Polystyrene (PS)

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With a world-wide consumption of 10.5 million tonnes in 2001 polystyrene is counted amongst the quantitatively most important thermoplastics and continues to be ranked in fourth place after PE, PP and PVC. Also in recent years on the average the dynamic development of consumption was a little greater than that of the gross domestic products of the corresponding countries and it is generally expected that this development will continue. General economic cycles as well as inter-polymer substitution processes (PP, PET, ABS) affect this development in different time frames.

The pressure of global competition and the strategic reorientation of important suppliers is also being expressed in a progressive consolidation of manufacturing industries. The merger of Elf Aquitaine and TotalFina to form Atofina in the year 2000 as well as the entrance of the North American Nova Chemicals into Europe (takeover of the activities of Shell Chemicals and Huntsman) led to a changed supplier structure in Europe as well as world-wide (Table 1). This process will continue, in particular in the Asiatic market area, also under the aspect that to achieve a competitive cost position investments in world scale new installations with capacities greater than 120 000 tonnes per year are necessary.

Increasingly in recent years polystyrene tended to lose its traditionally slight price premium compared to other standard plastics. The commodity character of polystyrene is expressed also in strongly fluctuating market prices that have led to extreme situations again and again such as unexpected consumption highs and lows because of temporary bottlenecks on the part of the crude products and partly also due to short term stocks and inventory reduction on the part of the processing plants.

Process Developments

Standard polystyrene (GPPS) and impact resistant polystyrene grades (HIPS) are manufactured predominantly in continuous, radical mass polymerisation processes.

Also here profit margin erosion forces manufacturers to give priority to reduction of specific production costs when further developing engineering processes. In addition, product property profiles, in particular high-impact resistant PS products, profit from engineering process development through improved control of the morphology of the dispersed polybutadiene rubber particles.

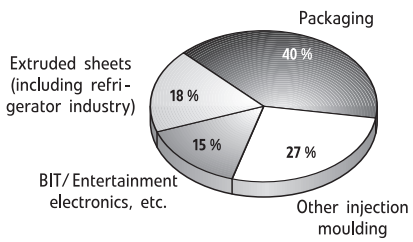

Fig. 1. Polystyrene consumption in Europe according to application (2001)

Besides the radical process, styrene and butadiene are also industrially converted to SBS block copolymers with tailor-made molecule architectures using an anionic process. Progress in the process engineering of anionic polymerisation and more thorough knowledge of the relationship between structure and properties have led

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to a considerable improvement of the performance spectrum of these transparent high-impact resistant polymers.

Products and Applications

The already mentioned commodity character of polystyrene and the economic necessity for the manufacturers to focus not only on uniform standard grades with as broad an application spectrum as possible with simultaneously limited differentiation of product performance, and also the rationalisation of the product assortments of some manufacturers that can be observed, could lead to the conclusion that product innovations are few and far between amongst styrene plastics. The fact that this does not apply at all is proven by numerous new developments by the market leaders in recent years, in particular in the area of impact resistant polystyrenes.

Production of rigid packaging remains the quantitatively most important area of application world-wide. In Europe this is about 40 % (Fig. 1). After the triumphant progress of the PET beverage package, polystyrene with a share of about 18 % remains also the second most important polymer for food packaging.

The simple and economical production of extruded flat and above all deep-drawn polystyrene films is still an important decision criterion, particularly in the above average growth FFS film sector where service reliable thermoforming behaviour and good thermostability in the area of hot filling are required.

While primarily the high-molecular GPPS grades are used in the transparent OPS sector, new high-toughness HIPS extrusion grades for packaging dairy products (example grade: Styron A-Tech 1200, manufacturer: Dow) have been developed with the goal of further improving the price performance ratio when mixed with suitable GPPS grades. Easier extrusion and better thermal mouldability of these mixtures should lead to productivity increases and to increased tolerance margins for smaller foil thicknesses because of an even wall thickness distribution for production of yoghurt beakers for example.

Improved mechanical performance with continually reduced packaging weight, thus essentially weight reductions, are also the mainspring for developments in the area of foamed packaging. Therefore standard polystyrene (XPS) foamed during the extrusion process continues to gain significance in food packaging. A new, high deflection temperature standard polystyrene with high melt strength (grade: FX 110, manufacturer: Nova Chemicals) should make possible improved inherent stability and toughness, higher productivity and wall thickness savings for foam foils and the trays and cardboards punched from it that are particularly suitable as packaging for fresh food (meat, vegetable, fast food).

More than proportional growth in the area of highly transparent food packaging has also secured the anionically produced SBS block copolymers a firm place among the transparent plastics on a long-term basis. A new SBS generation (grade: Styrolux 3G 55, manufacturer: BASF) makes it possible for the processor to use up to a quarter less SBS compared with previously in mixtures with standard polystyrene depending upon the application (Fig. 2) and thus to lower the manufacturing cost of the packaging.

