# 12 Oriented Film Technology

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## 12.1 Introduction

Today, oriented plastic films are produced industrially in large quantities. As such, the majority are biaxially oriented, that is, films are stretched in both directions, which is understandable when taking the improvement in characteristics into consideration [1]. The characteristics attained with biaxially oriented films ideally meet the demands on modern flexible packaging. As illustrated in Fig. 12.1, flexible packaging has to fulfill the protective function and product design in line with economic and, increasingly, environmental aspects. The required packaging product protection is attained by the excellent barrier properties against gases (water vapor, oxygen, and others) as well as good-quality seals. The product appearance is attained by high-gloss and transparent thin packaging film as well as by excellent printability. The requirements for sought-after economic packaging are met by good material utilization and the fulfillment of the demand for high-speed packaging lines. Environmental aspects, which play an ever increasing role, can be satisfied by utilizing environmentally friendly materials (such as polyolefin), as well as the optimum raw material yield, thus ensuring maximum packaging effect with minimum material cost.

To what extent biaxial orientation improves properties is shown in Fig. 12.2 using biaxially oriented polypropylene (BOPP) as an example. Along with a significant increase in the mechanical properties (Young's modulus and tensile strength), a considerable improvement in the optical (haze and gloss) as

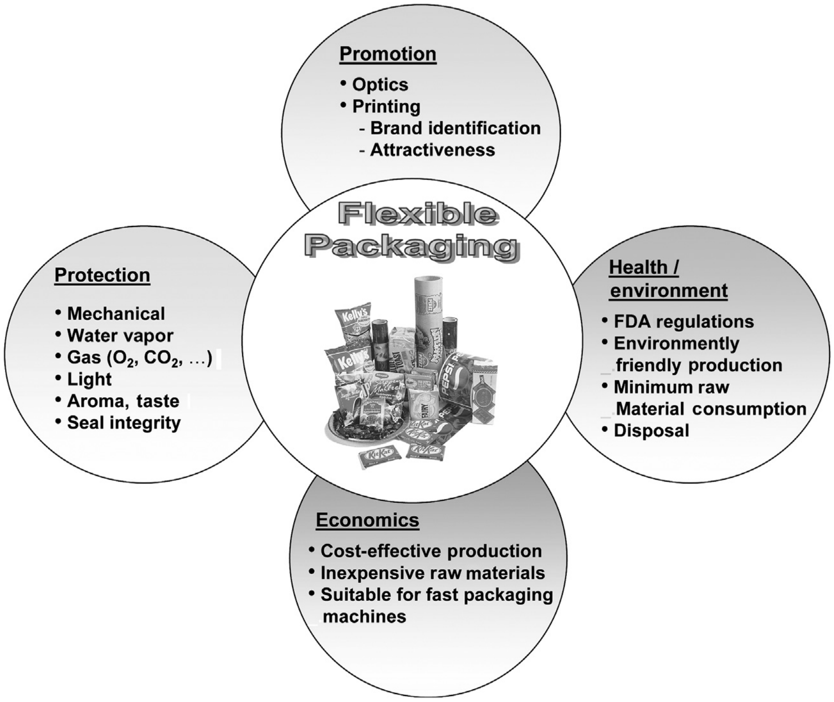


**Figure 12.1** Flexible packaging requirements for protection, promotion, health/environment, and economics.

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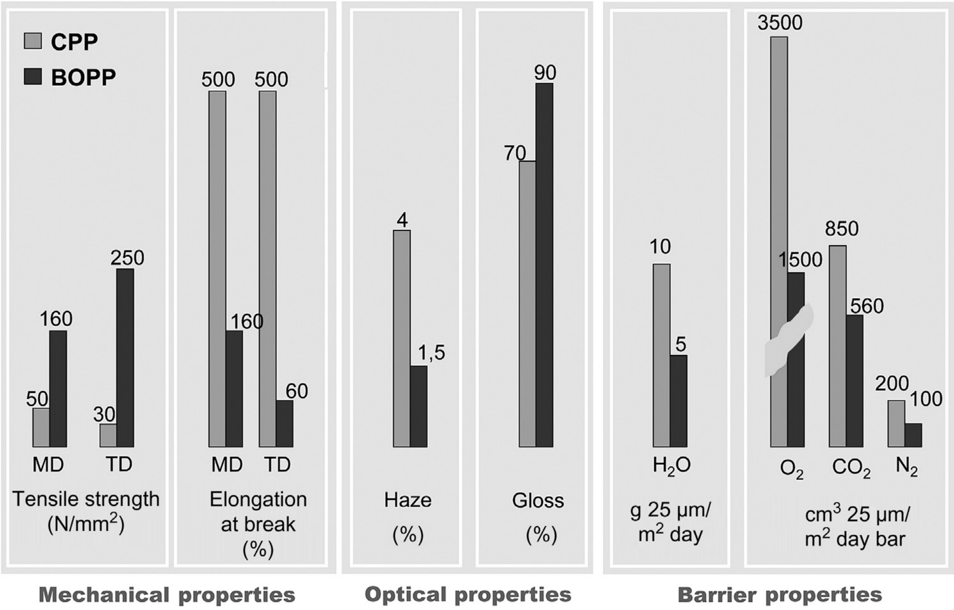



**Figure 12.2** Property improvement for biaxially stretched PP (BOPP) versus cast PP (CPP).

well as the barrier properties can be seen. The overall improved barrier properties attained are due to the orientation of the molecule chains which, for a non-oriented polymer, are random, whereas in the stretching process, a clear molecule chain orientation occurs. As such, biaxial orientation of plastic films represents a refinement process which is applicable for almost all plastics. Semicrystalline plastics in particular, such as polypropylene (PP) and polyester, also augment the crystallinity by the stretching process, which considerably improves the mechanical values.

Fig. 12.3 shows the increase in the Young's modulus in machine and transverse directions as a result of the biaxial orientation process for polypropylene and polyester. The exceptional mechanical properties in combination with the barrier and optical properties with comparably low raw material costs have led to the fact that BOPP and biaxially oriented polyethylene terephthalate (BOPET) films account for the largest and most significant share among stretched films.

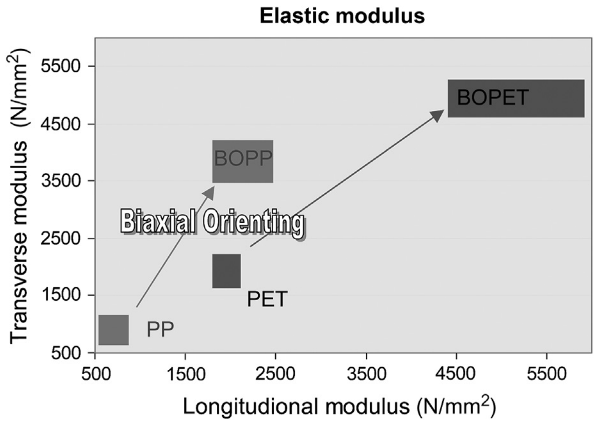



**Figure 12.3** Mechanical property enhancement for BOPP and BOPET.

## 12.2 Orienting Technologies

In orienting technologies, one can, in general, differentiate between the orientation draw direction and the related stretching process. The stretching processes shown in Fig. 12.4 (longitudinal, transverse stretching, sequential-biaxial stretching, and simultaneous-biaxial stretching) do not depict competitive, but rather supplementary features in order to attain specific film characteristics. As such, the required stretching equipment varies depending on the process. Stretching in the machine direction is normally done by means of a machine direction orienter (MDO) via rolls with increasing speed. Typical products are, for example, tear stripes or polypropylene adhesive tapes. For all transverse-oriented films, the stretching process takes place by means of a transverse direction orienter (TDO), where the film is fixed on both ends and, upon passing through an oven at various temperatures, is stretched in a transverse direction.

