints by designing two families of resins that provide the benefits of MDPE and HDPE without their typical drawbacks. The properties are perfectly suited for co-extruded films for a wide variety of flexible packaging applications.

## Finathene® 6400 Series: Clear HDPE Film Grades

A proprietary catalyst system is used to manufacture two MMW-HDPE grades with exceptional properties.

| | 6410 | 6450 |
|---|---|---|
| MFI 190°C 2.16 kg, g/10 min | 1.2 | 5.0 |
| Density, g/cc | 0.961 | 0.961 |

Typically, MMW-HDPE resins are incorporated into multi-layer film structures to provide the following benefits:

- Stiffness and tensile strength
- Heat resistance
- Moisture and oxygen barrier

6410 MMW-HDPE provides all of the typical benefits of HDPE with these value-added properties:

- Low haze
- High gloss
- Extremely low gel content
- Low taste and odor

6410 films have outstanding clarity and gloss for an HDPE resin. Figure 1 shows the remarkable difference in clarity between 1.0 mil films extruded from 6410 and a typical Ziegler-Natta MMW-HDPE film grade. These films were examined by Atomic Force Microscopy and the results are given in Figure 2. In general, 6410 films (extruded on a conventional blown film line) have a much smoother surface and smaller lamellae than typical MMW-HDPE films. The smaller lamellae lead to better clarity, but surprisingly, the 6410 films have a smoother surface than conventional HDPE resins. This is evidenced by the plots in Figure 2 that show the surface roughness correlates with the $45^0$ gloss. Surface roughness also correlates very well to haze. The combination of these features provides 6410 superior gloss and low haze compared to films of similar density.

The unique combination of properties of 6410 compared to hexene LLDPE and MMW-HDPE are illustrated in the graphs in Figure 3. In the past to obtain good clarity and low haze, a lower density resin would have to be used at the expense of stiffness. Now high stiffness, low haze, high gloss is achievable without compromise with 6410. This combination of properties is important for down gauging structures. Clearly, 6410 provides a property balance unmet by other polyethylene resins. Also, because 6410 is an HDPE resin, the MVTR is significantly better than LLDPE. This is a decided advantage for designing film structures needing clarity and lower water transmission rates.

6410 has excellent heat resistance properties owing to its melting point of 135°C and a very narrow melting range (Figure 4). Thus, it is suitable for boil-in-bag and other high temperature applications. Figure 5 shows that its seal initiation temperature is over 20°C higher than a 0.918 g/cc LLDPE. One example of how this property can be utilized is in form-fill-seal (F/F/S) films. 6410 can be used as an outer layer of a fin-sealed F/F/S film as a heat resistant layer to prevent burn through at high sealing temperatures and packaging speeds. Consequently, it broadens the heat seal and hot tack windows. Unlike traditional MMW-HDPE resins, 6410 creates an attractive outer layer for the package. Its high gloss, low gel content and stiffness make 6410 the ideal substrate for high quality printing and laminating.

6450 provides the same benefits of 6410, but it is designed for the cast film process. Figure 6 lists some typical properties of 6450 in cast extrusion.

## Finacene® Easy Processing Metallocene Polyethylene Resins

A new family of metallocene catalyzed PE film grades have been developed for blown and cast applications (Figure 7). The proprietary catalyst technology creates a polymer with outstanding processability. This is illustrated in Figure 8. Finacene resins extrude at lower melt pressure and have much higher melt strength. Lower melt pressure translates to easier extrusion and potentially higher throughput. Low melt strength is a common complaint for single-site PE resins. Often, throughput must be sacrificed to maintain good gauge control. These metallocene-catalyzed resins have high melt strength so they have good bubble stability and gauge control even at high extrusion rates.

Each new grade delivers an optimal balance of stiffness and clarity for its particular application. Figure 9 shows that films extruded from Finacene PE have a unique balance of stiffness (Modulus) and clarity (Haze) compared with other PE film grades. For example, ER 2277 has equivalent haze to an octene LLDPE with a density of 0.920 g/cc with double the modulus.

These resins also produce films with excellent heat seal properties. The increase in seal strength and broad sealing windows make them ideally suited for many automatic packaging applications (Figure 10).

