Highly Transparent with Excellent Sealability

New α-Olefin-PP Terpolymers for Flexible Packaging Manufacturers

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Newly developed PP terpolymers made from propylene, ethylene and higher α-olefins enable manufacturers of unoriented and oriented PP film packaging to achieve significant cost savings and property advantages. For example, through the use of cast films made from butene terpolymers, converting speeds to food packaging can be increased by up to 30% compared with previously used films, while the packaging itself is characterised by extremely high brilliance and purity.

The efforts of the flexible packaging industry to achieve continual cost savings in the manufacture and further processing of flexible packaging are increasingly linked to the development of polymers, processing plants and converting technology [1]. Films made from polypropylene (PP) are becoming increasingly important because of their excellent combination of optical, mechanical and thermal properties (heat resistance). The latter property is crucial, particularly for sterilisable packaging. However, to process these films on existing converting and packaging lines, it has proved necessary in the past to use random copolymers made from ethylene and propylene for welding and sealing. These C_2/C_3 random copolymers have become very firmly established on the market over the last 20 years, particularly in the cast film sector.

With the development of new terpolymers with the trade names Borseal and Borclear, Borealis has launched a new generation of polypropylenes on the market, which considerably extends the property and application range of PP cast films and BOPP films.

Characteristic Properties

Through the use of 1-butene as a comonomer in the terpolymer, important property advantages can be obtained over standard ethylene (C_2)/propylene (C_3) random copolymers:

In contrast to ethylene, 1-butene is distributed much more homogeneously in the polypropylene chain. This gives C_3/C_4 copolymers markedly higher stiffness than conventional C_2/C_3 copolymers, while causing a lower reduction in melting point (Fig. 1) [2].

Higher polymer stiffness frequently leads to low toughness values. Although the elastic modulus of conventional C_3/C_4 copolymers is much higher than that of C_2/C_3 copolymers with the same comonomer content, their puncture resistance (Dynatest) is significantly lower. With the development of the new Borclear grades, it was possible to overcome this disparity. Borclear grades have comparable stiffness to C_2/C_3 copolymers but their toughness far exceeds that of C_2/C_3 random copolymers, while they retain a similar melting point (Fig. 2).

The better distribution (randomness) and lower sequence length of 1-butene in the polymer chain, besides leading to higher stiffness, also results in improved optical properties of C_3/C_4 co- and terpolymers as compared with C_2/C_3 random copolymers [3]. This is the reason for the exceptionally high brilliance and transparency of the Borclear and Borseal grades.

During polymerisation, the considerably higher reactivity of ethylene in comparison with propylene and 1-butene leads to an increase in low-molecular-weight fractions, particularly at higher comonomer contents. These low-molecular-weight fractions have a relatively high ethylene content and are readily soluble in non-polar solvents such as hexane or xylene [4]. The much lower activity of 1-butene prevents the formation of such relatively high contents of low-molecular-weight compounds in the manufacture of butene co- and terpolymers. This means that C_4 co- and terpolymers, even with relatively high butene contents, behave in practically the same way as PP homopolymers in terms of their solubility in non-polar solvents (Fig. 3).

Specific Processing and Converting Advantages

Biaxially oriented PP films (BOPP): In the production of BOPP films, terpolymers are usually coextruded as thin, heat-sealable layers together with a main layer (normally homopolymer). The crucial criterion was to develop a product with the optimum combination of relatively high melting point with low sealing temperature. With normal standard terpolymers, a low sealing temperature automatically leads to lower melting points and higher amorphous fractions [5]. The problem of reconciling these two normally conflicting properties was solved by carefully tailoring the polymer structure of the Borseal terpolymers using the special polymerisation/catalyst technology developed by Borealis. This achieved the following advantages:

- Excellent processing properties: In this case, a Borseal grade has been developed with a relatively high melting point. This prevents the film sticking to the stretching rolls during longitudinal orientation and so avoids optical defects or film tears. This is particularly important on high-speed machines operating at speeds much over

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300 m/min. For end users of the films, this also offers converting advantages in the form of reduced blocking and good film running properties on packaging machines.