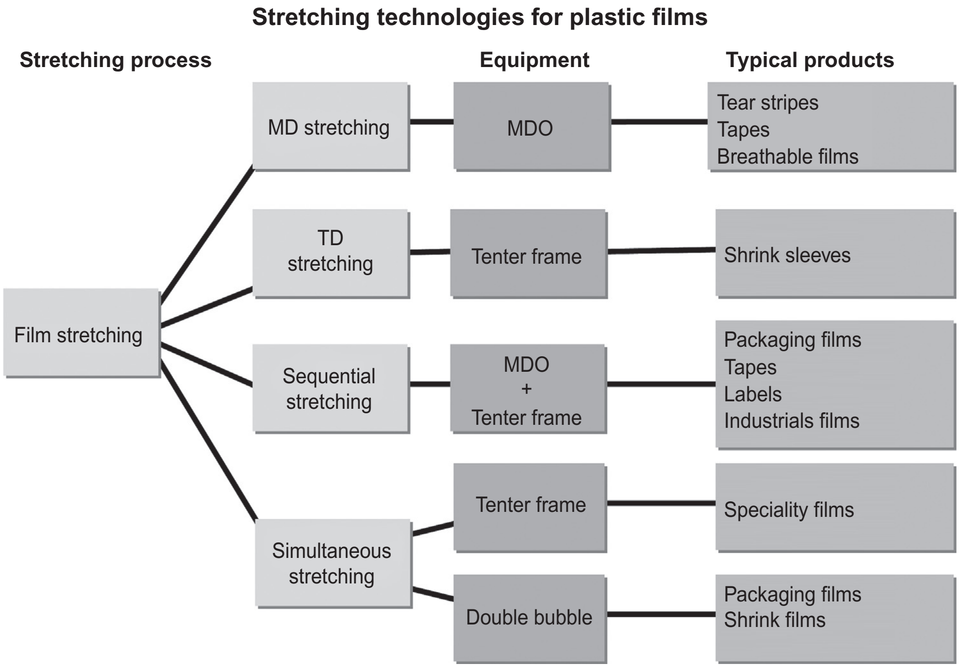



**Figure 12.4** Plastic film stretching.

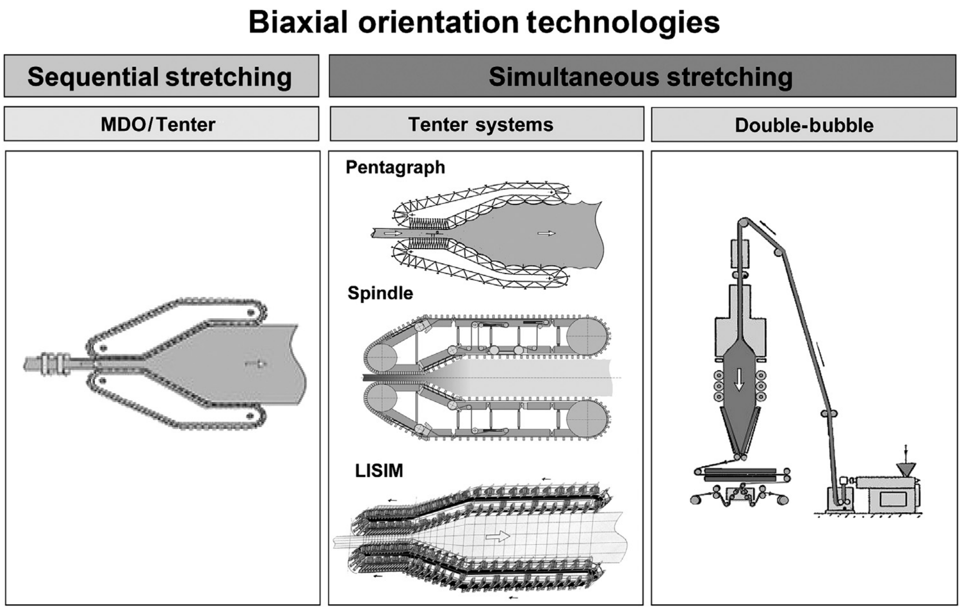



**Figure 12.5** Biaxial orientation.

Typical examples of transverse stretched film types are shrink sleeves, where shrinkage merely occurs in the transverse direction. Biaxial orientation, in the machine and transverse directions, can be done either sequentially or simultaneously. In the sequential process, an MDO and a tenter frame are successively utilized [2,3]. This process has the widest prevalence for all stretched film types. All types of packaging films, tapes, labels, and industrial films are manufactured with this process.

Simultaneous orientation, however, is possible with the tenter and the blown process (Fig. 12.5). The blown process is a so-called double bubble process where, initially, a tube is extruded, then rapidly cooled and then heated to the stretching temperature. A synchronous increase of the draw-off speed and bubble expansion by internal pressure results in the required simultaneous orientation process.

Sequential stretching first in the machine direction and then in the transverse direction utilizing an MDO and a TDO is the most prevalent process in use today. Fig. 12.6 is a cut-away view of a three layer−coextruded BOPP line that shows the main extruder, two coextruders, die and casting station, MDO, TDO, gauging station, treatment and full-width winder. Fig. 12.7 shows a typical BOPP process temperature profile. First, the PP resin is melted in the extruders, then quenched on the casting roll, transferred to the MDO where it is reheated and stretched in the machine direction. There is some annealing between the MDO and the TDO. In the TDO, the web is reheated before transverse stretching, annealed, and cooled down before winding. Fig. 12.8 shows a production line