Co-extrusion studies in blown and cast films show that these grades have excellent adhesion to polypropylene. Thus, they can be combined with polypropylene without the need for expensive tie layer resins or compatibilizers.

Introduced to the market in late 2001, M 3410 EP is a metallocene MDPE (0.9 MI, 0.934) blown film grade that has demonstrated value in a wide range of applications including bottled water shrink film, fresh produce packaging, protective packaging, shipping sacks and a variety of FFS films. Figures 11 through 15 show suggested formulations and film property data for several types of flexible packaging films. These data illustrate how M 3410 EP enhances the processability and film properties versus traditional formulations.

Finacene catalyst technology has been leveraged to design a broad family of products for blown and cast films (Figure 6). ER 2277 (0.9 MI, 0.927) has outstanding clarity and toughness. Its density is higher than most m-LLDPE grades, so it adds stiffness to films for easier converting and printing. The high molecular weight of ER2281 gives it outstanding toughness and strength needed for industrial applications, and the ER 2278 processes well in blown and cast film with good optics and mechanical strength. ER 2279 is designed for cast stretch film. When used in the skin layer it reduces unwinding force and noise. M 3410 EP is commercially available today. The other grades are experimental, and they are available for sampling in 2004.

## Conclusions

6400 Series and Finacene polyethylene resins are designed to meet the dynamic needs of the flexible packaging industry. These resins combine stiffness, toughness, clarity, gloss and sealability making them ideally suited for many flexible packaging applications.


**Figure 1. See-through Clarity of Finathene® 6410 Compared to a Conventional MMW-HDPE**

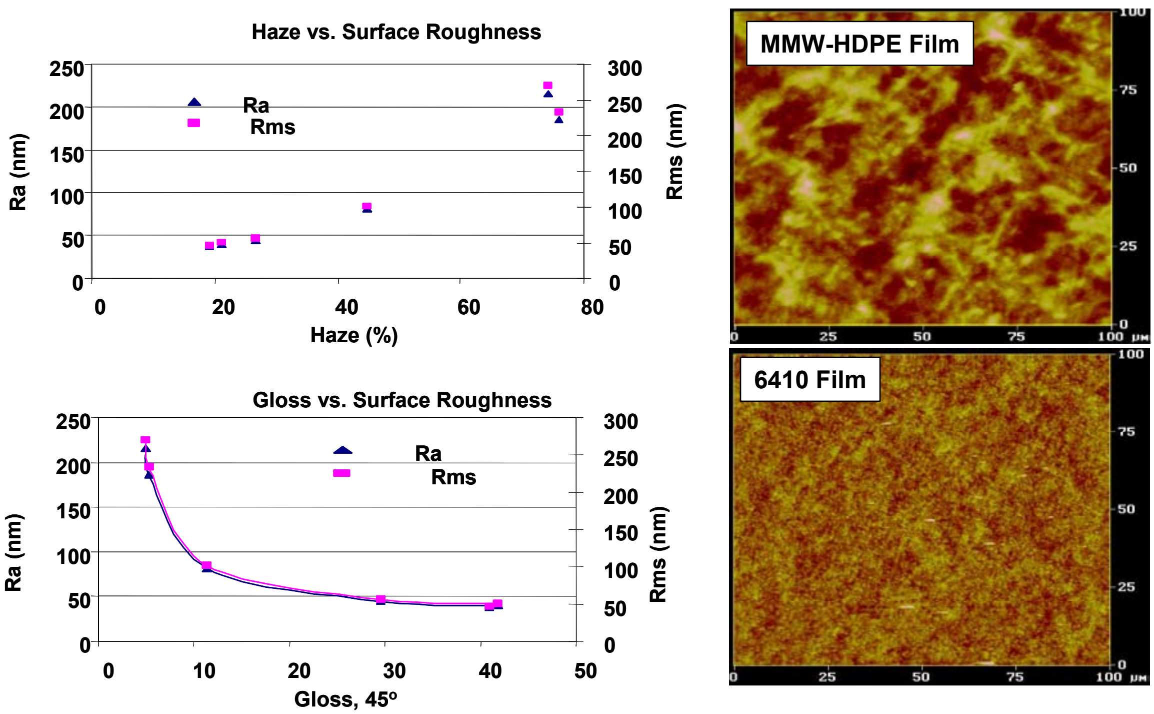


**Figure 2. The Atomic Force Microscopy data show that blown films produced with Finathene® 6410 have a smoother surface (higher gloss) and smaller lamellae (better clarity) than conventional MMW-HDPE films.**