- Sealing properties:
  The combination of relatively high melting point with low seal initiation temperatures, extremely high seal strengths and high hot tack provides a unique property profile. The low seal initiation temperatures in the range 100 to 108 °C (depending on the Borseal grade used) deserve particular mention (Fig. 4).

Unstretched cast films: The C_2/C_3 random copolymers with high C_2 content mainly used until now in the cast film sector have disadvantages in terms of blooming behaviour [6]. "Blooming" usually occurs when soluble constituents migrate to the film surface during production (e. g. chill roll deposits), film storage or downstream treatment operations such as sterilisation. Users notice a significant reduction in optical properties and a white deposit on the film surface. Through the use of C_3/C_4 terpolymers, these effects are significantly reduced – particularly at higher storage temperatures (Fig. 5). The main reason for this is the much lower content of low-molecular-weight and soluble constituents in the new Borclear generation.

Another very important property advantage, besides good mechanical properties, is the excellent sealing behaviour of these Borclear co- and terpolymers in comparison with C_2/C_3 random copolymers [7]. For example, bread bags can be produced in up to 30 % faster cycles than with previously used film formulations (Fig. 6). This results in significant efficiency increases for converters – and also a significant reduction in reject rates.

Application Advantages

The low content of low-molecular-weight and soluble constituents in these new-generation polymers means they have high purity compared with previously used standard polymers such as C_2/C_3 random copolymers with a high C_2 content.

This offers end users a number of property advantages, such as

- good organoleptic properties (minimal taint and odour),
- very stable surface properties, e. g. slow decline in surface tension after metallisation, good hot slip and very good sealability on the corona- or flame-treated side,
- very good adhesion in printing, metallising and lamination, and
- excellent optical properties and brilliance.

The main applications for BOPP films with Borseal terpolymers as the heat-sealable layer are in the vast food packaging sector, for example as snack packaging or metallised and general FFS (form-fill-seal) packaging. Typical cast film applications for Borclear grades, besides the traditional sector of office organisation, are those in which excellent optical properties, very high purity and the best possible sealability are required. Such applications include food packaging (special bread packaging) and all types of metallised film packaging (unstretched), labeling and display, and heat-sealable layers in coextrusion [8]. In the latter application, the higher stiffness of the new polymers compared to the previously used C_2/C_3 random copolymers with higher C_2 content should be stressed, as it results in considerably stiffer and more attractive packaging.

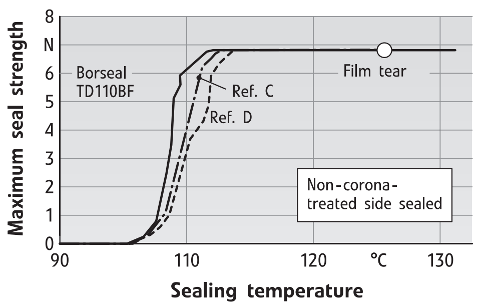

Fig. 4. Seal strength as a function of sealing temperature for Borseal TD110BF in comparison with two reference grades currently on the market

Future Outlook

The application potential of these new α-olefin PP terpolymers in the market is by no means exhausted yet. Future opportunities lie in the replacement of other materials such as metal, glass and also composite packaging. In α-olefin copolymer development, efforts will be concentrated on heterophasic copolymers to achieve similar property advantages with these, i. e. high stiffness and toughness combined with excellent optical properties and low soluble constituents.

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Fig. 1. Comparison of the stiffness of C3/C4 and C_2/C_3 random copolymers as a function of melting point
Biege-E-Modul = Flexural modulus; Schmelztemperatur = Melting point

Fig. 2. Comparison of the toughness of commercially available C_3/C_4 and C_3/C_2 random copolymers with Borclear terpolymers

Fig. 3. Comparison of the soluble constituents of C_3/C_4 and C_3/C_2 random copolymers as a function of melting point
Xylollösliche Anteile = Xylene-soluble constituents; Schmelztemperatur = Melting point

Fig. 5. Comparison of the optical film properties/blooming of Borclear with those of ethylene random copolymers (with high C_2 content) as a function of storage period and storage temperature
Folie = Film; Lagerzeit bei 40° = Storage period at 40 °C

Fig. 6. Use of Borclear for PP bread packaging produced in very fast cycles