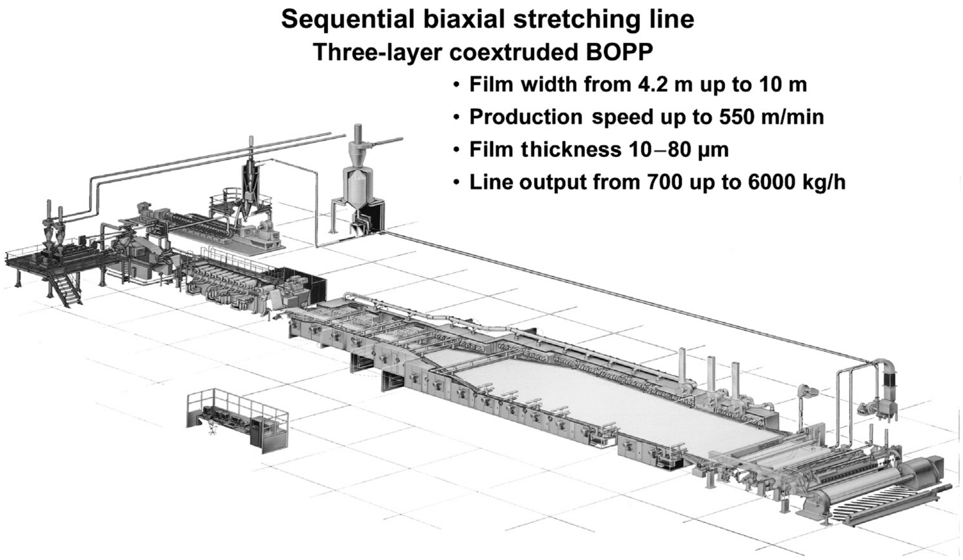



**Figure 12.6** A three layer−coextruded BOPP sequential stretching line.

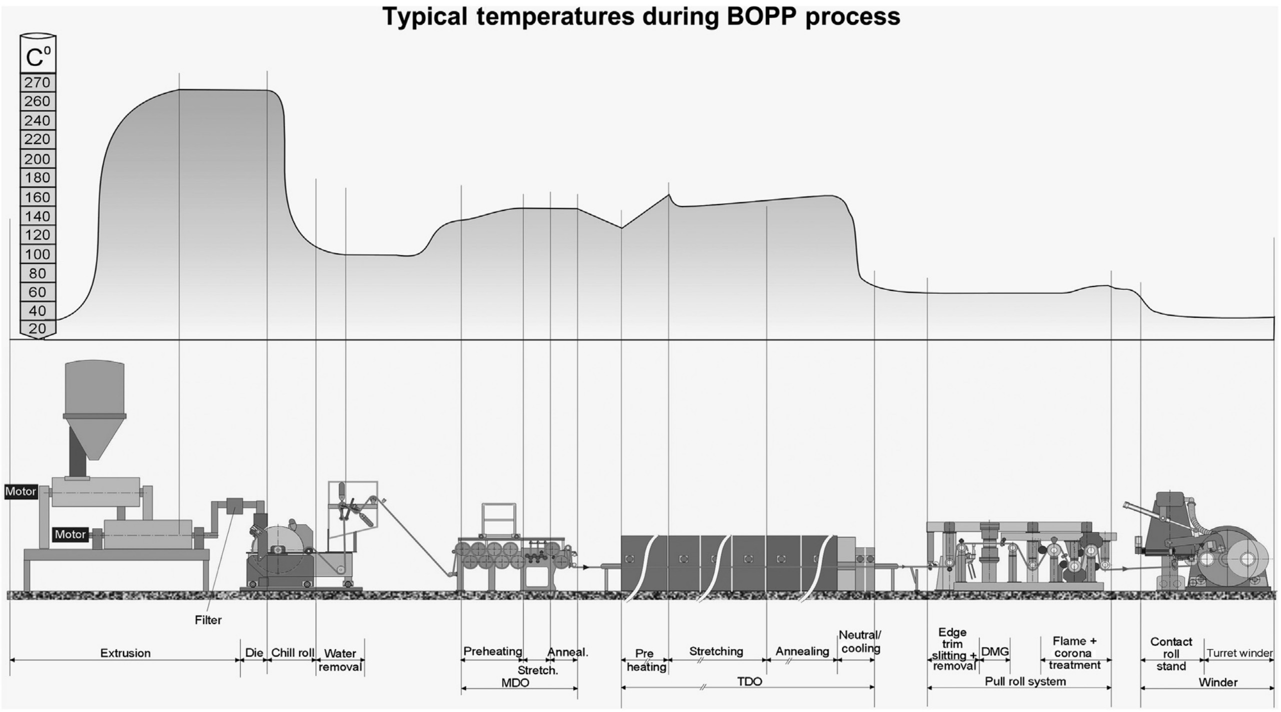



**Figure 12.7** Typical temperatures during the BOPP process.

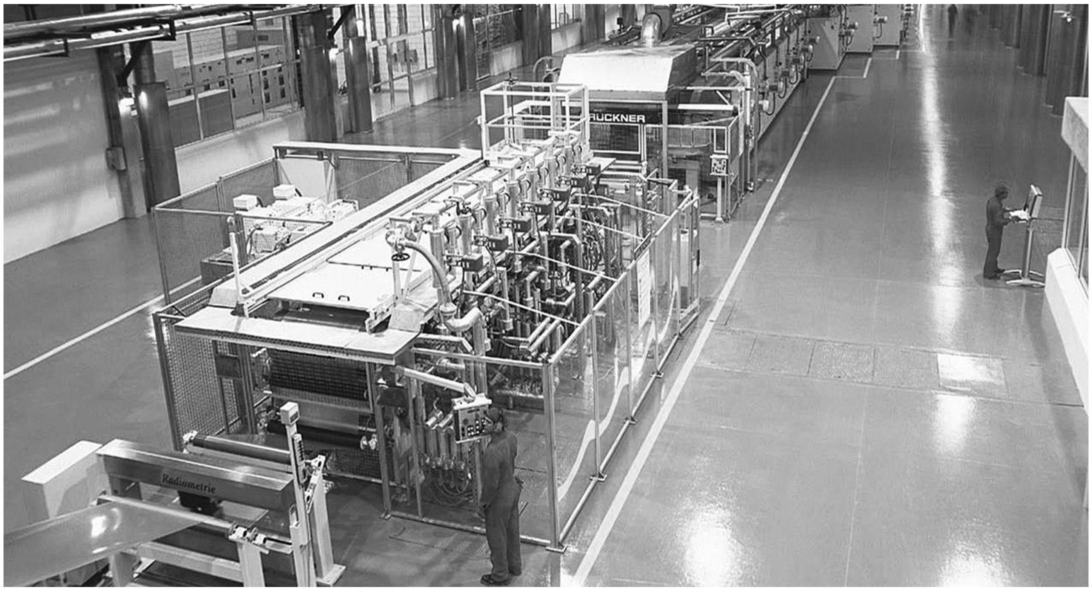


**Figure 12.8** Machine direction orienter with entrance.

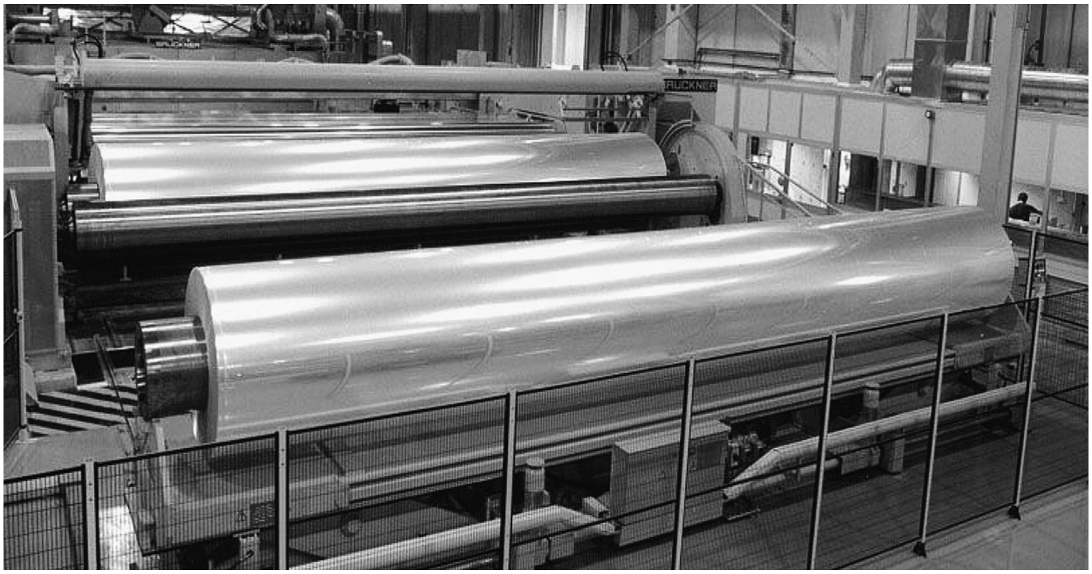


**Figure 12.9** Finished 10-m BOPP mill.

MDO and entrance to the TDO. Fig. 12.9 shows a finished 10-m mill roll after being removed from the winder.

Simultaneous orienting technology represents an alternative to the prevalent sequential orientation. Fig. 12.10 compares for BOPP the useable range for the stretch ratios between the sequential and simultaneous processes.

In sequential orientation, the stretching process occurs in two steps and a relatively small process window in terms of temperatures and stretching ratios is available. During simultaneous stretching, however, the usable stretching ratios are considerably larger. For instance, in machine and transverse directions, it is possible to set identical stretching ratios or even realize a higher stretching ratio in machine direction in order to achieve improved machine direction mechanical properties. A further advantage is the possibility to relax in simultaneous orientation by diminishing the clip spacing, not only in the machine but also in the transverse direction. Furthermore, it can be emphasized that, as a contact-free process, simultaneous orientation avoids the limitations of

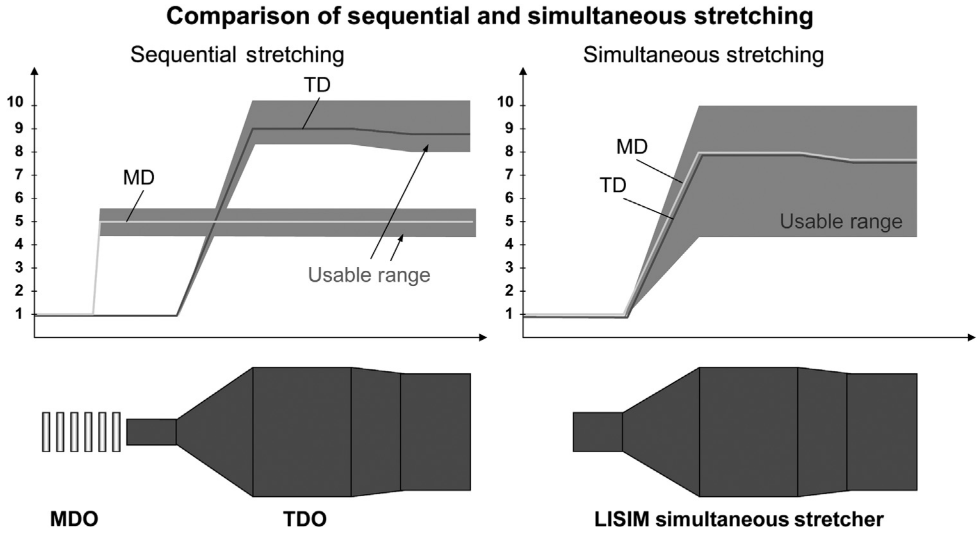



**Figure 12.10** Usable stretch ratios for sequential and simultaneous stretching.

stretching via rolls. Such differences lead to several advantages in terms of the product characteristics as shown in Fig. 12.11. In particular, a new developed system called LISIM (linear motor simultaneous stretching system) offers the following advantages [4]:

- high productivity (speed and width)
- high flexibility (stretching ratios and relaxation rates) in MD and TD
- high reliability.

These features are achieved by individually driven clips with linear motor technology. The improved mechanical properties are due to higher stretching ratios. The shrink characteristics are controlled by the unrestricted relaxation and tensilizing stretching possibilities. Barrier properties can be improved upon considerably by using coextruded barrier materials, where the process is particularly advantageous for those materials which cannot be stretched sequentially due to the crystallinity created