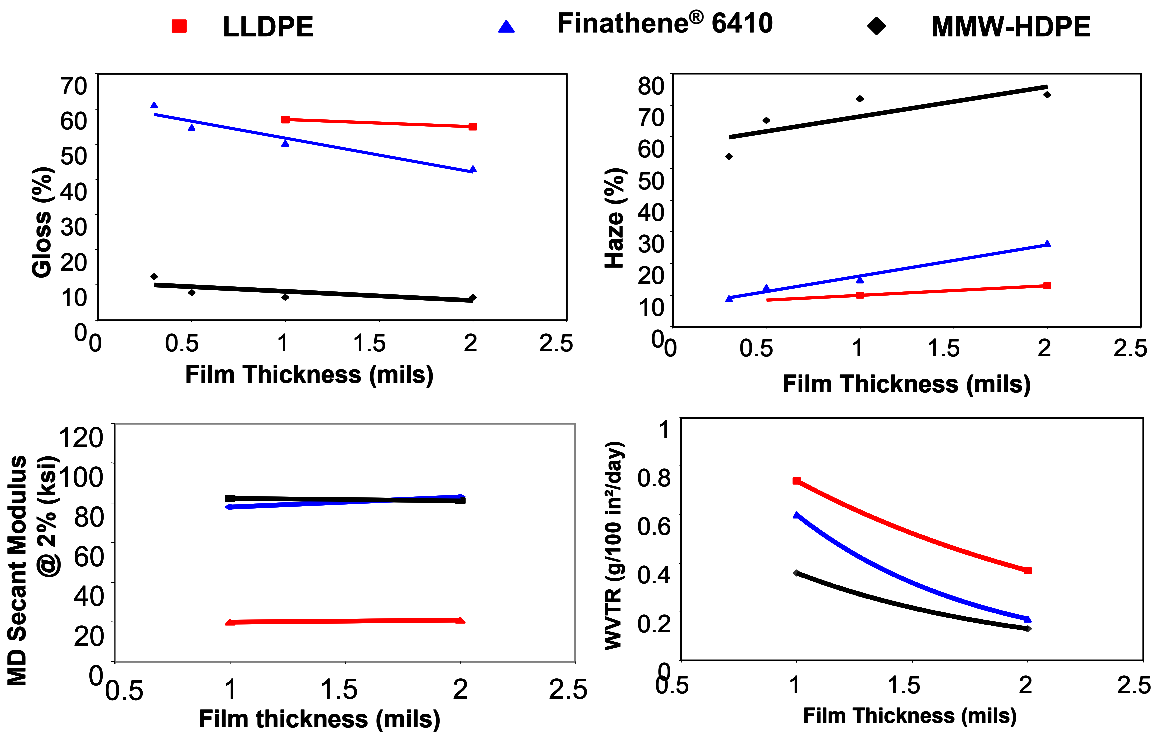


**Figure 3. Properties of blown films produced from a conventional LLDPE (1.0 g/10 min, 0.918 g/cc), MMW-HDPE (1.0 g/10 min, 0.962 g/cc) and Finathene 6410® (1.0 g/10 min, 0.962 g/cc)**