Manufacturer	Nominal capacity (1000 t/a)	Share (%)
BASF	650	24
Dow	610	22
Atofina	450	17
BP	400	15
Enichem	325	12
Nova	280	10
In total	2715	100

Table 1. Polystyrene manufacturers in Europe (2001)

The fact that here disadvantages must be accepted neither in the toughness rigidity relationship nor in the thermostability is demonstrated by the optimisation potential that has meanwhile been realised with this product innovation. Capacity extensions in Europe and investment in new installations in the NAFTA area for these SBS copolymers underline the confidence of the manufacturers in the lasting success of this class of material. The interpolymer competition of the PET and transparent PP grades, where considerable progress has also been made in processing technology (thermoplastic moulding), will present new challenges to it.

Newer applications for SBS rich polystyrene mixtures were launched in the area of shrink labels (shrink sleeves). For in mould printed foils produced in modified OPS stretch processes and intaglio printing adherence to defined pre-loading is particularly important transverse to the extrusion direction.

Transparent packaging foils for fresh food such as fruit and vegetables made of SBS/PS mixtures profit from the high permeation rates of oxygen, CO_2 and water vapour. An abundance of custom-made packaging foils were developed further using co-extrusion composites with barrier plastics (PE, EVOH, PETG), which take into account the trend toward packaging fresh food in modified atmospheres (MAP).

Styroflex (manufacturer: BASF) with the characteristics of a thermoplastic elastomer (S-TPE) has already been presented as a new development in the area of anionic block copolymers. As an additional component in transparent SBS/PS mixtures as well as in mixtures with impact resistant polystyrene for non-transparent applications, this polymer provides an enormous toughness increase and clearly improved stress crack resistance for fat containing foods. The increased toughness and tear resistance, in particular also in cold environments, are taken advantage of, for instance in the production of ice packaging.

The use of Styroflex for production of medical hoses is being evaluated in the context of a new development project.

Excellent toughness, outstanding stability against fat and decreased water vapour permeability also open special applications to blends of impact resistant polystyrene and polyethylene, not only in food packaging. New product developments (grade: Lacqrene 9217/9218, manufacturer: Atofina) extend the established offering in this speciality product class. Further extrusion and thermoformed products again constitute about 18 % of the consumption of impact resistant polystyrene. Here in particular the linings (liners) of cooling and freezing devices should be mentioned.

Thus new products have been introduced in the market also in the area of the stress crack resistant and impact resistant

extrusion grades (ESCR HIPS) specifically required in the refrigeration sector. Product innovations from Dow and BASF (Styron A-Tech 1175, manufacturer: Dow and Polystyrene 2710, manufacturer: BASF) promise higher margins in mechanical and ESCR properties and should permit a broader processing window, which again leads to a more even wall thickness distribution in deep drawn parts. The option of reducing the extruded sheet thickness justifies the claimed economic advantage.

In addition the new polystyrene 2710 with its higher melt-flow index also opens the possibility of injection moulding more demanding parts.

At about 47 % the other half of the polystyrenes is used in injection moulding process, among other things for office supplies, housings for entertainment electronics and office and information technology, household items, toys, furniture components and sanitary installations.

Having now achieved a high degree of maturity in their performance spectrum, impact resistant polystyrenes developed particularly for injection moulding of housings are characterised by an outstanding combination of melt flow rate and mechanical properties.

During development of a new, high gloss HIPS product (grade: polystyrene 555 G, manufacturer: BASF) particular value was put on a combination of high melt flow rate and high surface gloss value, whereby the weak dependence of the gloss on the processing parameters can be rated as a further plus (Fig. 3).

Newly developed glossy, impact resistant polystyrenes with good flow properties (grade: Styron A-Tech 1120, manufacturer: Dow) are used not only for injection moulded articles but also for production of external layers for large and small appliances.

Transparent SBS block copolymers also gain importance in injection moulding. Apart from the applications of SBS in the medical, household goods and toys sectors, now also in Europe transparent, tough, reusable coat-hangers made of SBS/PS mixtures now also replace traditional black hangers.

Although polystyrene already exhibits a certain degree of maturity in its product life curve, precisely the demonstrated versatility of polystyrene plastic justifies its position as one of the strongest materials in terms of sales. The numerous product developments of recent years prove that also for polystyrene the performance spectrum is still increasing and thus that economic value can be increased through weight reductions of the finished products.

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Fig. 2. SBS with high toughness: reduction of the SBS share in mixtures with GPPS (size of the circle = measure of toughness)
Anteil an SBS = Share of SBS; Herkömmliches SBS = Conventional SBS

Fig. 3. Gloss values of high impact strength polystyrene as a function of the melt temperature (measurement angle 60 °C, mould temperature 30 °C, short injection time)
Glanz = Gloss; Massetemperatur = Melt temperature; Glanzpolystyrol = Glossy polystyrene; Standardpolystyrol = Standard polystyrene

Fig. 4. Sanitary equipment made of glossy high impact polystyrene (polystyrene 555 G)