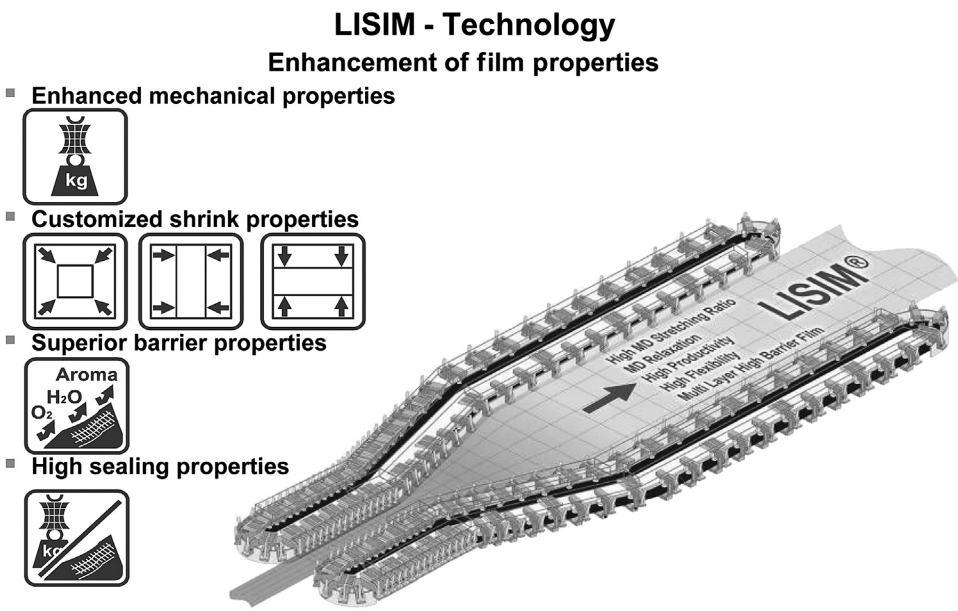



**Figure 12.11** Enhanced film property possibilities with LISIM.

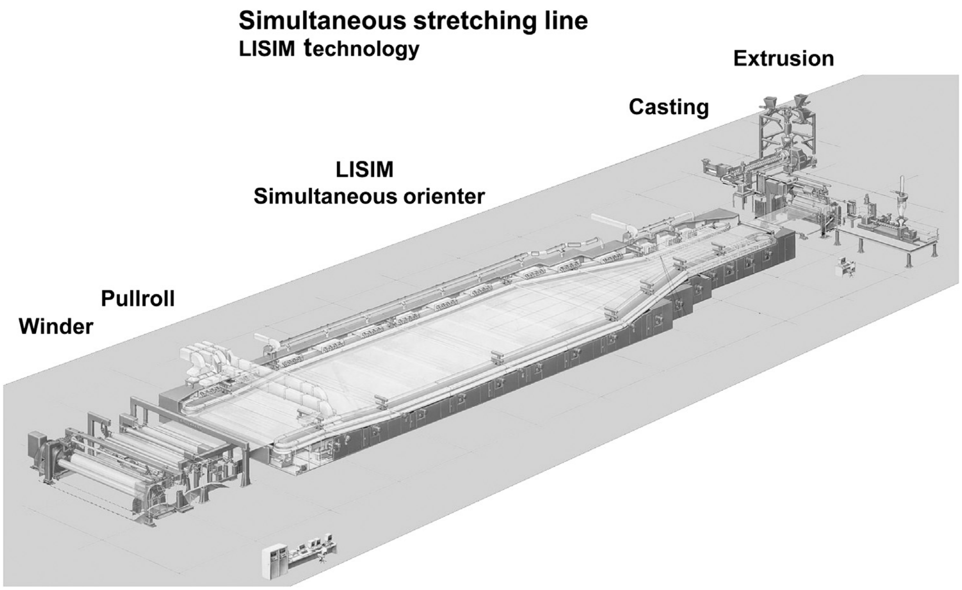



**Figure 12.12** Simultaneous stretching line.

by the first MD stretching process. Improved sealing properties are made possible because low seal temperature copolymers can be applied. These low-temperature heat sealing polymers are not processable in a standard MDO as they stick to the rolls during the machine direction orientation. LISIM technology has been scaled up from laboratory scale to production line dimension. Lines equipped with this technology for the production of polypropylene and polyester film have been running successfully and reliably for several years. The overall line layout is shown in Fig. 12.12. Apart from the orienter, the components of such a line are similar to those of a sequential line. In particular, those components at the front end, that is, raw material supply, extrusion and casting unit as well as those at the rear, that is, pull roll and winder are, apart from minor details, identical. Only the orienter components are different. Instead of MDO and TDO, a simultaneous orienter is applied. Typical output figures for sequential and simultaneous stretching equipment, representing today's state of the art are shown in the list that follows. Basically, in terms of output data, it can be said that the efficiency of these high-speed lines is increasing, since the output capacity for certain film thicknesses is merely a matter of speed and working width. Over the past 40 years, ever since this technology was implemented on an industrial scale, constant efforts have been made not only to increase the working width but also the line speed. As such, new technological challenges are constantly arising with the aim to overcome the bottlenecks in the line components. Today, the state of the art for BOPP lines features:

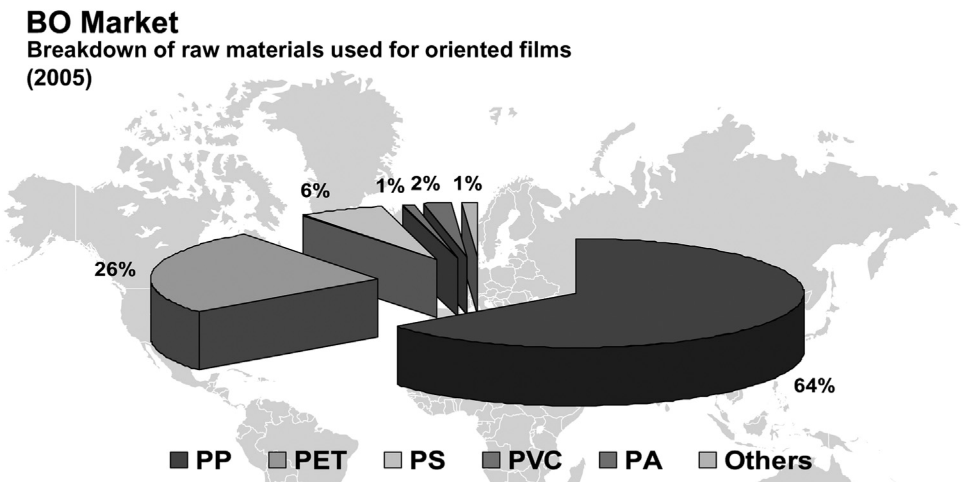
- working width 10 m
- speed 530 m/min
- output capacity 6000 kg/h

The trend for even higher output capacities will continue in the future. Nowadays, line concepts for even higher speeds and output capacities of 7 tons/h and above are being designed.

## 12.3 Oriented Film Types—Applications

In addition to the orientation technology outlined previously, the film products and their applications will now be explained. In most cases, stretched films for packaging applications are further processed. The most significant converting processes are vacuum coating (metallizing, $SiO_x$, $AlO_x$), offline coating (acrylic, polyvinylidene chloride, polyvinyl alcohol, etc.), lamination with other stretched films, polyethylene (PE) sealing layers and printing (front printing and reverse printing). Such downstream processing will not be discussed in this chapter.

Considering the market for oriented films in general, the various raw materials used can be distinguished.




| Raw material | PP | PET | PS | PVC | PA | Others | Total |
|---|---|---|---|---|---|---|---|
| 1000 tpa | 6089 | 2181 | 556 | 120 | 185 | 61 | 8972 |

Based on Name Plate Capacity (world) incl. 2004 contracts

**Figure 12.13** Biaxial-oriented film.

Fig. 12.13 shows a breakdown of oriented films manufactured worldwide. BOPP film constitutes by far the largest share with over 6 million tons per annum. In view of the favorable relation between raw material prices and film properties, it can be assumed that the steady growth of 7% per annum will continue. Biaxially oriented PET film has the second largest share followed by polystyrene (PS), polyvinylchloride (PVC), and polyamide (PA).

## *12.3.1 Films Oriented Biaxially*

Among oriented films, the biaxial orientation is the most preferred technology as it leads to improved properties in both (MD and TD) directions. This can be recognized by comparing the properties of the most common biaxially oriented film types, which are BOPP, BOPET, and BOPA (Table 12.1).

The various film types mainly differ with regard to the mechanical, thermal, and barrier characteristics and determine the particular application. Similarly, other properties, like thermal resistance or electrical properties, differentiate the film types and predestine them for specific applications.

### 12.3.1.1 BOPP Films

With a worldwide consumption of over 6 million tons, BOPP films constitute by far the largest share in biaxially oriented film. The applications are very diverse and can basically be split into packaging applications, not only in the food but also in the nonfood sector. Fig. 12.14 shows a few of these applications which play an important role in everyday life.

A further classification of such applications can be made in terms of the thickness range and the number of layers. The thinnest films are required for electrical applications, such as capacitor film, with a thickness of at least 3 μm. The thickest films are available within the synthetic paper sector up to 180 μm. As shown, films with a thickness range between 15 and 35 μm are widely applied for the varied packaging applications (Figs. 12.15 and 12.16).

One differentiates between one layer and multilayer, where the three layer−coextruded film has the largest share. The core layer of PP homopolymer is coextruded with the outer PP copolymer layers. The outer layers have a lower melting point thus ensuring

**Table 12.1** Film Properties of Common Biaxially Oriented Films

| Mechanical Properties | | Unit | 20 μm BOPP | 12 μm BOPET | 15 μm BOPA |
|---|---|---|---|---|---|
| Tensile strength | MD | $N/mm^2$ | 140 | 230 | 250 |
| | TD | $N/mm^2$ | 280 | 260 | 280 |
| E-Modulus | MD | $N/mm^2$ | 2000 | 4400 | 3500 |
| | TD | $N/mm^2$ | 3500 | 5200 | 3800 |
| Elongation | MD | % | 220 | 110 | 110 |
| | TD | % | 70 | 90 | 100 |
| Impact strength | | kg/cm | 5 | 5 | 15 |
| Tear propagation | | g | 3.5 | 3.5 | 7.5 |
| Thermal shrinkage | | % | 5% at 135°C | 2% at 190°C | 2% at 160°C |
| Density | | $g/cm^3$ | 0.91 | 1.393 | 1.16 |
| Yield | | $m^2/kg$ | 55 | 59 | 58 |
| OTR | | $cc/m^2$ day | 1600 | 90 | 40 |
| WVTR | | $g/m^2$ day | 6.0 | 8.5 | 270–300 |
| Surface tension | | Dyn | 40 | 50–55 | 50–55 |


**Figure 12.14** BOPP film applications.

that the sealing process necessary for packaging applications can take place at temperatures that do not deform the main layer. In the last few years, there has been a strong trend toward five-layer and, in certain cases, also to seven-layer films [5]. The advantages of five-layer technology are, on the one hand, improved characteristics, such as better optical, gloss, transparent, opaque properties, as well as cost advantages, expensive additives are predominantly added in the thinner intermediate layers. In Chapter "Web Handling and Winding," multilayer-oriented films, the various structures and applications are further described. Biaxially oriented PP films are widespread, not only the transparent applications but also the white opaque film types which are mainly applied for packaging and labeling. Inorganic additives (eg, calcium carbonate) are implemented in the polymer matrix [6]. These particles lead to an initial