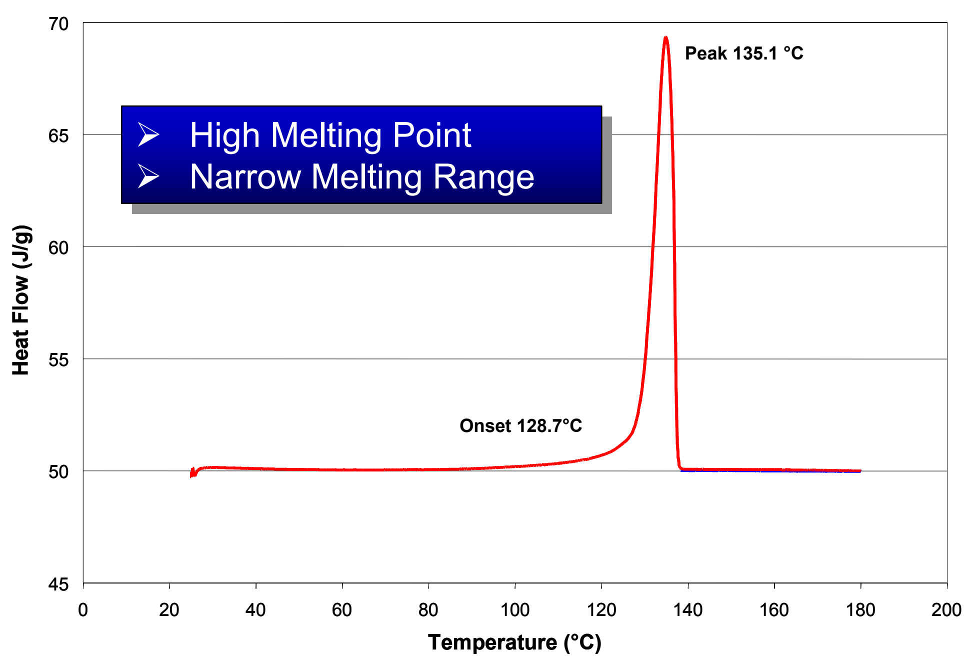


**Figure 4. Finathene® 6410 has a high melting point and narrow melting range making it suitable for applications requiring heat resistance up to 100°C, e.g. boil-in-bag.**

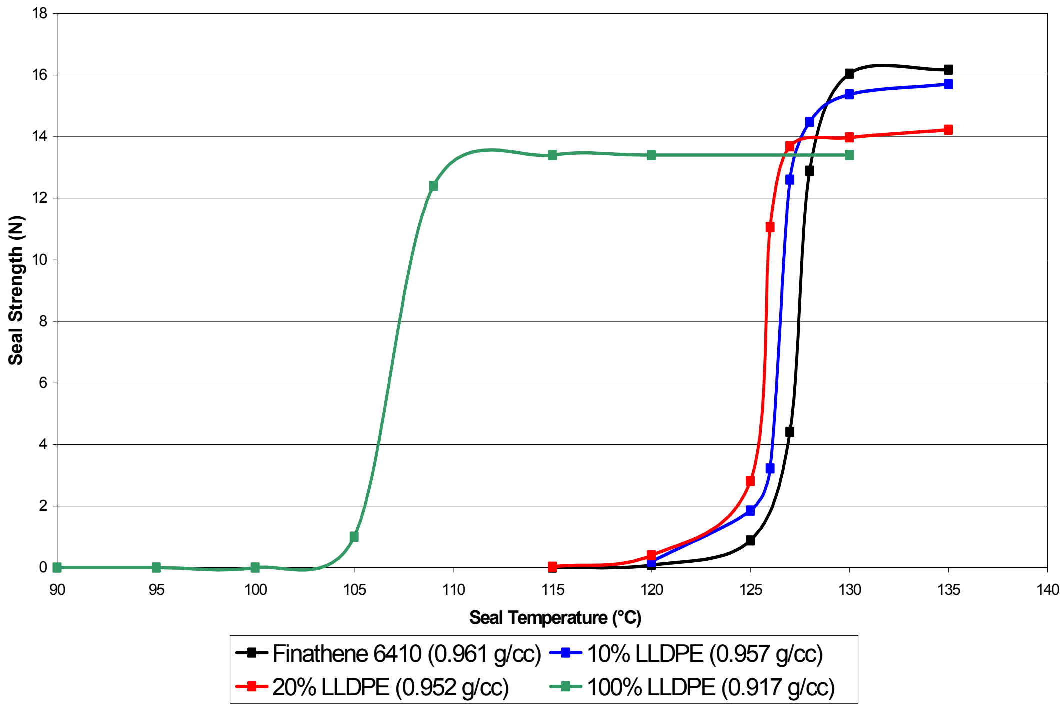


**Figure 5. Heat sealing curves for Finathene® 6410 films and blends with LLDPE (1.0 g/10 min, 0.918 g/cc) measured on 25 µm films on a Theller heat sealer. 6410 can be used as a heat resistant layer in a sealant web.**

| Film Properties | Typical Value |
|---|---|
| Haze | < 6.0 % |
| 45° Gloss | 85 |
| 1% Secant Mod. (MD/TD) | 100/130 ksi |
| WVTR @ 100°F | 0.5 g/100 in$^2$/day |