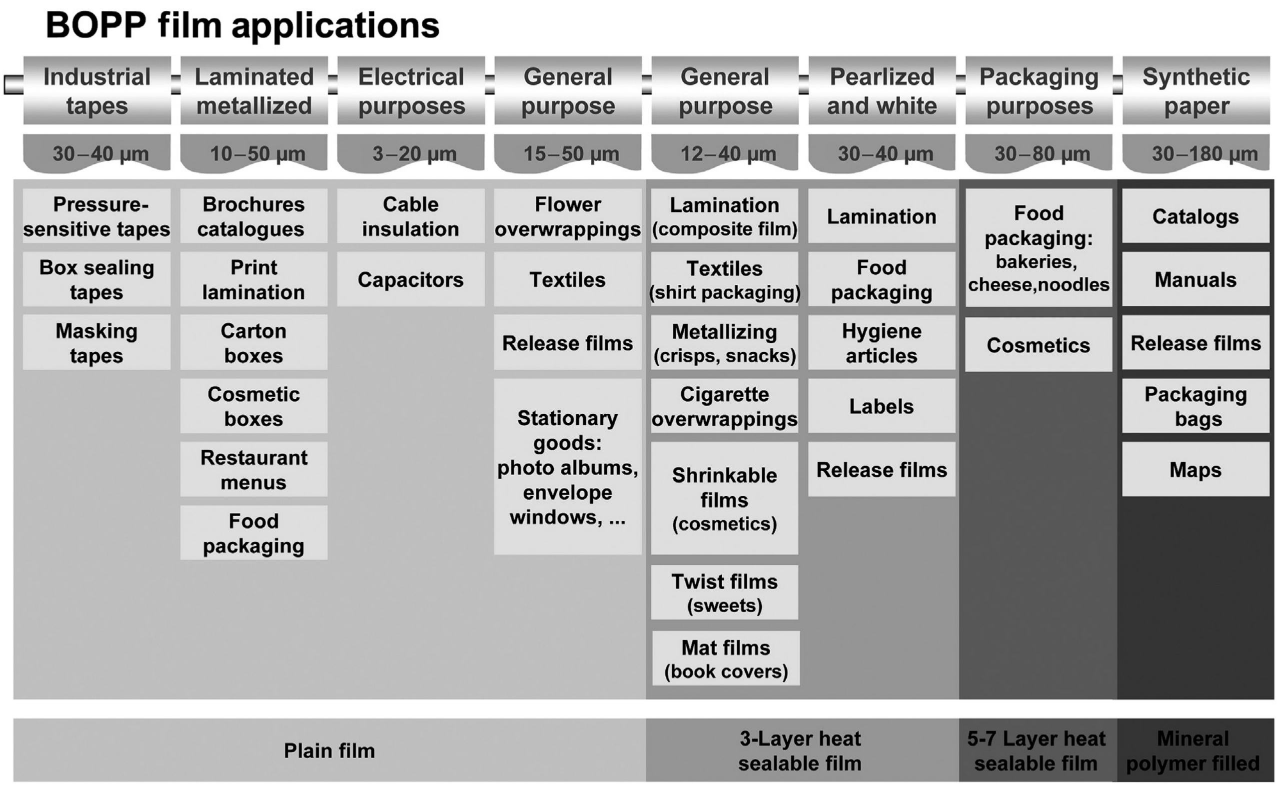



**Figure 12.15** BOPP film applications.

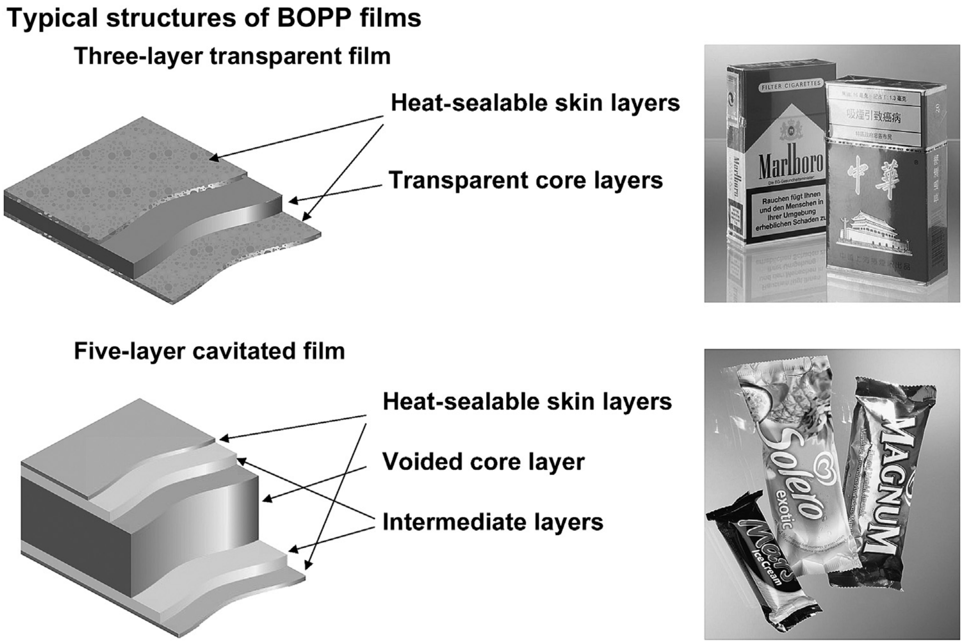



**Figure 12.16** Typical BOPP film structures.

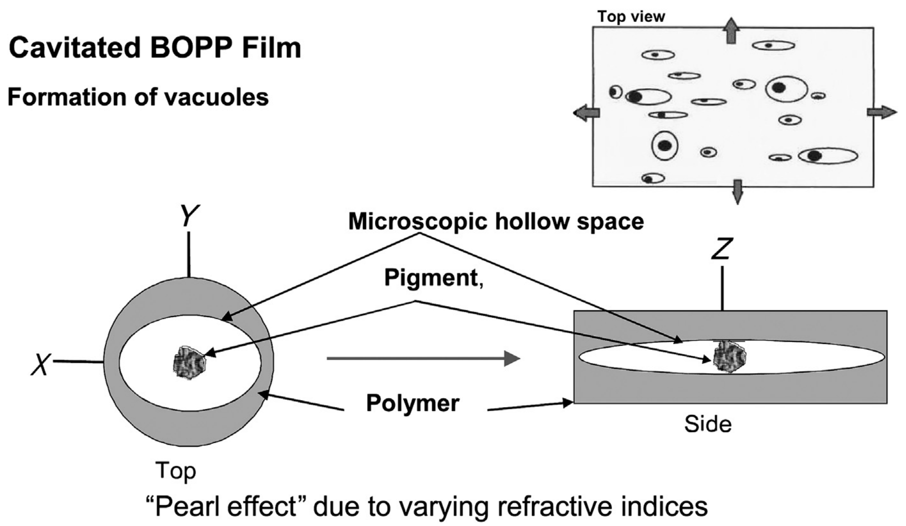



**Figure 12.17** Cavitated BOPP film mechanism.

flaking/separation from the polymer matrix during the machine direction orientation, so that, during consequential transverse direction orientation, small cavities occur (Fig. 12.17).

In view of these so-called vacuoles, the light is refracted in varying ways such that the required pearl effect arises. At the same time, the density reduction gives rise to the fact that, with the use of the same raw material, compared to noncavitated films, an enlarged thickness occurs. Both aspects are mainly used for confectionary, chocolate bars, ice-cream, etc. Synthetic paper takes a special role among cavitated BOPP films. The effect of vacuole formation during orientation is also made use of, where a larger density range of 0.6–0.9 g/cm$^3$ can be produced. Applications for synthetic paper are extremely versatile and cover a large thickness range (Table 12.2). Three- and five-layer films are coextruded where the surface is optimized in order to attain good printability.

Fig. 12.18 shows a 100-μm synthetic paper cross-section showing the calcium carbonate particles, the cavities, and the nondensity-reduced skin layers. Synthetic paper is frequently coated in further processing in order to attain a better absorption and a quicker drying of the printing inks.

**Table 12.2** Thickness Range for Synthetic Paper

| Thickness (μm) | Recommended Applications |
|---|---|
| 50–180 | Pressure-sensitive, cut and stack and wrap-around labels; release liners, posters, inkjet printing base |
| 75–100 | Pressure-sensitive, wrap-around, and in-mold labels |
| 75–200 | Cut and stack and wrap-around labels, posters, maps, shopping bags, business cards, calendars, banners |
| 75–250 | Labels, books, posters, calendars |
| 75–400 | Maps, posters, tags, cards, charts, menus, phone cards, calendars, banners |
| 130–700 | Carriers, files, folders |
| 250–1000 | Cards, tags, book covers, folders, charts, maps |

### 12.3.1.2 BOPET Films

Biaxially oriented polyester films (BOPET), with approximately 2 million tons per year, are the second most common oriented film following BOPP. In the past, BOPP films dominated in packaging applications and BOPET films dominated in technical applications. Biaxially oriented polyester film, with its high rigid properties, was ideal as a carrier film for magnetic tapes, floppy disks, and capacitors. Since this magnetic recording medium has been substituted by the optical data medium, this application has strongly declined over the last few years. At the same time, however, an increase in the prevalence of BOPET films in the packaging industry has taken place, resulting in a worldwide growth of 4–5%. Upon reviewing the breakdown chart for the various applications (Figs. 12.19 and 12.20), one can conclude that with approximately 40%, packaging applications represent the largest share.

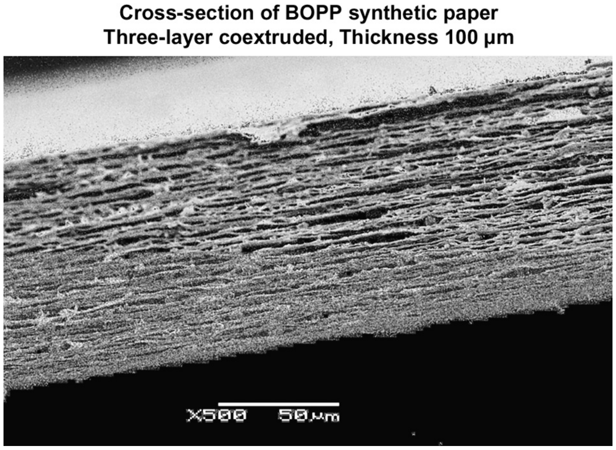



**Figure 12.18** Cross section of a 100-µm BOPP synthetic paper showing the calcium carbonate particles, cavities, and uncavitated skin layers.

The basic characteristics:

- high mechanical strength
- good temperature and chemical resistance
- dimensional stability over a broad temperature range
- adjustable friction coefficient
- excellent optical clarity
- good printability

reflect the specific beneficial features for the various applications accordingly (Fig. 12.21).

Variants ensue from the different stretching processes, recipes, coextrusion, and coating processes. In the sequential stretching process, the longitudinal-transverse (MD/TD) process is dominant [7]. However, the transverse-longitudinal (TD/MD) process and the longitudinal-transverse-longitudinal (MD/TD/MD) processes are also applied. For the MD/TD/MD process, higher stiffness values in machine direction can be achieved. The simultaneous stretching process is applied for very thin films, for example, for capacitor films,

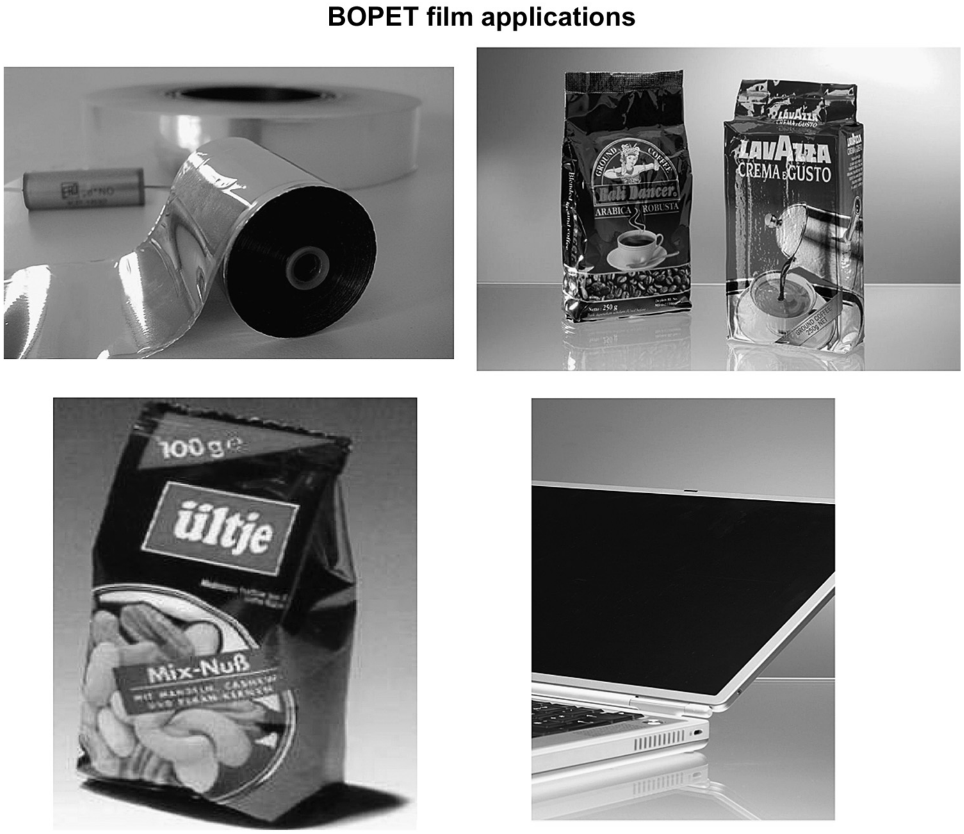



**Figure 12.19** BOPET film applications.

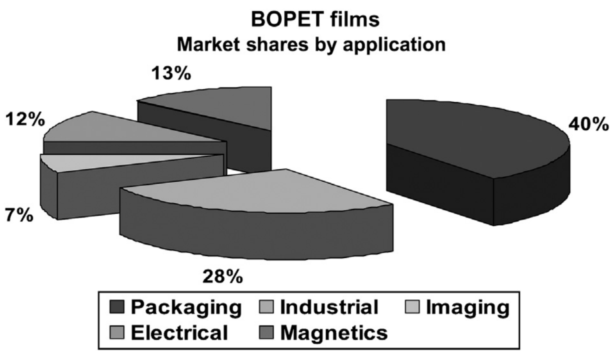



**Figure 12.20** BOPET films market share.

and the contact-free stretching technology allows for high-quality optical uses.

In view of the good stiffness values and sliding properties in the packaging sector, the benefits, such as excellent machinability plus good printability and optical appearance, are applied. With coextrusion, sealable or matte surfaces can be attained (Fig. 12.22).

Furthermore, a frequently applied advantage of coextrusion technology is the application of inorganic additives in the thin outer layers, in order to adjust the required friction coefficient without

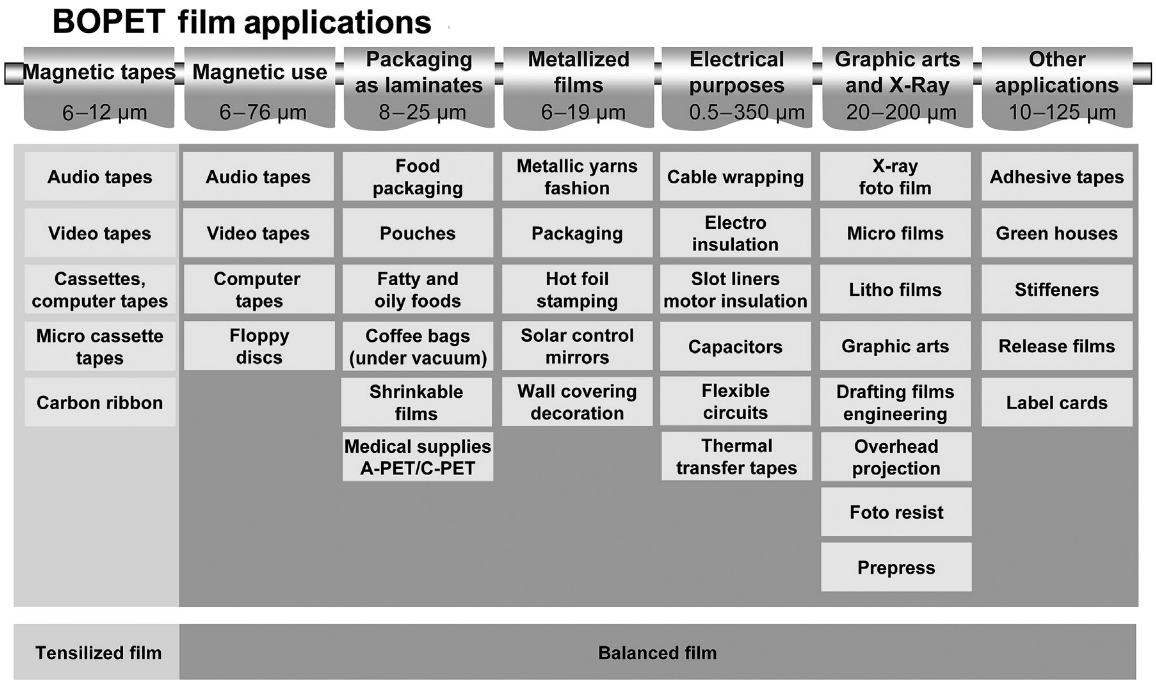



**Figure 12.21** BOPET film applications.

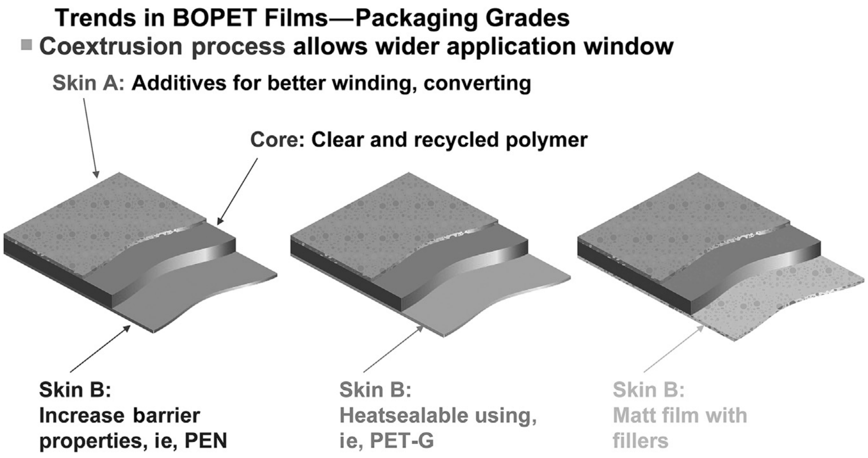



**Figure 12.22** Coextrusion trends in BOPET.

having a negative influence on the transparency. In-line coating processes are also widespread which ensure optimum printing ink adhesion. A common downstream processing phase of BOPET film is metallizing, which is mainly used not only to improve the barrier properties but also to attain an attractive visual appearance. For numerous food wrappings, the barrier properties, in terms of oxygen and aroma, are particularly vital criteria to ensure that the required minimum shelf-life is attained. With metallizing, an oxygen permeation value of $<1\ cm^3/m^2$ day bar can be reached (Fig. 12.23).