**Figure 6. Properties on 25 µm cast film extruded from Finathene® 6450 (5.0 g/10 min, 0.962 g/cc).**

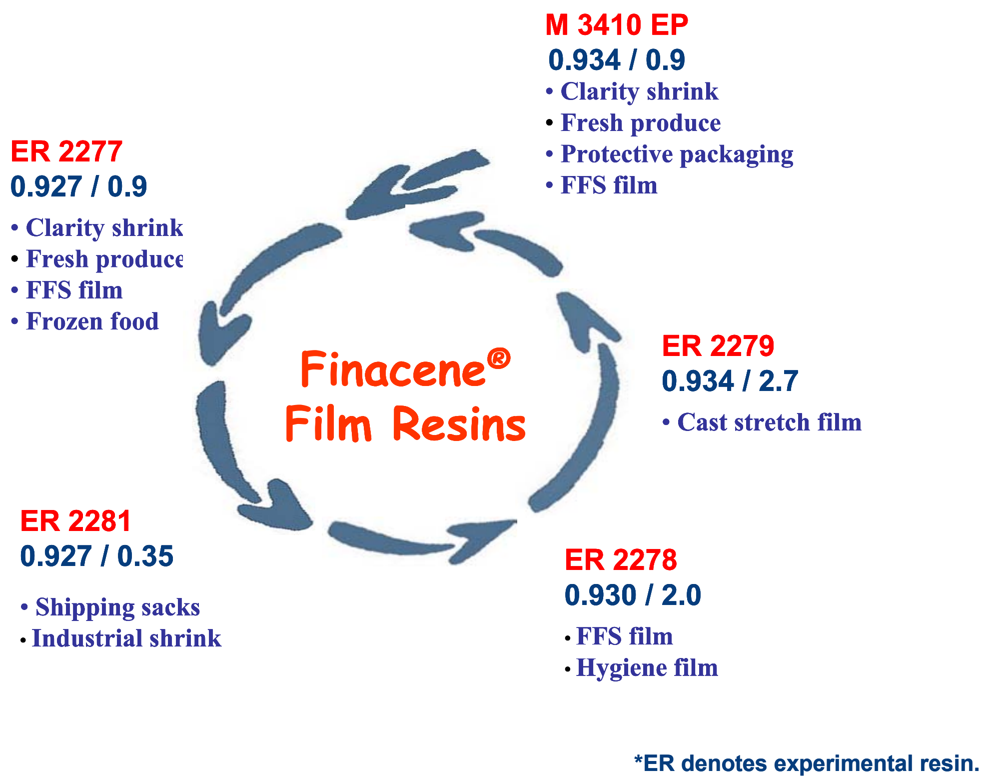


**Figure 7. Finacene® Grades for Film Applications**

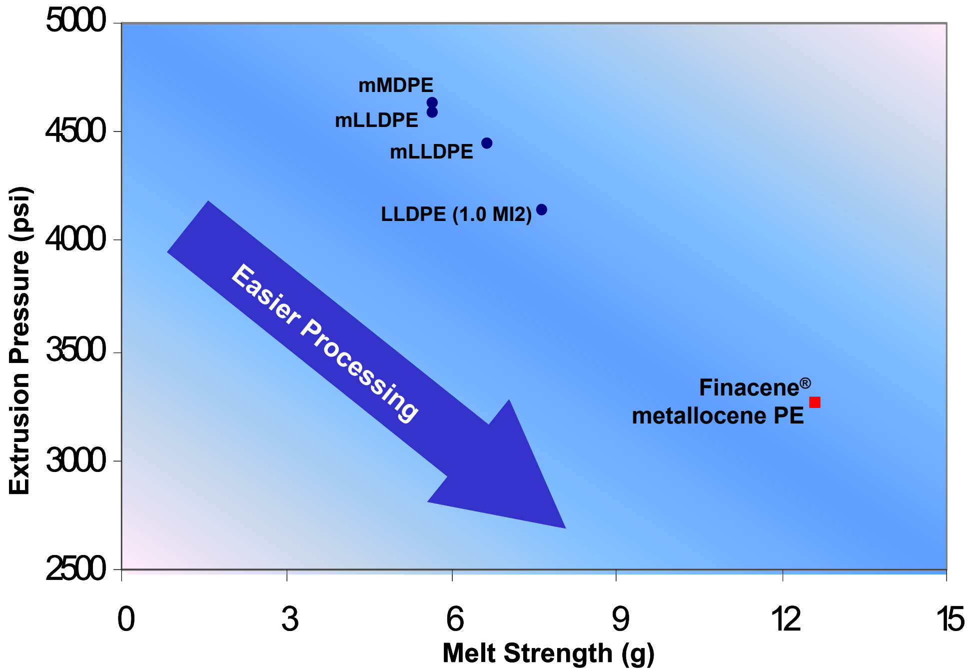


**Figure 8. Finacene® polyethylene grades have superior processing on blown film equipment compared to other single-site and conventional linear polyethylenes. Lower