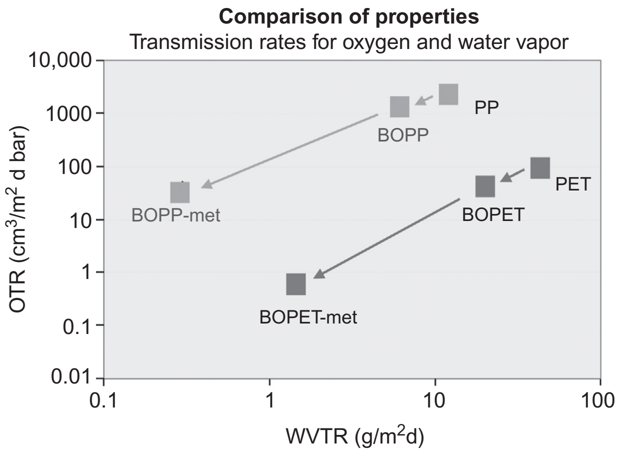



**Figure 12.23** Comparison of transmission rates for PP and PET.

Biaxially oriented polyester packaging films are usually laminations, that is, in a further process they are laminated with BOPP, PE film, aluminum foil, or other packaging material. A typical laminate structure is shown in Fig. 12.24 as an example for coffee wrapping. The polyester film is reverse-side printed and laminated with aluminum foil as a barrier layer and polyethylene film as a sealing layer. Good transparency, high gloss, and the print quality is thus reflected in the image appearance.

Apart from the packaging sector, there are numerous other industrial applications for BOPET films. For example, thermotransfer films for bar code and ticket printers to name a few. The high-temperature resistance is an excellent benefit. Biaxially oriented polyester is also widely used for capacitor and electrical insulating film, with thickness ranges from 0.5 to 350 μm.

In recent years, additional other applications for optical films have been gaining significance. In particular, LCD screens and flat screen TVs are undoubtedly ensuring good growth possibilities for high-quality BOPET films in the future.

### 12.3.1.3 BOPA Films

With a worldwide volume of 250,000 tons per annum, BOPA (polyamide or Nylon) films represent


**Figure 12.24** Typical PET film.

a small specialty segment, predominantly used in the packaging sector [8]. Particularly in view of the excellent puncture resistance along with good oxygen and aroma barriers, BOPA is primarily processed for flexible wrappings for sausages, cheese, fish, and liquid contents (Fig. 12.25). Thickness is normally in the range of 12−25 μm. Special application, such as gas-filled balloons, is primarily made from metallized thin BOPA film (10−12 μm).

In principle, all above-mentioned stretching processes are suitable for manufacturing BOPA films, that is, not only sequential but also simultaneous and double bubble lines are used. Sequential stretching lines with longitudinal-transverse process and a working width of 4−5 m are widely abundant. The stretching ratio is approximately 3 × 3, process temperatures are shown in Fig. 12.26.


**Figure 12.25** Typical applications of BOPA film.

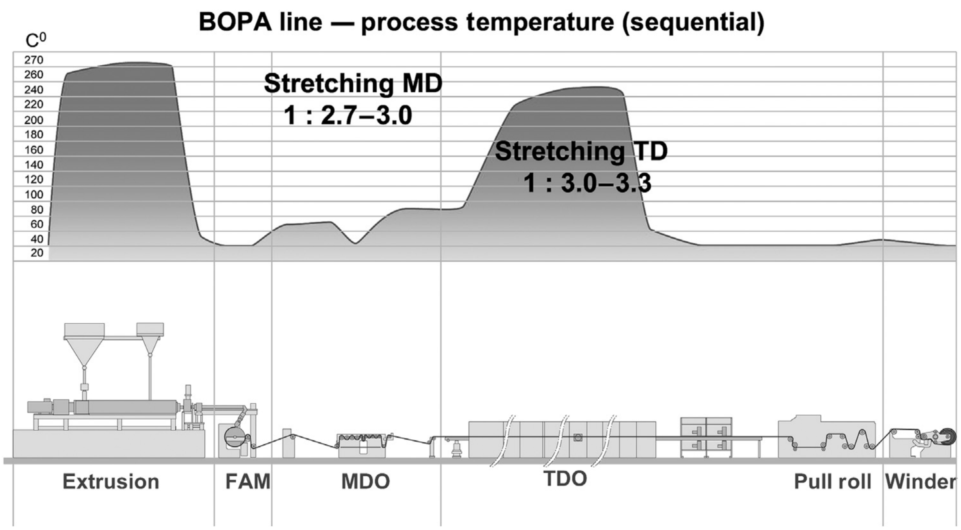



**Figure 12.26** Typical process conditions for MD/TD BOPA.

For packaging applications, BOPA films are laminated with other films, mainly PE, in order to ensure the sealability for bag manufacture. Typical laminate structures are shown in Fig. 12.27.

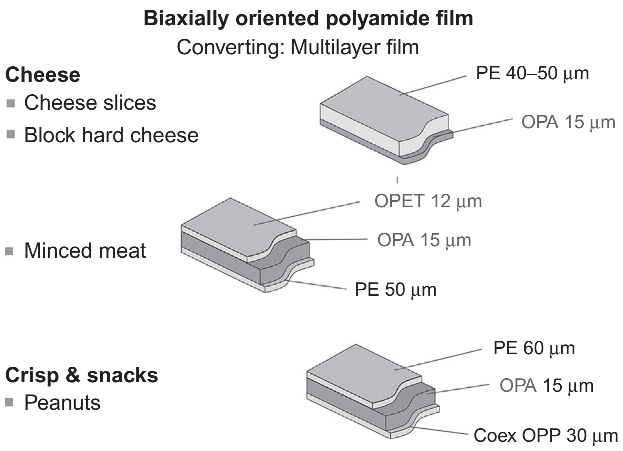



**Figure 12.27** Typical BOPA.

### 12.3.1.4 BOPS Films

The worldwide market demand for BOPS film (biaxially oriented polystyrene) amounts to approximately 600,000 tons per annum and is basically split into two market segments [9]. Thinner 30- to 150-µm films are suited for applications such as envelope windows and separating film for photo albums, and thicker 150- to 800-µm films are mainly cover applications such as deep draw vacuum packaging film (Figs. 12.28 and 12.29). Thinner film types very often require a matte surface and deep draw applications require high transparency and luster. In addition, a good deep draw performance has to be ensured and can be adjusted via the stretching parameters.

Biaxially oriented polystyrene films are produced exclusively with the sequential process (longitudinal-transverse). In order to make the cast sheet, a roll stack is used to ensure that the thick film has optimum surface quality. The temperature is controlled to such an extent, thus ensuring that processing is performed at temperatures higher than the glass transition, as otherwise, polystyrene would be too brittle (Fig. 12.30).