extrusion pressure promotes higher throughput, and higher melt strength improves bubble stability and gauge control.**

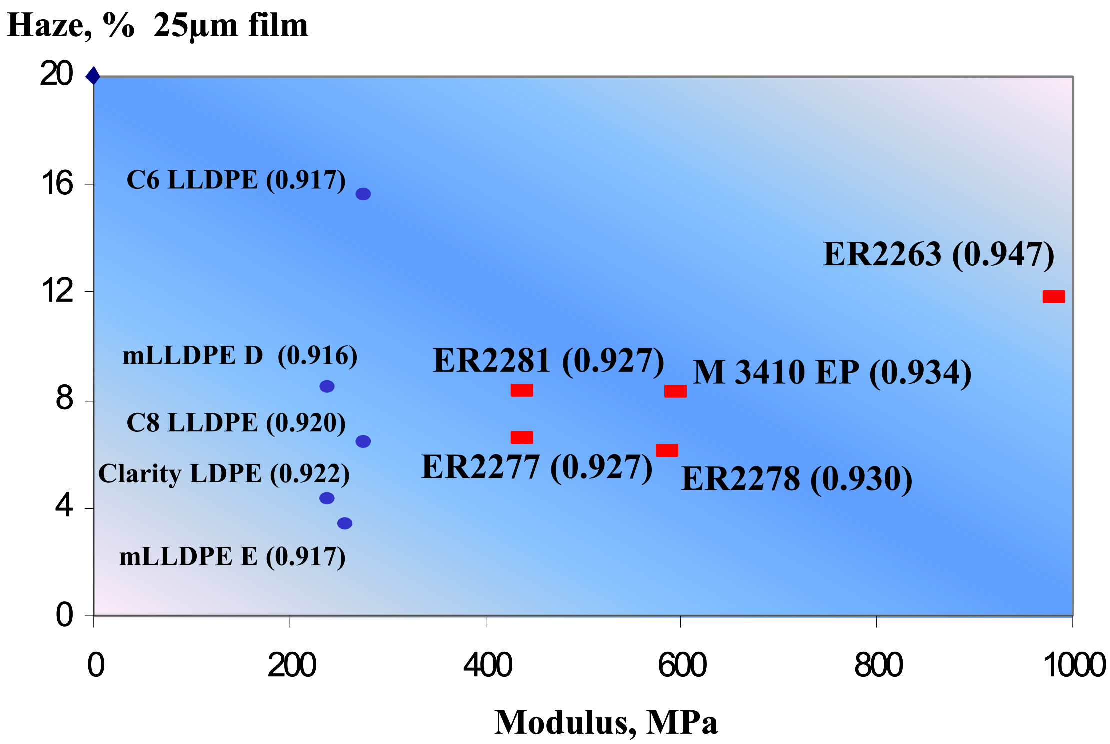


**Figure 9. Blown films extruded from Finacene® polyethylene have haze values similar to conventional and other single-site polyethylene resins with much higher stiffness to facilitate printing, converting and laminating operations.**

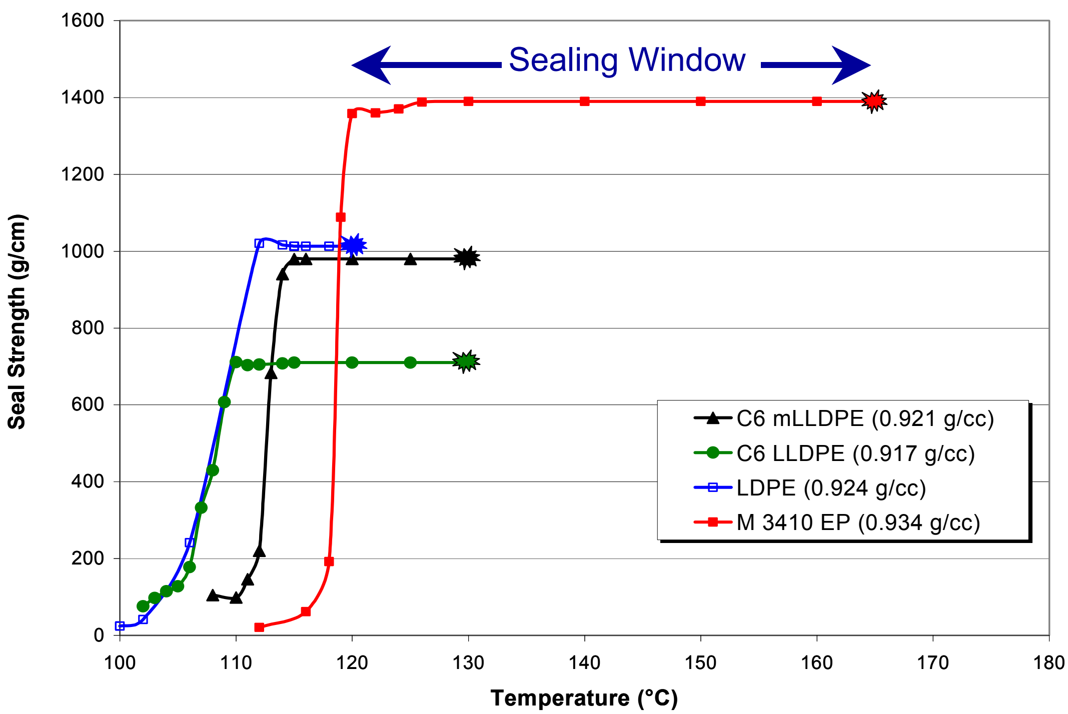


**Figure 10. Finacene® M 3410 EP can be used to broaden the sealing window and increase the seal strength of multi-layer films or monolayer blends.**

## Monolayer Clarity Water Bottle
## Shrink Bundling Film

Thickness: 2.0 mil

**30% Finacene® M 3410 EP** + 70% LDPE (0.8 MI, 0.924 g/cc) +
800 ppm Erucamide + Antistat

### Key Attributes

- High stiffness for high packaging speeds
- Good shrink properties
- Good optical properties (haze, gloss)
- Good tear strength
- Good puncture strength
- Good sealing properties for high conversion rates
- Excellent bubble stability & gauge control

| Film Properties | Typical Value | Method |
|---|---|---|
| Haze | 9.5% | ASTM D1003 |
| 45° Gloss | > 60 | ASTM D523 |
| 1% Secant Modulus (MD), psi | 26,000 | ASTM D 882, A |
| Elmendorf Tear (MD), g | 650 | ASTM D 1922 |
| Dart Impact, g | 130 | ASTM D1709, A |

**Figure 11. Monolayer water bottle shrink bundling film containing Finacene® M 3410 EP.**

## Co-extruded Clarity Water Bottle Shrink Bundling Film

### Film Structure

Thickness: 2.0 mil
3-layer A/B/A
Layer Distribution: 15/70/15%

A Layer
**85% Finacene® M 3410 EP**
15% LDPE (0.7 MI 2.16, 0.921 g/cc)
B Layer
LDPE (0.7 MI 2.16, 0.921 g/cc)