**Figure 12.28** BOPS film applications.

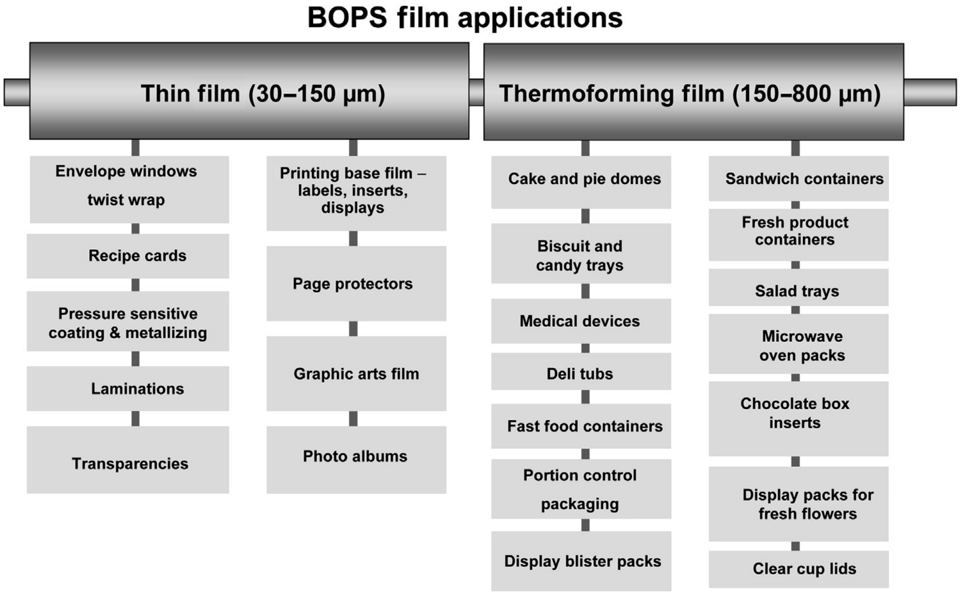



**Figure 12.29** BOPS film applications.

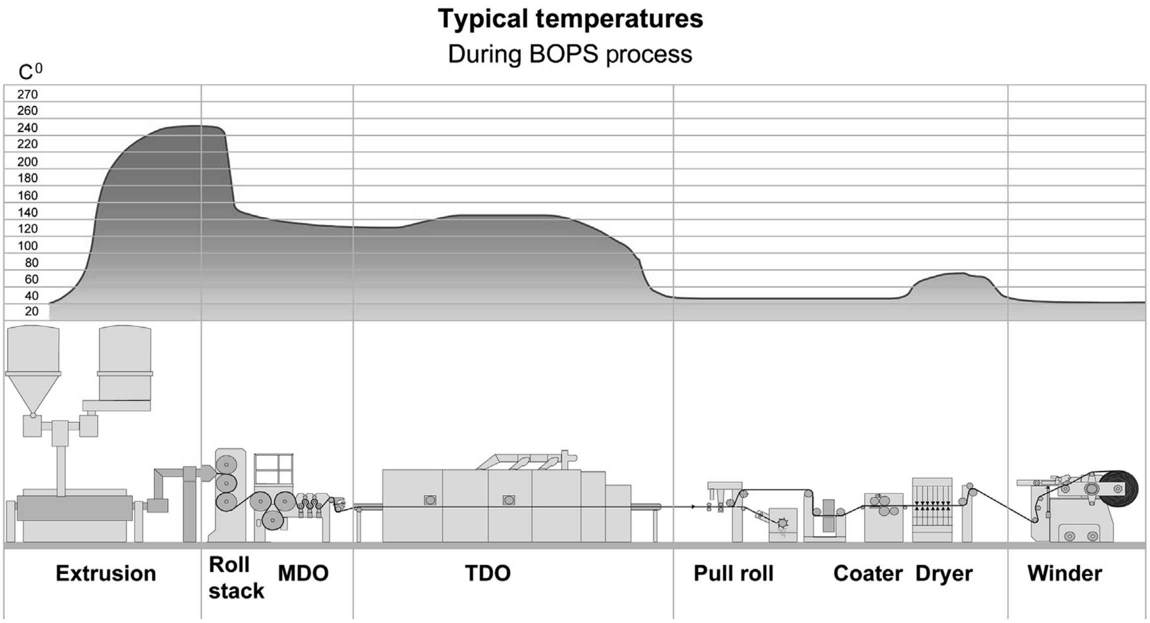



**Figure 12.30** Typical BOPS process temperatures.

### 12.3.1.5 Other BO Films

Besides the oriented films previously mentioned (BOPP, BOPET, BOPA, and BOPS), various other specialty film types need to be mentioned.

Biaxially oriented polyethylene films (BOPE) are solely in use as shrink film applications, where there are many different products varying in layer structure, recipe, and process parameters. In principle, each application has its own tailored shrink values, shrink forces, strengths, and barriers. Barrier properties preferably are attained by coextrusion with ethylene vinyl alcohol (EVOH). For the production of BOPE shrink films, the double bubble process is almost solely used.

Oriented films from renewable resins represent another even more exotic film type on the market at present and are biodegradable. Polylactide (PLA) is the major resin used because it has attractive properties and is already available in large quantities. The raw material is primarily based on corn. Similar to PS film, PLA film can be oriented and yields an attractive property spectrum (Fig. 12.31).

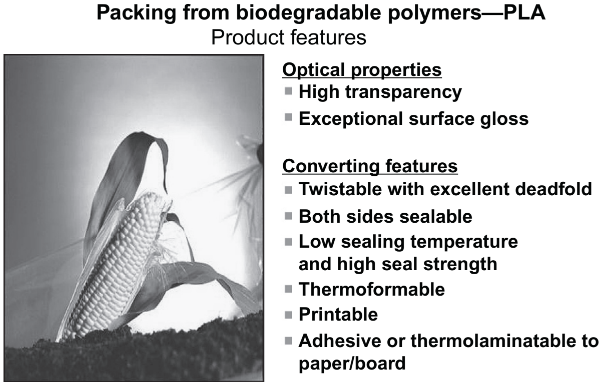



**Figure 12.31** Product features for biodegradable polymers (PLA).

In particular, the excellent visual appearance has made it an interesting alternative for packaging. Furthermore, the deadfold characteristics should be noted which are a prerequisite for twist-wrap. Compared with other packaging films, the water vapor barrier, however, is considerably inferior, although this to some extent can be compensated by means of metallizing or SiOx coating. Further uses ensue in view of the permeability for water vapor and thus, such a characteristic is most suited for bread and vegetable packaging (Fig. 12.32).

## 12.3.2 Film Oriented in Machine Direction

Films oriented solely in machine direction account for a small market share, since this stretching method is only interesting for certain special applications. As such, monoaxially oriented propylene films (MOPP) are used for decoration ribbons, banderoles and tear strips for cigarette packs, as they have a very high longitudinal strength. In addition, such films do have a distinct tendency to split, although this has no restriction on the above applications.

Breathable films made from highly filled ($CaCO_3$) polyethylene are also oriented only in the machine direction. Defined hollow spaces up to the surface are thereby produced so that the required water vapor permeability is attained. Such film types are used in the hygiene sector as well as for the breathable layer in the building industry.


**Figure 12.32** PLA film applications.

Also various special film types from longitudinally oriented polyamide (MOPA) are common. A three-layer structure PA/EVOH/PA is used to improve the barrier properties.

### 12.3.3 Film Oriented in Transverse Direction

A relatively large and growing market segment is represented by films oriented in the transverse direction. These are applied solely as shrink films where the demands are such that the films only shrink in the transverse direction while the machine direction shrink is not required. Such films are, to a large extent, used as sleeves and this anisotropic shrink behavior is required in order that the container-contours appear clearly and the desired print is attained (Fig. 12.33).

Shrink values of up to 80% in the transverse direction can be attained, whereas full body sleeves can also be attained for containers with strong contours. Polyvinylchloride, PS, PET-G, and PP materials are used where, in terms of shrinkage, the different characteristics of these materials become apparent (Fig. 12.34).

## 12.4 Trends for Oriented Films

Basically, oriented films are most suitable for meeting the trends in the packaging sector set by politics, society, and the industry. The stipulations, for example in Germany, namely packaging regulations, compel the industry to give consideration not only to the material and manufacturing costs but also to the disposal costs. This induces one to attain minimum packaging material and maximum protection with packaging. These goals can only be reached with high-strength materials to reduce thickness along with meeting the protection and barrier functions, plus operational properties that ensure high-speed packaging. With sophisticated orienting processes (eg, simultaneous stretching technology), a significant increase of strength can be attained for all plastics. Furthermore, future potential in terms of packaging can be further developed, for example, by the substitution of aluminum foil with transparent or metallized high-barrier stretched film. Another further large potential lies within the integration of many function layers in the production process of stretched films, so that complex processing steps can be waived [10]. For example, it was proved on a pilot line scale that all functions of a


**Figure 12.33** Shrink film applications.

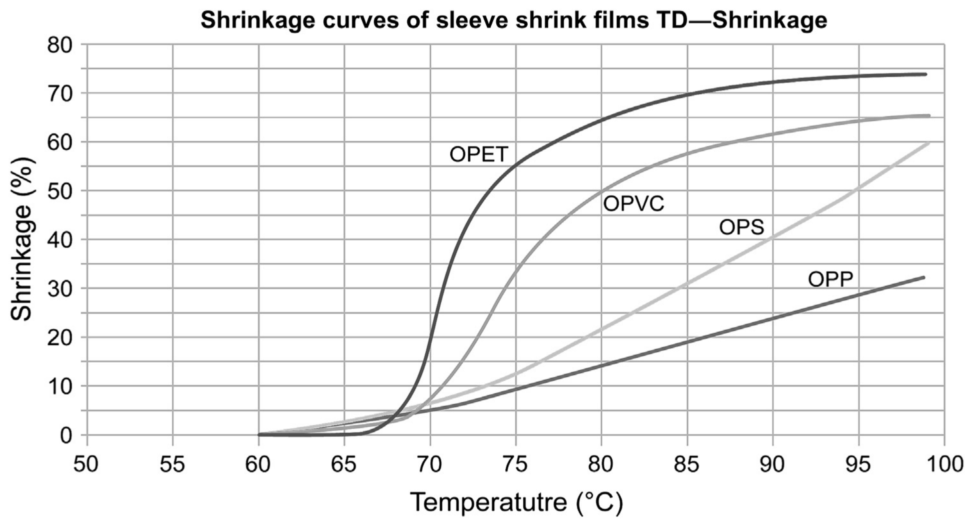



**Figure 12.34** TD shrinkage versus temperature for four shrink films.

complex triplex laminate could be attained by a coextruded stretched film manufactured in one process step.

In view of the limited crude oil resources, coupled with ever increasing oil prices, plastics manufactured with crude oil bases are also subject to price increases. This, accordingly, gives a boost for alternative materials and thus the possibility of cost-efficient production on an industrial scale. The production of suitable stretchable films for packaging applications from such alternative raw materials is evident in the PLA example. One can predict that much research and development will be performed within this sector in the near future.

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