### Key Attributes

- High stiffness for high packaging speeds
- Excellent shrink properties
- Outstanding optical properties (haze, gloss)
- Very high tear strength
- Good puncture strength
- Good sealing properties for high conversion rates
- Excellent bubble stability & gauge control

| Film Properties | Typical Value | Method |
|---|---|---|
| Haze, % | 8.5 | ASTM D 1003 |
| 45° Gloss | 70 | ASTM D 523 |
| 1% Secant Modulus (MD), psi | 21,200 | ASTM D 882, A |
| Elmendorf Tear (MD/TD), g | > 800 / > 500 | ASTM D 1922 |
| Dart Impact, g | 150 | ASTM D1709, A |

**Figure 12. Co-extruded water bottle shrink bundling film containing Finacene® M 3410 EP.**

## Co-extruded Automatic Packaging (F/F/S) Film

### Film Structure
Thickness: 1.0 mil
3-layer A/B/A 15/70/15%

A Layer
86% m-LLDPE (1.0 MI2, 0.918 g/cc)
10% LDPE (0.8 MI2, 0.922 g/cc)
Antiblock
B Layer
**100% Finacene® M 3410 EP**

### Key Attributes
- High output
- Excellent bubble stability & gauge control
- High stiffness for high packaging speeds
- Outstanding optical properties (haze, gloss)
- Good sealing properties for high conversion rates

| Film Properties | Typical Value | Method |
|---|---|---|
| Haze, % | 4.0 | ASTM D 1003 |
| 45° Gloss | 80 | ASTM D 523 |
| 1% Secant Modulus (MD), psi | 43,000 | ASTM D 882, A |
| Elmendorf Tear (MD/TD), g | 70 / 160 | ASTM D 1922 |
| Dart Impact, g | 175 | ASTM D 1709, A |

**Figure 13. Co-extruded automatic packaging film (F/F/S) containing Finacene® M 3410 EP.**

# Co-extruded F/F/S Shipping Sack Film

## Film Structure

Thickness: 5.0 mil
3-layer A/B/A
Layer Distribution: 25/50/25%

A Layer
**30% Finacene® M 3410 EP** + 70% m-LLDPE (1.0 MI2, 0.918 g/cc)
800 ppm Erucamide + Antistat + Antiblock
**B Layer**
**92% Finacene® M 3410 EP** + 8% white MB

## Key Attributes

- Excellent bubble stability & gauge control
- High stiffness for high packaging speeds
- High impact and tear strength
- Excellent puncture strength
- Good sealing properties for high conversion rates
- High gloss

| **Film Properties** | **Typical Value** | **Method** |
|---|---|---|
| Dart Impact, g | 600 | ASTM D 1709, A |
| Slow Puncture | | ATOFINA Method |
| Max Load, lb | 210 | |
| Energy, ft-lb | 4.2 | |
| Elmendorf Tear (MD/TD), g | 850 / >1600 | ASTM D1922 |
| Tensile Strength @ Yield (MD/TD), psi | 1900 / 2000 | ASTM D882 |
| Elongation @ Break (MD/TD), % | 700 / 700 | ASTM D882 |
| 45° Gloss | 50 | ASTM D523 |

**Figure 14. Co-extruded F/F/S shipping sack film containing Finacene® M 3410 EP.**

## Co-extruded Tissue & Towel Overwrap

### Film Structure
Thickness: 0.75 mil
3-layer A/B/A
Layer Distribution: 25/50/25%

A Layer
**25% Finacene® M 3410 EP** + 70% LLDPE (1.0 MI2, 0.920 g/cc)

B Layer
**75% Finathene® 6410** + 25% LLDPE (1.0 MI2, 0.920 g/cc)

### Key Attributes
- Excellent bubble stability & gauge control
- High stiffness for high packaging speeds
- Excellent optical properties (haze,gloss)
- Good sealing properties for high conversion rates

| Film Properties | Typical Value | Method |
|---|---|---|
| Haze, % | 6.3 | ASTM D 1003 |
| 45° Gloss | 77 | ASTM D 523 |
| 1% Secant Modulus (MD/TD), ksi | 71/106 | ASTM D 882, A |

**Figure 15. Co-extruded high clarity tissue and towel overwrap film containing Finathene® 6410 and Finacene® M 3410 EP.**